06

Green Roads to Growth

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TABLE OF CONTENTS

PART I INTRODUCTORY CHAPTERS 11

1 INTRODUKTION – ØKONOMISK OG POLITISK KONTEKST 12

2 INTRODUCTION AND POLICY CONTEXT 16

3 FACILITATOR'S SUMMARY OF THE EXPERT FORUM OF THE GREEN ROADS TO GROWTH MEETING 1 MARCH 2006 20

3.1 (To what extent) do you see any fundamental conflicts between the policy goals of higher economic growth, increased employment (or reduced unemployment) and an improved environment? 20

3.2 (To what extent) do you think further economic growth 'automatically' will lead to environmental improvements? 20

3.3 (To what extent) do you think it is possible to address all the three goals simultaneously through environmental policy instruments? 20

3.4 If it is possible: for which types of policy in which environmental areas could it most likely be the case? 21

3.5 What are likely to be the most important economic and environmental impacts of the development of a more knowledge-based economy in general? 21

3.6 What are the main drivers of new inventions and their diffusion? 21

3.7 How can policy-makers best (from a cost-benefit perspective) stimulate the development of more environmentally friendly 'technologies'? 21

3.8 How can policy-makers best (from a cost-benefit perspective) stimulate the diffusion of existing and new environmentally friendly 'technologies'? 22

3.9 What role can internalisation of negative environmental impacts in the prices of goods and services play? 22

3.10 How can one best avoid that environmental benefits from new innovations are (partly) lost due to 'rebound effects'? 22

3.11 What are the main arguments for applying "green taxes" (and other similar economic instruments)? 22

3.12 Is an 'employment dividend' likely to appear? 22

3.13 What could be the impacts of "green taxes" on innovation and economic growth – in practice? 22

3.14 What would be the main environmental advantages (and disadvantages) of increased organic farming / biomass production / renewable energy production? 23

3.15 What are likely to be the overall economic / employment impacts of such increases – when taking "general equilibrium effects" into account? 23

3.16 What would (from a cost-benefit perspective) be the 'best' way to stimulate such increases (to the extent they would be desirable overall)? 23

3.17 To what extent could a better "internalisation of externalities" elsewhere in the economy 'automatically' trigger a desirable outcome in this regard? 23

4 Summary of the Policy Maker Forum, 2nd March 2006 24

4.1 Automatic decoupling 24

4.2 Policy design 25

4.3 Barriers 26

PART II FRAMEWORK PAPER 27

5 What are the Linkages between Environmental Policies, Economic Growth and Employment? 28

Abstract 28

5.1 Introduction 28

5.2 Three objectives: growth, employment and the environment 30

5.2.1 The three objectives 31

5.2.2 Variables and welfare 39

5.3 Link I: The Environmental Kuznets' curve 42

5.3.1 The empirical EKC 43

5.3.2 Interpreting the EKC 44

5.3.3 What can we learn from the EKC? 46

5.3.4 Policy implications 48

5.4 Link II: externalities and the "double dividend" 48

5.4.1 Environmental policies 48

5.4.2 The double dividend 52

5.5 Link III: Innovation and environmental policy 56

5.5.1 Two market failures 56

5.5.2 Government policies 58

5.5.3 Does eco-innovation make environmental regulation costless? 60

5.6 Link IV: The Porter Hypothesis 61

5.6.1 Arguments and theoretical explanations 63

5.6.2 Empirical evidence 67

5.6.3 Costless environmental regulation? 71

5.7 Link V: Non-environmental policies – International integration 71

5.7.1 International integration and the economy 72

5.7.2 The environmental effects of globalisation 74

5.7.3 Policy implications 77

5.8 Final comments 78

5.9 References 82

PART III CASE STUDY #1 89

6 Case study paper no. 1: Innovation, technology and the global knowledge economy: Challenges for future growth 90

6.1 Abstract 90

6.2 Introduction 90

6.3 Perspectives on growth: From mechanization to knowledge 92

6.4 Understanding innovation based dynamics: Conceptual framework and empirical evidence 97

6.5 The global knowledge economy and the ICT revolution 103

6.6 Summing up the argument – implications for policy 113

6.7 References 116

7 Opponent note no. 1a: Innovation, technology and the global knowledge economy: Challenges for future growth 120

7.1 General Comments 120

7.2 Key themes on growth 121

7.2.1 Divergence in growth 121

7.2.2 Is growth properly calculated? 121

7.2.3 Can growth become less material-intensive? 122

7.3 Key themes on knowledge and innovation 123

7.3.1 The direction of knowledge development and innovation 123

7.3.2 The diversity of innovation strategies 123

7.3.3 The effects of innovation on jobs 124

7.3.4 The effects of innovation on skills 125

7.3.5 The effects of technology on work organisation 126

7.3.6 The effects of innovation on wages 127

7.3.7 The relevance of macroeconomic contexts and policies 128

7.4 Key policy themes 130

7.5 References 133

8 Opponent note no. 1b: Innovation, technology and the global knowledge economy: Challenges for future growth 136

8.1 Fagerberg's questions and answers 136

8.1.1 Is there anything new about "The Knowledge-based Economy? 136

8.1.2 Do some Countries Distinguish Themselves from the Other? 137

8.1.3 What are the Policy Challenges? 137

8.1.4 Is EU Pursuing the Right Goals? 138

8.2 THE FOUR QUESTIONS ONCE AGAIN 138

8.2.1 Is there anything new about "The Knowledge-based Economy? 138

8.2.2 Do some Countries Distinguish Themselves from the Other? 141

8.2.3 What are the Policy Challenges? 142

8.2.4 Is EU Pursuing the Right Goals? 145

8.3 Postscript 145

8.4 References 145

PART IV CASE STUDY #2 149

9 Case study paper no. 2: What trade-off between knowledge-based growth and the environment? 150

9.1 Abstract 150

9.2 Introduction 151

9.3 FORA's model for wealth creation in the knowledge-based economy 153

9.3.1 FORA's framework 155

9.3.2 Innovative capacity differences between countries 158

9.3.3 The policy challenges 160

9.4 Data and computation methods 163

9.4.1 Constructing the knowledge-based-growth index 164

9.4.2 Construction of an environment Index 165

9.5 Results 167

9.6 Growth friendly environmental policy based on regulation, government demand and strategic government investments in R&D 170

9.7 Conclusion and discussion 173

9.8 References 175

10 Opponent note no. 2a: What trade-off between knowledge-based growth and the environment? 180

10.1 Opponent note 180

10.2 References 184

11 Opponent Note no. 2b: The Lisbon strategy, knowledge-based growth and the environment 185

11.1 Three Goals 185

11.2 European employment and unemployment 185

11.3 Knowledge-based growth and unemployment 187

11.4 Empirical investigation of knowledge-based growth 188

11.5 Knowledge-based growth and environmental pressures 189

11.6 Conclusion 190

11.7 References 190

PART V CASE STUDY #3 191

12 Case study paper no. 3: Environmental Innovations and Economic Success of Firms 192

12.1 Abstract 192

12.2 Background: Research questions 193

12.3 Monitoring: What do we know about environmental innovation behaviour in firms? 194

12.3.1 Key definitions 195

12.3.2 Trends in environmental innovation at the firm level 197

12.4 What are the determinants of environmental innovations
- Theoretical approaches and empirical evidence 201

12.4.1 Regulatory push/pull 202

12.4.2 Technological capabilities 203

12.4.3 Market demand 204

12.4.4 Possibility of appropriation, co-operations 205

12.4.5 Firms size 206

12.4.6 Market structure 206

12.4.7 An illustrative example: Drivers of green innovation in the Dutch construction industry 206

12.5 The economic impacts of environmental innovations 208

12.5.1 The Porter hypothesis 208

12.5.2 Environmental performance and economic performance of firms 210

12.5.3 Employment impacts of environmental innovations 211

12.6 Review of policy options 213

12.6.1 Lisbon initiatives 214

12.6.2 Related ongoing activities 216

12.7 Conclusions for policy co-ordination 224

12.8 References 227

13 Opponent Note no. 3a: Eco-innovation – environmental benefits, economic growth and job creation 233

13.1 Overview 233

13.2 Defining eco-innovation 234

13.3 The business enterprise 236

13.3.1 These include 236

13.3.2 *Market* 237

13.3.3 *Knowledge* 237

13.3.4 *Managerial coupling* 237

13.3.5 *Business strategy of differentiation* 237

13.3.6 *Disruptive innovation* 237

13.4 The sociotechnical system 239

13.5 References 241

14 Opponent note no. 3b: Environmental innovations and economic success of firms – a rejoinder 243

14.1 Introduction 243

14.2 Typology of environmental innovation 243

14.3 Drivers for environmental innovation 247

14.4 Does environmental policy hamper competitiveness or does it promote it? 249

14.5 Growth trends and potentials related to eco-innovation 257

14.6 Policies for eco-innovation 263

14.7 References 269

PART VI CASE STUDY #4 275

15 Case study paper no. 4: Green taxation 276

15.1 Abstract 276

15.2 Introduction 277

15.3 The theoretical arguments for and against green taxation as a tool for environmental and economic policy 278

15.3.1 The pure externality argument 278

15.3.2 The fiscal-employment benefits argument 284

15.4 The empirical evidence for externality types green taxes and double dividend type green taxes 298

15.4.1 Empirical evidence and history of externality type taxes and other market-based instruments 298

15.4.2 Empirical evidence on the double dividend 312

15.5 Conclusions 323

15.6 References 325

16 Opponent note no. 4a: Green taxation 328

16.1 Summary on Markandya's paper 328

16.2 Alternative theoretical considerations 330

16.3 Further empirical considerations 332

16.4 Outlook 333

16.5 References 335

17 Opponent Note no. 4b: Green taxation 337

17.1 Introduction 337

17.2 The case for environmental taxes and other market mechanisms 337

17.3 Is there a double dividend? 340

17.3.1 *The "weak" double dividend* 340

17.3.2 *Improving the efficiency of the tax system* 341

17.3.3 *Simulation models and the (strong) double dividend* 342

17.4 Environmental taxes and competitiveness 342

17.5 Conclusions 345

17.6 References 346

PART VII CASE STUDY #5 347

18 Case study paper no. 5: Support to organic farming and bio-energy as rural development drivers 348

18.1 Abstract 348

18.2 Overview 348

18.2.1 Organic farming 348

18.2.2 Bio-energy 350

18.3 Introduction 351

18.3.1 *Rural development policy* 352

18.3.2 *Objectives of the study* 352

18.3.3 *Approach* 353

18.3.4 *Outline* 353

18.4 Organic Farming 353

18.4.1 The analytical framework 354

18.4.2 Literature review 356

18.4.3 Danish case study 364

18.4.4 Conclusion concerning organic farming 375

18.5 Bioenergy 376

18.5.1 Overview of the role of biofuels 376

18.5.2 Analytical framework 381

18.5.3 Literature reviews 382

18.5.4 Conclusions 388

18.6 References 389

19 Opponent note no. 5a: The Lisbon Strategy and the common agricultural policy: Impacts on the "common conventional" and "differentiated new" agriculture in the EU-25, and globally 394

19.1 Introduction 394

19.2 Multifunctional Agriculture and Policies 396

19.3 Transaction costs and efficiency of policies 399

19.4 Is the common agricultural policy common enough? Prospects for co-financing and renationalisation, or regionalisation, of the CAP? 401

19.5 Bioenergy and rural development in the international/global perspective 402

19.6 Conclusions (mainly with regard to the case study paper by Abildtrup & Dubgaard, 2006) 404

19.7 References 406

20 Opponent note no. 5b: Support to organic farming and bio-energy as rural development drivers 408

20.1 Summary 408

20.2 Introduction 408

20.3 Short background on economic growth 409

20.4 Conclusions case study paper on organic farming 410

20.4.1 *Comment* 411

20.5 Organic farming 411

20.5.1 The Dutch experience 411

20.5.2 High tech agriculture 412

20.6 Conclusions case study paper on bio-energy 416

20.6.1 *Comment* 416

20.7 Bio-energy 417

20.7.1 The Dutch experience 417

20.7.2 High tech applications 418

20.7.3 *Conclusions* 420

20.8 Conclusions 420

20.9 References 422

PART VIII CASE STUDY #6 423

21 Case study paper no. 6: Renewable energies – environmental benefits, economic growth and job creation 424

21.1 Abstract 424

21.2 Introduction 424

21.3 Environmental effects of renewable energy utilisation 425

21.3.1 Comparison of the environmental effects of renewable and conventional energy utilisation 427

21.3.2 CO_2 emission reduction 435

21.3.3 Conclusion 441

21.4 Macroeconomic aspects of RES 442

21.4.1 General remarks on growth prospects 442

21.4.2 Macroeconomic effects of the deployment of RES 445

21.4.3 Effects of promotion of RES for selected sectors 450

21.4.4 Conclusion 451

21.5 Policy instruments and measures 452

21.5.1 Characterisation of policy instruments for RES 454

21.5.2 Assessment of instruments 469

21.5.3 Quotas versus feed-in tariffs 479

21.5.4 Case study Denmark 484

21.6 Conclusions and forecast 485

21.7 References 486

22 Opponent note no. 6a: Increasing the role of renewables in the EU: Gloomy prospect or pitfall 490

22.1 Abstract 490

22.2 Introduction 490

22.3 Goals and Instruments 491

22.4 Environment 494

22.5 Jobs 496

22.6 Technology and growth 497

22.7 Conclusion 499

22.8 References 500

23 Opponent note no. 6b: Renewable energies – environmental benefits, economic growth and job creation 502

23.1 Introduction 502

23.2 Most important issues 504

23.2.1 Environmental impacts and benefits – externalities 504

23.2.2 Job creation and economic growth 505

23.2.3 The problem of intermittency 507

23.2.4 Renewable technologies impacting the spot power price 513

23.2.5 Policy instruments and measures 516

23.2.6 Conclusions 519

23.3 References 521

PART IX ORIGINAL PROGRAMME & PREVIOUS REPORTS 523

Annex 1: Original programme 523

Previous reports from the Environmental Assessment Institute 529

Part I Introductory chapters

This introductory part of the report includes the Director's introduction in Danish (chapter 1) and English (chapter 2), the Facilitator's summary of the Experts' Forum (1 March, chapter 3), and a summary of the Policy Makers' Forum (2 March, chapter 4).

A copy of the original 4-page programme of the Green Roads to Growth meeting 1-2 March 2006 arranged by the Environmental Assessment Institute can be found as Annex 1 at the end of this report.

1 Introduktion – økonomisk og politisk kontekst

Peter Calow, Direktør for Institut for Miljøvurdering, Danmark. E-mail: pca@imv.dk.

"Grønne veje til vækst" beskriver et arbejdsprogram, der udføres af Institut for Miljøvurdering for at sondere mulige koblinger mellem miljøpolitik og økonomisk vækst. Fokus er på EU, men principperne har bredere relevans.

Den *økonomiske* kontekst for "Grønne veje til vækst" kan inden for EU karakteriseres ved øget konkurrence fra lande uden for EU, en aldrende befolkningssammensætning, samt i mange medlemslande ved et behov for jobsikkerhed for at sikre social sammenhængskraft. Den *politiske* kontekst er defineret i den såkaldte Lissabon-strategi lanceret i Lissabon (2000) af Rådet for den Europæiske Union for at øge fokus på vækst og beskæftigelse. Strategien blev udvidet til at omfatte bæredygtig udvikling, der var en ambition udtrykt i Göteborg-strategien (2002), og blev genfremsat af Rådet for den Europæiske Union i marts 2005 med fornyet fokus på jobskabelse og vækst.[1] Man ønskede at opnå denne refokusering på en måde, der var klart sammenhængende med strategien for bæredygtig udvikling udtrykt på Göteborgmødet. Men der var fortsat en opfattelse af, at miljøpolitikken var blevet marginaliseret, og det var en forståelig reaktion blandt miljøfortalerne, at man ønskede at fremme det synspunkt, at udover at miljøpolitik på ingen måde ville stå i vejen for økonomisk fremgang, så vil "en god miljøregulering i Europa kunne understøtte en ren og konkurrencedygtig økonomi og et sundt miljø på arbejde og i fritiden."[2]

Mens dette skrives, er der større økonomisk optimisme i EU. Ved rådsmødet i marts 2006 peges der på økonomisk restitution siden slutningen af 2005, og at "væksten

[1] Et godt resume fines på: European Policies Research Centre (2005). Delivering the Lisbon and Gothenburg Agenda. http://www.elisabeth-schroedter.de/downloads/Newcastle_Arbeitspapier.pdf. All e web referencer i introduktionen til GG-rapporten virkede den 12. juni, 2006.

[2] Network of Heads of European Environment Protection Agencies (2005). The contribution of good environmental regulation to competitiveness. http://www.environment-agency.gov.uk/commondata/acrobat/prague_1229630.pdf

forventes at vende tilbage til sit fulde potentiale i 2006".[3] I den forbindelse bliver miljøpolitik fortsat præsenteret blandt andet med henvisning til dens betydning for vækst og beskæftigelse. Paragraf 75 i Formandskabets konklusioner (marts 2006; fodnote 3) siger: "Udover dets betydning på egne præmisser så kan en fornuftig miljøpolitik bidrage væsentligt til jobskabelse og vækst og kan have en positiv afsmitning på centrale områder som befolkningens sundhed og udgifter til sundhedsvæsnet foruden at bidrage med social sammenhængskraft og udvikling af en fælles europæisk energipolitik, inklusive forsyningssikkerhed og effektiv udnyttelse af energi".

"Grønne Veje til Vækst" rejser to spørgsmål, der er centrale for denne debat:

i. Kan miljøpolitik understøtte bestræbelserne for samtidigt at løse miljøproblemer og fremme økonomisk vækst samt jobskabelse? Nøglespørgsmålene er her:
   - Under hvilke omstændigheder?
   - Med hvilke politiske redskaber?
   - I hvilket omfang?

ii. Hvad er potentialet i miljøpolitik i forhold til en bredere strukturel politik i forhold til at nå miljømæssige, økonomiske og jobskabende mål? Nøglespørgsmålene er her:
   - Hvad er de respektive effekter?
   - Hvori består sammenhængene?

Dette område er så vigtigt, at det helt naturligt har tiltrukket stor opmærksomhed. "Grønne Veje til Vækst" anvendte tre forskellige tilgange.

For det første adresserede man de generelle spørgsmål fremsat her ovenfor gennem fem tilgange til gensidige forbindelser mellem miljøpolitik og økonomisk

[3] Conclusion of the European Council of March 2006. http://register.consilium.europa.eu/pdf/en/06/st07/st07775.en06.pdf.

vækst. Dette omtales i kapitel 5 (det såkaldte ”framework paper”), der danner en slags forståelsesramme for de øvrige arbejder.

For det andet undersøgte man kritisk disse nøgle-sammenhænge på grundlag af litteraturstudier omkring særlige ”case-studier”, hvilket indebar at såvel analyser som diskussioner var baserede på fakta. Der var seks sådanne ”case-studier”, der omfattede vidensøkonomi (to studier), miljømæssig innovationer, grønne skatter, landbrug samt vedvarende energi. Hvert af disse ”case-studier” blev kritisk evalueret af to opponenter, hvis indlæg er gengivet efter de relevante studier.

Og for det tredje præsenterede "Grønne Veje til Vækst " analyserne på en form der var målrettet mod at informere beslutningstagere og politik.

Processen kulminerede i to seminardage. Den første dag åbnede mulighed for diskussion af nøgleemner mellem de involverede eksperter; dette var organiseret omkring ”case-studie”-materialet. Den anden gav mulighed for udveksling af ideer mellem eksperterne og beslutningstagerne på basis af et resume af ekspertseminaret skrevet af seminarets ordstyrer, Nils-Axel Braathen. Resumeet af eksperternes seminardag findes i kapitel 3,og der gives et kort resume af beslutningstagernes seminardag i kapitel 4. Resten af rapporten samler de øvrige input og fungerer som proceedings for mødet. Hovedparten af de indsendte indlæg blev revideret efter diskussionerne, men de er ikke redigeret yderligere, før de er bragt i denne rapport. Programmet for de to seminardage findes som appendiks 1 sidst i denne rapport.

På basis af de samlede arbejder, der var resultatet af ”Grønne Veje til Vækst”, formulerede Institut for Miljøvurdering en række konklusioner:

- For det første er der ikke nødvendigvis sammenhænge mellem grønne veje og veje til vækst. Faktisk var det et tilbagevendende tema, at man ikke skal forvente sig for meget af miljøpolitik i retning af at opfylde de generelle mål for økonomisk vækst og beskæftigelse. Miljøpolitik skal først og fremmest indrettes for at værne om miljøet. Manglende klarhed omkring målene med miljøpolitik hjælper ikke dem, som søger at opfylde samfundets øvrige mål. Men det skal samtidig erkendes, at en målrettet miljøpolitik ikke kun gavner befolkningens sundhed og den økologiske balance i naturen, den indebærer samtidig en omkostning for samfundet. Vi skal derfor være beredt på at diskutere miljøpolitik åbent og ærligt på disse præmisser.

- For det andet er det klart, at ikke alle veje til vækst er ”rene”, men også at ikke alle veje er forurenende; at komme på en ”ren” vej til vækst gennem politiske initiativer forudsætter i al væsentlighed, at man bruger gevinsterne fra vækst til at udvikle den rette teknologi.
- For det tredje kan en veltilrettelagt miljøpolitik i denne sammenhæng være nøglen til at skabe markedsbetingelser, der fremmer innovation på en måde, der fører samfundet i retning af renere teknologier. Det skal være bredt funderet med vægt på brugen af økonomiske instrumenter – og ikke være alt for målrettet, da der altid vil være et antal ”taberprojekter” for hvert ”vinderprojekt”; der skal skabes markedsbetingelser, der muliggør egeninvestering frem for offentlig støtte, og det som skal støttes skal være bredt funderede forsknings- og udviklingsprogrammer.
- For det fjerde er det vigtigt, kompleksiteten taget i betragtning, at udføre grundige analyser, der afvejer fordele mod ulemper forbundet med alle indgreb. Et tilbagevendende emne ved konferencen var, at alle parter skal være opmærksomme på forsimplede delløsninger. Det er væsentligt at inddrage de samlede virkninger af påtænkte indgreb på økonomi og beskæftigelse, og at erkende at gevinster inden for ét område kan fremkomme på bekostning af tab inden for andre. Desuden skal man i senere analyser af sammenhængen mellem brugen af politiske instrumenter og økonomiske gevinster undgå forhastede konklusioner vedrørende årsagssammenhænge, da der i den virkelige verden er mange skjulte variable. Lovgiverne skal regulere med størst mulig bevidsthed om disse kompleksiteter.

Det er vores hensigt, at de generelle konklusioner fra ”Grønne Veje til Vækst” skal danne et væsentligt fundament for fremtidige arbejdsprogrammer ved Institut for Miljøvurdering, og derved bidrage til den løbende debat om sammenhænge mellem miljøpolitik og økonomisk vækst i Danmark og internationalt.

2 Introduction and policy context

Peter Calow, Director, Environmental Assessment Institute, Denmark. E-mail: pca@imv.dk.

"Green Roads to Growth" describes a programme of work carried out by the Danish Environmental Assessment Institute to explore the possible linkages between environmental policy and economic progress. The emphasis is on the EU but the principles apply broadly.

The economic background to "Green Roads to Growth" in the EU is characterised by intensified competition from abroad, an ageing population and in many Member States a need to secure jobs to facilitate social cohesion. The policy context is set by the so-called Lisbon Agenda that was initiated at the Lisbon Council (2000) to focus on growth and employment, was broadened to include sustainable development as an aspiration at the Gothenburg Council (2002), and was re-launched at the European Council in March 2005 re-focussing priorities on jobs and growth.[4] This re-focussing was supposed to be achieved in a way that was coherent with the Sustainable Development Strategy brought into focus at Gothenburg. But still there was a perception that environmental policy was being marginalised and an understandable reaction from the "environment camp" was to promote the view that environmental policy would not only not get in the way of economic progress but that, "good environmental regulation in Europe can support a clean, competitive economy and a healthy environment in which to work and live."[5]

At the time of writing there is more economic optimism in the EU. The Council of March 2006 sees evidence for economic recovery since the end of 2005, "with

[4] A good summary is given by: European Policies Research Centre (2005). Delivering the Lisbon and Gothenburg Agenda. http://www.elisabeth-schroedter.de/downloads/Newcastle_Arbeitspapier.pdf. All web refs in this introduction to the GG-report were last checked 12 June, 2006.

[5] Network of Heads of European Environment Protection Agencies (2005). The contribution of good environmental regulation to competitiveness. http://www.environment-agency.gov.uk/commondata/acrobat/prague_1229630.pdf

growth expected to return to potential for 2006".[6] It, nevertheless, continues to set environmental policy in the context of economic performance. Paragraph 75 from the Presidency Conclusions (March 2006 (footnote6)) states "Over and above its importance in its own right, environmental policy can make an important contribution to jobs and growth and can impact positively on important sectors such as public health and healthcare costs, and social inclusion and cohesion as well as on the development of a Energy Policy for Europe, including the promotion of energy security and energy efficiency".

"Green Roads to Growth" raises two questions that are central to this debate:

i. Can environmental policies underpin the aspirations to simultaneously address environmental problems while promoting economic growth and jobs? The key questions here are:
   - Under which circumstances?
   - With which policies?
   - To what extent?

ii. What is the relative potential of environmental policies and broader structural policies in relation to addressing environmental, economic and employment objectives? The key questions here
   - What are the relative impacts?
   - What are the inter-linkages?

The area is so important that there is naturally a lot of interest in it. However, the "Green Roads to Growth" programme brought three distinctive approaches.

First, it addressed the general questions defined above systematically by expressing them in five clearly defined linkages between environmental policy and eco-

[6] Conclusion of the European Council of March 2006. http://register.consilium.europa.eu/pdf/en/06/st07/st07775.en06.pdf.

nomic performance and vice versa. This is covered in Chapter 5 which provided something of a framework for the other work.

Second, it critically examined these key linkages on the basis of evidence culled from the literature and organised around specific case studies - so the analyses and discussions were evidence based. There were 6 case study papers covering the knowledge economy (two studies), environmental innovations, green taxation, agriculture and renewable energies. Each was subject to critical analysis by so-called ”opponents" and their contributions are given as notes after appropriate chapters.

And finally, "Green Roads to Growth" presented the analyses in a way that was deliberately intended to inform the policy makers and policy.

The process culminated in two Forums. One provided discussion of the key issues by experts. This was organised around the case study material. The other Forum provided for an exchange of ideas between experts and policymakers and was informed by a summary paper from the chairman of the Expert Forum, Nils-Axel Braathen. The summary paper from the Expert Forum is included as Chapter 3 and a brief summary of the Policy Maker Forum (compiled by the Institute) is included as Chapter 4. The rest of the report collects together all the inputs and is intended as a record of proceedings. Most of the chapters were modified after the discussions, but they have not been edited further for this report. The Forum Programmes are summarised in the Annex.

On the basis of all the work emerging from "Green Roads to Growth programme", the Environmental Assessment Institute framed several general conclusions:

- First, green roads do not necessarily connect with roads to growth. Indeed a recurrent theme was that we should not expect too much from environmental policies with respect to broader goals of economic growth and employment. Environmental policies should be designed, in the first place, to protect the environment. Lack of clarity in the aims of environmental policy is not helpful to any of the players. But it should also be recognised that environmental policy not only brings benefits to human health and ecology it will also generally bring costs to the economy. We should therefore be prepared to judge environmental policy transparently in these terms.
- Second, it is clear that not all roads to growth are clean – but not all are roads are dirty either - getting on to a clean policy road depends impor-

tantly on using the benefits from growth to feed back into development of the right technology.

- Third, in this context well designed environmental policies may well become key in creating market conditions that promote innovation that takes society in the direction of cleaner technology. This should be broad based, emphasise economic instruments, should not be too targeted - because picking losers is more likely than picking winners – create market conditions that enable inward investment rather than government subsidy, and support broad-based R&D.
- Fourth, given the complexities, it is important to carry out careful analyses to weigh benefits against costs for all interventions. Another recurrent theme at the conference was that all should beware of the too simplistic, partial approaches. It is important to consider overall effects of interventions on the economy and employment and to recognise that gains in one sector may well be at the expense of losses in others. Moreover, in *post hoc* analyses based on correlation between policy instruments and economic outputs, analysts need to beware of jumping to conclusions about causation because of the many hidden variables in real-world situations. Policymakers need to make policy interventions with as much awareness of these complexities as possible.

Our intent is that these general conclusions will provide an important basis for the development of IMV's future programmes and contribute to the on-going debate about linkages between environmental policy and economic progress in Denmark and internationally.

3 Facilitator's summary of the Expert Forum of the Green Roads to Growth meeting 1 March 2006

Nils-Axel Braathen, OECD (Acted as facilitator, not representing OECD views).

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The answers given to the pre-defined questions, indicated below in bold face, are Nils-Axel Braathen's summary of extended discussions to these questions.

3.1 (To what extent) do you see any fundamental conflicts between the policy goals of higher economic growth, increased employment (or reduced unemployment) and an improved environment?

There does not seem to be any such fundamental conflicts – lasting improvements in all three dimensions *can* be achieved simultaneously. It can, however, be more challenging to achieve a 'strong decoupling' of some negative environmental impacts from economic growth than others.

3.2 (To what extent) do you think further economic growth 'automatically' will lead to environmental improvements?

One should not assume that further economic growth automatically will solve the remaining environmental problems – there *is* a need for policies directed specifically at addressing environmental problems. In other words, the benefits to society as a whole are likely to exceed the costs to society of putting in place new environmental policies in a number of areas.

3.3 (To what extent) do you think it is possible to address all the three goals simultaneously through environmental policy instruments?

Environmental policies will probably normally *not* have a significant positive impact on economic growth and employment – at a national level. These policies should primarily be focused on achieving the desired environmental improvements in a cost-effective way – and not be given the 'responsibility' for 'solving' other major policy objectives.

This being said, well-designed environmental policies are *not* likely to have any clear *negative* impact on growth or employment either.

3.4 If it is possible: for which types of policy in which environmental areas could it most likely be the case?

The policies would probably have to offer a lot of flexibility for firms and households to find the cheapest abatement options – and stimulate further technology development. It is, however, very difficult to speculate on which environmental areas are the 'strongest candidates'.

3.5 What are likely to be the most important economic and environmental impacts of the development of a more knowledge-based economy in general?

A knowledge-based economy could to a certain degree lead to environmental improvements, with less focus on increased use of capital and natural resources as drivers for economic growth. On the other hand, it could also lead to shorter economically viable life-spans for some product categories – which could lead to higher 'resource through-put'.

3.6 What are the main drivers of new inventions and their diffusion?

Demand pull, technology push and regulation push can all play a role.

Prospects of making money can often be an important motivation. To the extent that this matters, 'getting the prices right' by internalisation of the social costs of environmental damages will provide incentives for innovations in the right 'directions'.

3.7 How can policy-makers best (from a cost-benefit perspective) stimulate the development of more environmentally friendly 'technologies'?

There is a case for some subsidies for R&D, etc., given the positive spillovers related to new invention, etc., – as those who make an invention do not reap all the benefits this invention can cause. The 'better' the price structure of the economy, the less will the need for subsidies be.

The policies to support development of new technologies should be broad-based, targeted at the environmental problem areas at hand, but not at specific technological solutions.

It is important that the choices about technological solutions are made at a decentralised level. Public authorities should avoid prescribing specific technological options.

3.8 How can policy-makers best (from a cost-benefit perspective) stimulate the diffusion of existing and new environmentally friendly 'technologies'?

The case for subsidies to stimulate diffusion of existing technologies seems weaker than the case for supporting R&D – as there generally are fewer positive spillovers and less risk involved. Those who start applying an existing technology will reap most of the benefits for themselves.

'Correct pricing' can again play an important role.

3.9 What role can internalisation of negative environmental impacts in the prices of goods and services play?

An important role – but there will still be some scope for R&D support.

3.10 How can one best avoid that environmental benefits from new innovations are (partly) lost due to 'rebound effects'?

By 'getting the prices right'.

3.11 What are the main arguments for applying "green taxes" (and other similar economic instruments)?

That they can provide a cost-effective option for abating emissions (static efficiency) and that they provide lasting incentives for technology development (dynamic efficiency).

3.12 Is an 'employment dividend' likely to appear?

No.

3.13 What could be the impacts of "green taxes" on innovation and economic growth – in practice?

They can probably significantly stimulate innovation – but more empirical evidence is desirable. At present industry is mostly exempted from environmentally related taxes. Hence, we have few cases that illustrate the impacts 'better pricing' can have

on innovation. The EU CO_2 trading scheme can provide interesting data on innovation impacts in the years to come – as can the increases in crude oil prices that we have seen over the last few years.

3.14 What would be the main environmental advantages (and disadvantages) of increased organic farming / biomass production / renewable energy production?

Somewhat lower GHG emissions – but one needs to take the fuel used in producing biomass into account.

Less water and soil pollution from organic farming – but the land requirements could increase.

3.15 What are likely to be the overall economic / employment impacts of such increases – when taking "general equilibrium effects" into account?

It does *not* seem likely that stimulation of these sectors will contribute significantly to higher economic growth or employment – at a national level. Any increases in employment in these sectors will to a large extent (if not fully) be offset by decreases in other sectors – through competition in product and/or labour markets, and due to the efficiency losses related to the financing of any subsidies needed to stimulate the sectors in question.

3.16 What would (from a cost-benefit perspective) be the 'best' way to stimulate such increases (to the extent they would be desirable overall)?

Reduce existing subsidies to competing activities – for instance subsidies to fossil-based energy production. Internalise any negative environmental externalities in the same sectors. Remove other obstacles to a good functioning of the markets in question.

3.17 To what extent could a better "internalisation of externalities" elsewhere in the economy 'automatically' trigger a desirable outcome in this regard?

Probably to a significant extent – but there are too few examples of such approaches to allow absolute conclusions to be drawn.

4 Summary of the Policy Maker Forum, 2nd March 2006

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The aim of the Policy Maker Forum was to enable a dialogue between experts (largely economists) and policy makers.

Participants included members of the European Parliament, members of the Danish Parliament, EU Commission staff, Environmental NGOs, Industry Spokesmen and key experts. Kim Bildsøe Lassen, a journalist from the Danish Broadcasting Corporation News, was independent Chairman.

The main conclusions from the discussions were that environmental policy cannot solve Europe's growth and unemployment problems. But a well designed environmental policy can contribute to creating market conditions that stimulate the development of new technologies to lead us in a more environmentally friendly direction.

4.1 Automatic decoupling

The starting point of the discussion emerged from the question: *Can environmental problems be solved by getting rich?*

The policy makers agreed with the recommendations made by the expert Forum that economic growth does not necessarily lead to improved environmental conditions.

One politician made the point that:

"Environmental problems cannot be solved by us becoming rich, but by taking decisions, creating new markets and new jobs. Focus must be on the scientific side, it is not only a job for economists, scientific knowledge is also necessary. The main issue is the tremendous global growth and wealthier countries must develop new technology."

Another politician drew attention to the need for Denmark to be a front runner:

"Denmark is a leading country. We must find new areas and develop new technologies in order to stay as the front runner in the environment."

There was general agreement that it was necessary to design proper environmental policies.

4.2 Policy design

Another discussion centred on the questions: *"What is the role of policymakers and how should policies be designed?"*

Both experts and policymakers agreed that the economic analyses should not stand alone. However, it was stressed that it is the economic analysis that can inform and improve the decision making by providing overviews of costs and benefits.

Some politicians advocated the use of voluntary agreements, public procurement, command, and control measures. Others alternatively advocated the use of economic instruments by stressing the need to meet the environmental objectives by the lowest possible cost.

The experts argued that non-economic measures are not the most effective. Instead they recommended adopting economic instruments such as green taxes.

One politician gave three arguments against the use of green taxes: evidence from the 1990s indicated that the instruments had not had any environmental effect. They are regressive. Many do not like the principle that paying a tax gives licence to pollute.

Some of the policymakers stressed the need for a more assertive innovation policy. This could induce “learning loops”. Industry representatives argued for further support for research.

But it was noted by the experts that innovation can be uncertain; it is hard for policymakers to pick winners. Some suggested that goals should be set for addressing problems, that these should provide a broad framework for developments, that industry should be left to come up with specific solutions and that the market should be left to pick winners. Others suggested that European countries might act as “experimental laboratories” for different policies and solutions in a way that was co-ordinated by the EU institutions.

4.3 Barriers

Finally the focus turned to the question of: *"What are the barriers to policy development and implementation?"*

Many drew attention to the massive global market in environmental technologies. Yet there was reticence in EU policymakers to develop policies that encouraged appropriate attention to these opportunities. A fundamental problem was that the environment was not engaging public interest. "People think that more progress has been made than there has been in reality". The political systems also are inclined to defend the old industries – such as agriculture and heavy industry. The need to create employment is also a major driver. In consequence there is often a lack of political will to engage in the developmental of progressive environmental policy.

As well, EU policy and legislation addressing environmental and economic issues is complex, represented in a range of often poorly co-ordinated instruments and not easily understood by the business sector and the ordinary citizen.

Experts have the role of drawing attention to the likelihood of policies succeeding in bringing benefits for least costs according to theory and past experience. All agreed this is only part of the process. Political vision that engages the public mood is paramount. In this the power of good, easily understood information about the state of the environment and the aims of environmental policy and legislation should not be underestimated.

Part II Framework paper

5 What are the Linkages between Environmental Policies, Economic Growth and Employment?

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Abstract

This paper considers linkages between environmental policies, economic growth and employment based on a selective overview of the theoretical and empirical literature. The discussion of links between the environment and production began in earnest in the 1970s when economic growth was frequently seen to inevitably put additional pressure on the environment. The debate has recently acquired new impetus after the finding of an inverse-U relationship between production and many pollutants. The upshot is that there is no mechanical one-to-one relationship between production levels and environmental performance. This article shows that the links are numerous and indeed very complex. It is, however, vital to understand these links and their interactions in order to devise policies which can reconcile economic and environmental policy objectives.

5.1 Introduction

For decades, policy makers and the general public have been interested in the complex relationships between the environment, economic growth, and employment. The discussion has long moved past the simple and pessimistic ideas of the 1970s represented by the Club of Rome and the commissioned report *Limits to Growth* (Meadows *et al.* 1972), which held that economic growth was necessarily harming the environment. In its place is a new set of ideas that we describe in this paper. We take stock of the academic discussion on possible links between the environment and economic performance, surveying both theoretical and empirical work.

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This paper focuses on the intersection between the microeconomic analysis of environmental issues and the macroeconomic analysis of production and employment. One particular area of interest is whether there are circumstances under which government intervention can lead to win-win outcomes where the environment and the economy improve simultaneously. The background for this approach is twofold. First, the amount of environmental policies has increased markedly since the 1960s and is increasingly affecting the economy in many countries (OECD 2003). Second, the approach is meant to relate to the polical discussion where the focus is on easily observable economic variables like output and employment. Frankel (2003, p. 1) states that: "People care about both the environment and the economy".

The issues involved are complex and do not lend themselves to simple or universal answers. This stems from the somewhat unusual approach of seeking to link the welfare economic analysis of environmental policies and its macroeconomic effects. To accommodate the complexity of the issues, we have organised the discussion around five links, which aim to capture many of the ideas from the public and academic debate.

Link I: The Environmental Kuznets' Curve. The first link is the empirical observation that the relationship between income levels and the environment sometimes follows an inverted-U shape: at low income levels, economic growth leads to increased pollution, while at higher income levels growth is associated with a less pollution. Environmental impacts may be decoupled from economic growth as economic growth does not necessarily lead to increased pressure on the environment.

Link II: Environmental externalities. The second link is the traditional notion of an "externality" that affects other firms or individuals. Externalities in the form of pollution or congestion can lower social welfare. Environmental policies can address the negative externalities and improve welfare. The effect of environmental policies in the form of green taxation will depend on the way the tax revenue is utilised.

Link III: Knowledge spillovers. Link three considers the case of two simultaneous externalities: an environmental externality as in Link II and a knowledge externality where one firm's innovation spills over to other firms. The knowledge externality may lead to underinvestment in environmental technologies in the absence of government intervention. In this case, the government may also seek to affect the innovation process in order to pursue environmental goals.

Link IV: The Porter Hypothesis. Link four is the Porter Hypothesis, which states that appropriately designed environmental policies can improve the performance of affected industries and possibly the whole economy. The Porter Hypothesis rests on the premise that firms in many instances waste resources in the production process and also do not take advantage of new profit opportunities e.g. from being the first in new markets.

Link V: Market opening. Link five considers how a structural policy like international economic integration simultaneously affects both the economy and the environment – irrespective of any mutual interaction between these variables. Market opening also raises issues related to the effect of environmental regulation. Environmental policy cannot be reduced only to specific environmental regulation.

The five links are neither exhaustive nor mutually exclusive. We focus on the five links because they shed light on some important arguments in the debate on the role of environmental policies and their effects on economic performance. The links also illustrate that the relationship between environmental policies and economic performance is highly complex.

An extensive literature deals with specific examples of the relationship between environmental policies and the macroeconomy. There are, however, relatively few articles taking a broad view of the literature – with two chapters in *Handbook of Environment Economics* as the main exceptions. Heal & Kristrom (2005) consider how national income can be measured and adjusted when there are externalities in the economy; Xepapadeas (2005) discusses how environmental issues can be incorporated into growth models. Other studies include Atkinson *et al.* (1997) where the focus is on sustainable development indicators. McMorran & Wallace (1995) and IMF (1995) are short papers discussing some links between the environment and the macroeconomy. Daly (1991) seeks to delineate the boundaries of environmental macroeconomics with special emphasis on sustainability issues. Other studies discuss and survey linkages between the environment and economic growth but focus on one certain area. A prime example is Copeland & Taylor (2004) which discuss the impact of trade on growth and the environment.

5.2 Three objectives: growth, employment and the environment

The aim of Green Roads to Growth is to examine whether there are policies which can reconcile environmental improvement with income and employment growth. The triplet of economic growth, high employment and a sound environment are

goals which few people would object to. People want a higher material standard of living, the security of employment, and a sound environment. It is, however, useful to consider in some detail how to interpret these goals and how to understand the aim to improve all three at the same time.

5.2.1 The three objectives

5.2.1.1 Economic growth

Economic growth is measured as the change in the gross domestic product over a given period of time. Real GDP is the value of the total registered production of marketed goods and services. GDP is a *gross production* measure and not an income measure as the depreciation of capital and international income transfers are not accounted for.

Only goods and services that are sold and bought in a market are included in GDP, so household production, neighbour help and work carried out at home are left out. The same applies to externalities, where one agent's activities affect other agents' utilities or profits without a market-based payment. A prime example is pollution which is not traded in a market. Economic growth as conventionally measured does not take into account environmental impacts which are not reflected in the marketed production of goods and services.

The term economic growth is used in very different meanings depending on the time horizon, i.e. whether we consider the expansion of production in the long term, the medium term or the short term (OECD 2004a):

(i) Economic growth can be associated with the long-term expansion of production over a horizon of, say, 20 or 30 years. The long-term economic prosperity of a country is an exponential function of the average growth rate. The effects on production of different growth rates can be staggering; a growth rate of 2.3% implies that the production doubles over 30 years, while a growth rate of 4.7% implies that the production quadruples over the same time period.

It is usually assumed that the market mechanism will ensure full utilisation of all resources in the long term. Relative prices will adjust so that capital, labour etc. are fully utilised. As means of an example, involuntary unemployment would exert downward pressure on real wages, making it more favourable to employ additional labour until the point where the involuntary unemployment has vanished. The same reasoning applies to other factors of production. It might take some time

before the adjustment of relative prices take place. This implies that the short-term dynamics can differ from the long-term case of full resource utilisation.

The presumption of full resource utilisation implies that long-term production must be explained by the supply of factors and the efficiency with which these are utilised, the so-called total factor productivity (TFP). We start by considering the supply of production factors (Romer 2006, ch. 1). Land is in fixed supply in the long term. Other factors like physical capital can be accumulated via net investments but with the cost of reduced consumption in the short term. Without population growth the number of workers cannot be affected in the long term, but the effectiveness of labour can be increased via education, training, better health or improved work ethics. The labour supply adjusted for its effectiveness is often called the stock of human capital – as education, health and ethics cannot be separated from the human individual. The accumulation of production factors is often perceived to yield only limited potential for *long-term* economic growth, as there are likely diminishing returns to scale in the accumulation of reproducible factors.[9]

Changes in total factor productivity thus appear to play a crucial role for long-term growth. Measuring over long time horizons, changes in TFP have often contributed one-half or even substantially more of total growth. Growth in TFP has been seen as difficult to explain and largely the result of exogenous factors; it is sometimes referred to as "manna from heaven" (Romer 2006, ch. 1). The endogenous growth literature gained prominence in the 1980s and seeks to explain TFP growth by using ideas by Joseph Schumpeter and others tracing back to the beginning of the 20th century. The main argument is that technical and organisational inventions and innovations and their diffusion are major drivers of TFP growth. The firms' incentives to invest in innovation depend on their ability to recoup the initial outlay which again is a function of market structures, patent and trademark protection, innovation subsidies etc. Endogenous growth models often ascertain that invention and innovation – and more generally: knowledge accumulation – will be undersupplied in private equilibrium as the individual firms will not internalise positive spillover effects. This implies that the level of knowledge creation and diffusion can be inefficiently low and there is scope for government policies, e.g. in the form of pat-

[9] Diminishing returns to scale implies that as production increases a given increase in the production factors will result in a smaller and smaller increase in production.

ent protection, innovation subsidies, etc. (Romer 1990, 1994; see also section 5.4).

Technological innovations are unlikely to arrive in a continuous and predictable way. Innovations will to an extent be random with the result that one or a few firms are able to produce existing products with lower costs or that entirely new products are developed. The result will be that sales, production and employment move to the firms with lower costs or new products, while other firms will decline. This form of growth via "creative destruction" implies that long-term TFP growth will co-exist with – and partly result from – sectoral shifts of resources from declining sectors to sectors with positive innovation results (Romer 1990).

(ii) Short-term changes in economic growth rates are synonymous with business cycle fluctuations. All countries experience upturns and downturns where the growth rate is, respectively, above and below the long-term trend growth rate. Business cycle fluctuations are often emphasised in the media and draw a lot of public interest, in particular if the growth fluctuations greatly affect employment and unemployment. There is some disagreement about the underlying reasons for the short-term economic fluctuations. The conventional explanation is that the fluctuations are caused by shocks to the economy, e.g. unusual weather, oil price changes, interest rate movements, trade shocks, etc. In the absence of shocks, the economy will be at its "natural rate" as determined by the long-term growth process. Rigidities in the setting of wages or prices imply insufficient adjustment to shocks to keep production at its natural rate. This means that e.g. a foreign demand shock in the form of increased demand for the country's production lead to higher production and possibly also higher employment and lower unemployment (Romer 2006, ch. 5).

Per definition – and construction – positive and negative shocks will appear to an equal extent. This implies that shocks will only have a temporary effect on the rate of growth. Many economists would therefore prefer to reserve the term growth to describe the long-term change in production and use the term business cycles about short-term fluctuations. In policy-oriented work, however, the term economic growth is typically used in both cases. We do the same here.

The length of the business cycle appears to vary considerably across countries (Blanchard 1997). Some countries have rather short business cycles, while the

business cycled in other countries exhibits substantial persistence. The USA is an example of the former case, while many continental European countries appear to have longer business cycles. It may be useful to consider also a medium term, where changes in production (and employment) are set in motion by shocks but where structural changes propagate the shocks and make them highly persistent (Blanchard 1997). The slow European growth in the 1970s could represent such a development. The oil price shock of 1973 made labour less productive but was not followed by a corresponding adjustment of real wages. The result of an excessive real wage was that producers within a sector substituted away from labour to capital and across sectors shifted towards capital intensive industries. The result was even less labour demand which lead to even higher unemployment in a situation with insufficient real wage adjustment. The result was a medium term characterised by low employment and subdued economic activity.

The government might seek to combat economic fluctuations by counter-cyclical policies, e.g. by loosening fiscal policy in recessions and tightening it in booms. Another policy option may be to implement structural policies reducing the frequency and severity of business cycles.

It is important to distinguish between the different interpretations or horizons of economic growth. When considering policies aiming to increase growth, there can easily emerge a conflict between raising economic growth in the short term and in the long term. Increased fiscal expenditures financed through the issuance of debt might increase growth in the short term, but reduce labour supply and other factor supplies in the long term when taxes must be raised to service the debt.

5.2.1.2 Employment

As in the case with economic growth, it is useful to consider employment in the long term and in the short term separately. Labour supply, employment and unemployment are determined jointly in often complex ways (Romer 2006, ch. 9).

In the (very) long term, adjustment mechanisms are assumed to ensure that all resources, including labour, are employed; short-term fluctuations have played themselves out. There will still, however, be some unemployment. This “natural rate of unemployment” can be split into frictional unemployment and structural unemployment. Frictional unemployment is the result of worker flows in and out of employment; firms lay off workers which then search and wait for jobs. Structural unemployment is the result of mismatches between workers’ skills and employers’

demands; workers stay unemployed and wait for jobs that fit their qualification and meanwhile receive unemployment benefits or welfare payments.

Economic theory would suggest that the natural rate of unemployment is the result of labour turnover as well as labour market institutions, including unemployment benefits. These claims are backed by empirical evidence. Empirical work on OECD countries shows that labour market institutions can explain a very large part of the differences in long-term unemployment rates across the countries and over time (Nickell *et al.* 2005).

The long-term level of employment depends on the profitability of hiring workers. The real wage relative to the productivity of labour is thus of vital importance for the determination of the natural rate of employment. A higher labour supply will depress real wages until the point where the unemployment equals the natural rate of unemployment.

The long-term labour supply is determined by population growth, culture, norms and economic incentives. Focusing on the latter, it is usually presumed that the labour supply depends on the expected after-tax returns to supplying labour relative to the alternative of withdrawal from the labour market. Individuals supplying labour will either work or stay unemployed, and the respective after-tax real remunerations determine the expected return from supplying labour. Individuals can withdraw from the labour market to receive pensions, student grants, welfare payment or simply nothing.

It follows that the natural rate of employment depends on a host of factors. All in all, it is reasonable to assume that the natural rate of employment is lowered by higher pensions and welfare payments, higher or more easily obtained unemployment benefits, reduced matching efficiency and likely also increased taxation affecting the real wage. Technological progress leading to higher growth has an indeterminate effect on the natural rate of employment as both labour demand and labour supply are shifted upwards.

(ii) Short-term employment is driven by the same dynamics affecting short-term production levels. Shocks to the economy can lead to output fluctuations which again translate into employment fluctuations. Absent major changes in the labour supply, the employment fluctuations lead to fluctuations in the unemployment rate. If the economy exhibits only limited real wage flexibility, the shock will mostly be absorbed through fluctuations in output, employment and unemployment.

In the discussion of economic growth, it was argued that shocks to the economy could have medium-term effects on production and employment if the firms react to wage and price rigidity by intra- and inter-sectoral substitution. The question is why such inflexibility would occur, i.e. why involuntary unemployment does not lead to downward pressure on real wages, which again should reduce unemployment. Hysteresis in the unemployment rate can be explained by so-called insider-outsider theories: High firing and hiring costs imply that the insiders, i.e. the currently employed, have little risk of becoming unemployed and, hence, have little motivation for real wage moderation (Lindbeck & Snower 2002). The result is a slow adjustment to shock and hysteresis in the unemployment rate.

5.2.1.3 The environment

Also the environmental objective raises several conceptual and methodological issues. At first take, it is not easy to define an environmental problem. An artificial fertilizer is an important nutrient improving yields on farmland, but easily constitutes an environmental problem if it is leached out into a river. Clearly, we cannot define a pollution problem in terms of its physical characteristics. An environmental problem must be depicted in terms of its impact on social welfare.

Adam Smith argued in 1776 in the *Wealth of Nations* (Smith 1776) that – under certain circumstances – individuals acting in their own self-interest would unwittingly take actions that are beneficial for the whole society. The modern incarnation of Adam Smith's idea is the *first welfare theorem* which states that the market equilibrium is Pareto efficient, i.e. the economy cannot be reorganised so that some people are better off without making anybody else worse off. In other words, when the conditions of the first welfare theorem are satisfied, the market equilibrium implies that no resources are wasted.

From an economic viewpoint, an environmental problem is a form of *market failure* where the first welfare theorem breaks down, i.e. where the private market equilibrium is not efficient any more. The reason is that the environmental impact constitutes an externality. Externalities are costs or benefits not borne or accrued by the self-interested individuals making the economic decisions.

Pollution is an important example of a negative externality. In deciding how much to drive his or her car, a self-interested driver may take into account the cost of fuel, time, and vehicle depreciation, but will not consider the congestion or pollution imposed on others. Hence, drivers impose social costs in excess of the bene-

fits they receive from driving, and consequently drive in excess of what would be socially optimal, or economically efficient.

Another important externality is the *open access problem* or the *tragedy of the commons*. The market failure stems from many having open access to a shared common resource which is in limited supply; the resource is overexploited in market equilibrium as the negative externality is nottaken into account by the users of the ressource.[10]

A related market failure is *congestion*. Each person who chooses, for example, to drive a private vehicle imposes external costs on other drivers in the form of congestion. By crowding the road further, each driver makes it more difficult for others to use public roads. Analysts have found automobile congestion to be an even more costly externality than automobile pollution (Parry & Small 2005).

The common theme for all of these externalities is that they constitute market failures, and the market outcome is economically inefficient. The assumptions of the first theorem of welfare economics are violated, and individuals acting in their own interests behave in ways that are socially harmful. There is the possibility for a government to enact regulations that can, in theory at least, make somebody better off without making anybody worse off.

Environmental problems comprise a host of different forms of pollution, congestion and resource depletion. Even within each subcategory it is very difficult to get a picture of the extent of environmental pressure. For example, pollution can take the form of traffic noise, second-hand cigarette smoke, emission of greenhouse gasses etc. This implies that a government policy or another change affecting society might ease some pollution problems but aggravate others. This will indeed occur in many cases if a sufficiently detailed partition of the environmental problems is employed. Clearly, this makes it difficult to pinpoint what amounts to an environmental improvement.

One approach to this problem would be to consider only policies that improve *all* indicators of environmental performance. This is very restrictive as there are likely only few policies which will bring about improvement in all indicators – at least if the division of environmental problems is fine-grained. Alternatively, the overall

[10] For an example of this phenomenon in action, see Tyedmers *et al.* (2005), who report that fishing boats are using more and more fuel per fish, as fish stocks decline.

impact on social welfare of e.g. a government policy could be estimated using e.g. economic valuation methodology. In this way one could obtain a monetary measure of the overall effect on the environment of the policy. This approach also has drawbacks. In many cases it is difficult to obtain reliable estimates of society's valuation of the environment with the consequence that the assessment will be very uncertain. It is also time-consuming and costly to undertake socio-economic assessments.

Another solution is to construct *one* aggregate measure of environmental pressure. Numerous organisations publish aggregate indices that weigh together different measures of the state of the environment, but the weights employed usually do not have a welfare theoretic foundation, i.e. there is generally no assurance that the weights reflect society's assessment of the different forms of environmental pressure. One consequence of the arbitrary weights is that different organisations and institutions produce very different environmental pressure indices. The aggregate indices also tend to be subject to numerous alterations over time as the weights are changed.[11]

The geographical delineation must be considered irrespective of which measure of environmental performance that is being employed. It is customary to distinguish between national externalities falling solely within the national boundaries, international externalities where (typically) neighbouring countries are affected and global externalities like ozone layer depletion or global warming (Frankel 2003). It is a difficult choice whether only national environmental effects should be considered or whether broader international and global environmental effects should also be taken into account.

The time horizon also plays an important role when defining the environmental objective. Some types of pollution will be short-lived, e.g. noise pollution. Other types of pollution will remain long after the activity generating the pollution has ceased; a prime example is radioactive pollution. The timing of the peaks and

[11] The index published by the Center for Environmental Law & Policy at Yale University was extensively reweighted in 2006 and at the same time underwent a change of name from the Environmental Sustainability Index to the Pilot 2006 Environmental Performance Index, see http://www.yale.edu/epi/.

troughs of the pollution could also be important as many environmental policies reallocate the pollution impact over time.[12]

5.2.2 Variables and welfare

This subsection discusses the methodological approach of Green Roads to Growth in more detail. The aim is to examine to different links between three key variables and discuss policies which might affect all three positively – or more explicitly: reduce environmental pressures, increase growth and create new jobs. The focus is on key variables instead of explicit measures of societal welfare (Frankel 2003).

One advantage of this approach is that it does not require difficult and expensive welfare economic assessments of environmental policies which interact in very complex ways. A related benefit is that the approach considers variables that are observable and does not rely on welfare economic measures, which can be uncertain and complicated to calculate. The approach directly addresses issues like the environment, economic growth and employment appearing in the public and political debate.

The lack of an explicit welfare theoretic foundation also has drawbacks. First, it is not clear under which circumstances an increase in any one of the three variables improves welfare. While there are reasons to believe that higher employment are improving welfare in many cases, the opposite might also be the case. It is usually assumed in microeconomic models that individuals dislike working and only work to earn income. Second, even accepting the merit of each one of the three different objectives, there is no means to prioritise between the objectives as no aggregate measure of the three variables is specified. This explains the approach of Greens Roads to Growth of focusing on win-win solutions where winning refers to improved environment, higher growth and increased employment. Even among win-win policies we can only choose the best policy if it is better than all other policies in all three areas of interest.

We saw in subsection 5.2.1 that there are complex issues related to the contents and interpretation of all three variables; environment, growth and employment. One important issue is the time horizon. The effects of different policies on the

[12] A bridge replacing ferries could pollute significantly when constructed, but might save the environment the pollution from ferries for years to come.

economic and environment variables are likely to differ depending on the time horizon considered. Ideally, one would like to take into account the dynamic effects of current policies on the environment, growth and employment.

The time frame also enters the analysis in another way. We have generally not specified the exact horizon throughout which we look for win-win solutions. This is again related to the lack of an explicit social welfare criterion. It is also a serious restriction on the analysis: A government policy might lead to a better environment, higher growth and increased employment in the short term, but these effects might be reversed in the long term. An example would be an economy in recession where increased environmental spending leads to higher production and employment, but at the cost of substantial government borrowing. In the longer term, the debt must be financed and the resulting fiscal contraction might lead to adverse environmental and economic effects. It is open for interpretation whether such a policy should be considered a win-win policy.

Possible employment effects of environment policies have received a lot of attention from policy makers and environmental organisations, but the discussion in subsection 5.2.1 suggested that there were only few theoretical and empirical causes for considering the variable in environmental policy analyses. We will develop this point considering, in turn, the long term and the short term:

If environmental policies are to affect employment rates in the long term, they must affect the labour supply and/or the natural rate of unemployment. The labour supply will increase to the extent that the policies increase the real after-tax income from supplying labour relative to inactivity. This could be the case if environmental policies manage to push up real labour income or lead to lower taxes on labour. Environmental policies can only lower the natural rate of *un*employment if they affect the frictional and structural unemployment and this effect is likely to be small.

Environmental policies in the form of public or private building programmes etc. might be used as a counter-cyclical policy tool for short-term stabilisation, but the long lags in such policies will restrict their practical applicability. Consider an economic downturn which the authorities intend to soften by environmental programmes. Legislation must be passed, projects be announced, contracts be awarded and projects be engineered before the actual construction takes place. The business cycle might have turned before the actual construction work takes place in which case increased demand for labour would likely lead to bottlenecks.

In any case, if counter-cyclical environment policies manage to smooth the employment fluctuations during the business cycle, then they would also smooth the production fluctuations. In other words, there is little reason to focus specifically on the short-term employment consequences of environmental policies.

In sum, environmental policies can affect the employment in specific areas or sectors, but are unlikely to play any major role in increasing employment or combating unemployment in the economy as a whole. And *if* the policies were to affect employment, it would most likely be the result of higher income and/or lower taxes (OECD 2004b). Furthermore, if environmental policies manage to push up the employment, then the employment effect would likely be correlated with the output performance. We will therefore focus on economic growth and the environment in this paper, while employment considerations will be incorporated selectively, mainly in subsections 5.4.3 and 5.7.1.

Taking for granted that the two main variables of interest are economic growth and the environment, we still face the dilemma that we cannot make trade-offs between the two variables. One approach to tackle this problem would be to choose a weighting between the two indicators, e.g. by adjusting the production by measures reflecting the induced environmental pressure.

This is in essence what is undertaken in the green GDP calculations in green national accounts (Dasgupta & Maler 1994, Heal & Kristrom 2005). The idea is to treat the environment as a production factor (of environmental services) in the same way as other production factors like physical capital and human capital. The corrected green production measure then includes, *inter alia*, the value of investing in the stock of natural capital and subtracted the value of the current wear on the natural capital (all measured in terms of consumption). In some respect, changes in the corrected, green GDP reflect the sustainability of the development in a country. A declining green GDP indicates e.g. less sustainability. The green GDP has one major drawback, namely that it requires a valuation of all forms of environmental impacts in society. Such a valuation is very difficult and also uncertain. We will not pursue this idea further, but consider the conventional measure of GDP and environmental performance separately.

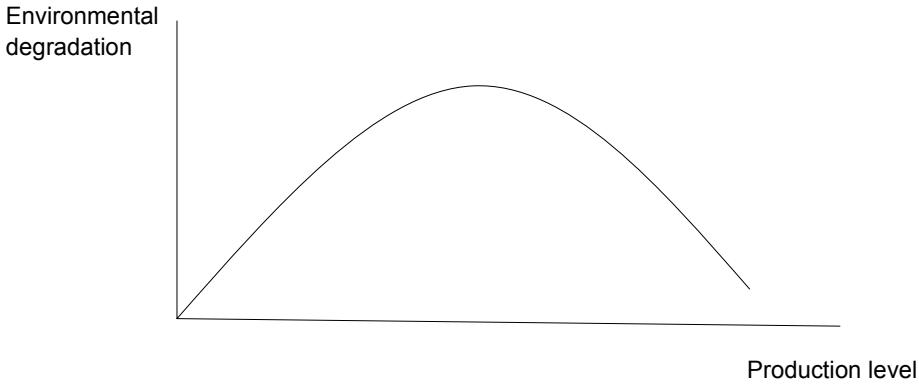
Clearly, even a win-win solution with higher growth, more jobs and better environment does not imply that everybody will win. Distributional issues by themselves could be of concern to society, i.e. society could have preferences with respect to the distribution of income, employment and environmental degradation. Distribu-

tional issues can, however, also be of importance for the political process. In democracies, the different interests of the winners and the losers will combine to influence the decision-making process (Oates & Portney 2003).

5.3 Link I: The Environmental Kuznets' curve

We start our discussion on links between the environment and economic performance considering the observed, empirical picture. In the early 1990s, several groups of researchers observed that different forms of environmental degradation appeared to follow an inverse-U shaped pattern relative to a country's income (Grossman & Krueger 1995). This relationship has come to be called an Environmental Kuznets' Curve (EKC), after the pattern of inequality and income described in Kuznets (1955). Figure 1 shows a stylised depiction of this pattern.

Figure 1 A stylised Environmental Kuznets Curve



Research on the EKC has proliferated since the early 1990s, and a recent survey found more than 100 refereed publications dealing with theoretical or empirical aspects of the EKC (Yandle *et al.* 2004). This section discusses the literature and seeks to identify under which circumstances production and environmental degradation follow an Environmental Kuznets Curve.

The observed relationship between production and the degree of environmental degradation varies depending on the pollutant considered. For some pollutants, the relationship takes the form of an Environmental Kuznets Curve, where economic growth is associated with more environmental damage at low income levels and less environmental damage at high income levels. Empirical observation thus suggests that there is no one-to-one relationship between economic performance

and environmental quality. This underscores the premise of this paper, namely that there are numerous and complex links between economic growth and environmental quality.

Production and environmental degradation can be positively as well as negatively correlated. In particular, we cannot count on the EKC to resolve the risk of conflict between growth and the environment. The EKC is an observed correlation that cannot be interpreted causally and thus has almost no normative policy implications. Furthermore, the observed pattern is not stable, in that the income-pollution path has different shapes for different pollutants, different countries, and different points in time. However, the EKC research does demonstrate that environmental degradation is not an unavoidable by-product of economic growth.

5.3.1 The empirical EKC

The first phase of the EKC literature was entirely empirical. The World Bank (1992) and Grossman & Krueger (1995) took the simple approach of regressing measures of ambient air and water quality on country-level GDP and GDP squared, along with other covariates. They plotted the resulting line, and found that it was inverse-U shaped, peaking for many pollutants at GDP per capita around $8000 in 1995 dollars. Since then, researchers have studied different pollutants, including automotive lead, greenhouse gases, indoor air pollution, deforestation, and methane emissions from cattle, among others. Researchers have studied different country groupings, and different time periods, and have subjected the data to alternative statistical approaches, including fixed and random effects, non-parametric techniques and splines. And, researchers have tried including a variety of other country-level controls, including corruption, democratisation, trade liberalization, and inequality.

Across these scores of research papers, a few generalizations can be drawn. First of all, the pollutants that get cleaned up the earliest (at the lowest levels of GDP/capita) are those that involve local spillovers, rather than interstate or international spillovers. These include, for example, biological oxygen and fecal coliform in water. In fact, in the data these types of very local water pollution appear to decline with income, rather than being inverse-U shaped, because the data typically does not go back far enough to capture the part of history where the local pollution was increasing. At the other end of the spectrum are pollutants that are global in nature. These, such as carbon dioxide and other gases that contribute to global

climate change, appear to rise steadily with GDP/capita over the relevant range of incomes observable in the world today.

A second broad generalization that can be made about this research is that the pattern of pollution and incomes is not stable. Different countries have seen their automotive emissions, for example, peak at different levels of per capita income. In general, those countries that begin to abate pollution first do so at higher levels of GDP/capita. One explanation for this is what Hilton (2001) calls the "late abater's advantage": those countries that clean up later (in time) can take advantage of their predecessors' experiences. Later abaters have an easier time identifying pollutants that are problems and coming up with solutions, because other countries have taken the first steps. Consequently, these following countries abate pollution at earlier stages of economic development.

This observation, that the observed EKC is not stable and that later abaters do so at lower incomes, is important for it means that the observed EKC is not a prediction for the future relationship between GDP growth and pollution that countries will follow when they grow richer.

5.3.2 Interpreting the EKC

If the EKC does not predict the future pollution-income paths for developing countries, what can we learn from it? The answer, it turns out, is very little. The empirical EKC literature consists of reduced-form regressions of pollution on income and other covariates. All of the papers exclude important unmeasured country variables, the most important being the level of environmental regulations. Hence, we do not know what causes the turn in the inverse-U shaped path where we see one.

This ambiguity has not stopped people from trying to infer policy implications from the observed EKC. Some have argued that the fact that countries get polluted before they get clean means they make some sort of policy mistake that eventually gets rectified. This would justify, for example, developed countries putting pressure on, or assisting, developing countries to improve their environments as they grow.

This argument has at least one major flaw: there is nothing about the empirical observation – that countries first get dirty and then clean – which implies that the overall path is not optimal. Andreoni & Levinson (2001) show this theoretically by writing down a one-person model that follows this inverse-U shaped path. One-person economic models are sometimes called "Robinson Crusoe" models, for

obvious reasons. When Crusoe is poor, he concentrates his energy on production and as he gets richer his pollution increases. Past a certain level, however, the pollution gets bad enough and Crusoe gets rich enough that he starts to care about the environment, and takes steps to abate pollution, causing the pollution-income path to reverse itself as in an EKC. While stylised, this one-person model demonstrates that an inverse-U shaped EKC is completely consistent with Pareto optimality and consistent with rational economic policy-making. There are no market failures in a one-person model. There are no externalities or spillovers. What Crusoe does in his own self-interest is by definition also in the social best interest.

Are there real-world analogies to this one-person model? Chaudhuri & Pfaff (2003) show that indoor air pollution in Pakistani homes follow an inverse-U with respect to the households' incomes. As with the one-person model, there are no externalities associated with indoor air pollution (if we assume the family makes a decision as a unit). Poor households use polluting fuel, but cannot afford much of it. Somewhat richer households use more fuel and suffer from the pollution. The richest households purchase clean fuel. This inverse-U shaped pollution income path is optimal, given the household's budgets.

Levinson (2002) provides another example from fatal automobile crashes in the United States. Poor people in the U.S. drive the fewest miles and face a relatively low risk of fatal automobile crashes. Middle-income drivers travel many more miles, and suffer the highest risk of driver fatalities. Rich people also drive many miles, but do so in well-maintained, late-model cars with more safety equipment, and face a relatively low risk of driver fatalities. Again, this inverse-U shaped pattern is consistent with optimal decision making given people's budgets.

This example with driver fatality risk also illustrates one more key point: there is nothing particularly "environmental" about the EKC. The key is that a product which people like to consume is linked to production of a bad (pollution, or accident risk), and that some technology can ameliorate that link, at a cost. Poor people will choose not to use the technology; rich people will use it. The resulting relationship between the "bad" and income can be inverse-U shaped, and optimal.

If the EKC does not tell us if poor countries – by becoming dirtier – are making a policy mistake, what about the opposite inference? Some analysts have concluded from the observed EKC that environmental abatement is optimal, or automatic. Beckerman (1992), for example, argued that the EKC "demonstrates that in the longer run, the surest way to improve your environment is to become rich." Implicit

in the statement is that environmental improvement somehow automatically accompanies economic growth.

Some analysts have taken this one step further and argued that: "Existing environmental regulation – by reducing economic growth – may actually be reducing environmental quality" (Bartlett 1994). In other words, the argument goes the EKC shows that environmental cleanup eventually automatically accompanies economic growth; environmental regulations slow down economic growth; and therefore environmental regulations slow down environmental cleanup. This, of course, neglects the fact that the EKC correlations do not account for environmental regulations. As Grossman & Krueger (1995) note in their original article, the most likely explanation for the improvement in environmental quality with economic growth is the environmental regulations that Bartlett (1994) and Beckerman (1992) dismiss.

So the observed EKC does not inform us that poor countries are necessarily making a mistake by becoming more polluted as they grow, because that pattern is completely consistent with an optimal growth path. And the observed EKC does not tell us that the environment automatically improves with economic growth, because the EKC estimates omit environmental regulations. In the next subsection, we discuss what is left for us to learn from the evidence.

5.3.3 What can we learn from the EKC?

The one compelling piece of evidence from the EKC studies is that pollution does not appear to be automatically increasing with GDP growth. Grossman and Krueger (1995) make this point in their original paper “we find no evidence that economic growth does unavoidable harm to the natural habitat”.

Here we have to be a little bit careful. The EKC does not by itself support that claim. It might be, for example, that the reason rich countries’ environments improve is that they export the most pollution-intensive production processes to poorer countries. If that is the case, then the EKC does not show what Grossman and Krueger claim, but rather only shows that pollution gets redistributed around the world. In fact, since the poorest countries will not themselves have even poorer countries to which they can outsource polluting production, this alternative explanation would be bad news for the developing world.

Fortunately, this does not seem to be true. Economists have divided the pollution growth relationship into three parts: scale, composition, and technique. Scale refers to the fact that if an economy grows by merely replicating itself (doing more of

everything proportionally), pollution will by definition grow proportionately with the environment. Composition refers to the fact that as economies grow, the mix of industries it produces will shift away from polluting goods, and hence its pollution will decline. Some of that composition effect may come from changes in consumption, as richer people consume different goods. But some may come from trade, if rich countries impose environmental regulations that shift polluting industries to developing countries. Finally, the technique effect refers to changes in production processes, and installation of pollution abatement technologies, that enable rich countries to produce the same mix of goods but generate less pollution.

What we would like to know is how much of the environmental cleanup associated with the EKC is due to a trade-related composition effect, which would be bad news for the developing world's environment, and how much is due to the technique effect, which would be good news for the developing world's environment. The evidence to date suggests the latter.

First, the late abaters' advantage (Hilton 2001), as discussed above, shows that Environmental Kuznets' Curves seem to peak earlier in developing countries than in developed countries. That would be difficult to explain if the EKC was due to trade-related changes in the composition of industries. Second, economists have found scant evidence that polluting industries relocate from developed to developing countries (see also section 7). One explanation for why polluting industries do not relocate is that the most pollution-intensive industries are geographically immobile because they are tied to local factor or product markets (Ederington *et al.* 2005). Third, over time the composition of imports from developing countries to the U.S. has become less pollution intensive, not more. Fourth, pollution from non-traded goods also seems to decline with economic growth at high incomes. (Automotive air pollution has declined in many developed countries in the last three decades, despite large increases in vehicle traffic, and that cannot be because developed countries somehow import their driving.) Fifth, we see EKCs even in household-specific goods where there are no externalities, and no opportunities for trade, such as indoor air pollution.

Hence, the evidence does not seem to suggest that the EKC declines at high incomes because of trade-related changes in the composition of industries in developed countries. And thus Grossman and Krueger's statement, that the EKC demonstrates that pollution does not necessarily increase with economic growth, holds up under scrutiny.

5.3.4 Policy implications

In the last decade, researchers have noted that some pollutants appear to follow an inverse-U shaped path relative to countries' incomes per capita. In this section, we have discussed the possible lessons and policy implications of this observation.

First, there is no functional form that describes the pattern between economic activity and pollution for all pollutants or all time periods. Nor should we expect it to. Pollutants that are less dangerous, harder to clean up, or cross international borders peak at higher incomes than dangerous, easy-to-abate, local pollutants. This means that the EKC does not predict the pollution-income paths of the future. In some cases there is evidence that countries developing later begin abating pollution at lower levels of income and pollution than those countries abating first.

Second, EKC in part reflect the intervention of policy. What we observe in the EKC may reflect wholly rational policy choices. Developing countries are not necessarily making a mistake by getting dirtier, that developed countries are doing things right just because they are getting cleaner, or that countries will eventually and automatically become less polluted as they grow. In fact, the EKC is consistent with both efficient policies and inefficient policies. It has almost no normative implications.

Third, the one conclusion we can draw from the EKC research is that environmental degradation is not necessarily a by-product of economic growth. Pollution is not inevitably linked to economic growth. We can grow and become cleaner.

Fourth, the EKC is a correlation, not a causation. The EKC does not give us reason to believe that countries will automatically become less polluted as they become richer.

5.4 Link II: externalities and the "double dividend"

5.4.1 Environmental policies

Green Roads to Growth are roads addressing environmental problems. The rationale for and entitlement of environmental policies is the correction of externalities (see also subsection 5.2.1). We therefore take a closer look at the principles of environmental regulation.

Before we delve into types of regulations that correct market failures, several points deserve mentioning. First, it is important to note here that the economically efficient amount of pollution is not zero. Abating pollution is increasingly costly the

more that is abated and the benefits of abatement typically decline with abatement. At some point, the costs of extra abatement outweigh the benefits, and spending more on pollution abatement would be socially wasteful.

Second, Pareto efficiency requires that government regulations achieve the optimal amount of pollution. Too much pollution and the benefits of abating the last bit of pollution outweigh the costs; too little pollution and the benefits of allowing slightly more pollution exceed the costs. In practice this is difficult to measure. The benefits of pollution abatement involve valuing human sickness or health, aesthetics, damage to buildings and structures, preserving ecosystems and species, etc. On the other hand, the cost of pollution abatement is also uncertain. Not only does technology change rapidly, but there are many ways of reducing pollution: cutting back output, end-of-pipe technological changes, substitute goods, relocating production facilities to less sensitive areas, etc. Given the uncertainties involved in measuring the benefits and costs of pollution abatement, attaining the economically efficient amount of pollution seems daunting.

Third, given that the efficient level of pollution abatement is known, the abatement should be cost-effective. Within a given source of pollution, all of the possible means of abating pollution should have the same marginal cost: reducing production, installing an end-of-pipe technology, changing the production technology, using cleaner fuels, or even relocating. Across all sources of pollution within a given firm, efficiency requires that the marginal abatement costs should be equal. And, across all firms, cost efficiency entails that firm-specific marginal abatement costs should be equal.

This brings us to the issue of policy instruments. Some government policies have the advantage of automatically leading to cost-effectiveness, regardless of whether the targeted level of environmental quality is efficient. The standard approach has been government-imposed technology standards. These include catalytic converters required on all new automobiles, scrubbers required on smokestacks, and bans on certain types of fuels (leaded gasoline). Often these technology standards appear as statutory emissions limits. But when the regulator chooses the emissions limits based on engineering estimates of available technologies, and the regulated industries know the technologies used to set the emissions limits, the limits effectively become technology standards.

While these types of command-and-control policies may have contributed greatly to environmental quality, they have not done so in the least costly way. They do not

equate marginal abatement costs across methods. Nor do they give polluters the right incentive to invent better abatement technologies, (cf. section 4 below). Tietenberg (2005) summarises nine empirical papers that assess the costs of achieving a given environmental quality using environmental regulations based on technology standards. The regulations in use are estimated to be 7-2200% more expensive than the least cost means of achieving the same pollution reduction.[13]

Economists' ideal policy for reducing pollution externalities in a cost-effective way is a tax on emissions, called a *Pigouvian tax*, a *corrective tax*, or a *green tax* for more obvious reasons. The idea is to impose a tax per unit of pollution emitted. Suppose, for example that we impose a tax of $200 per ton of sulphur emitted into the air. All firms will have the incentive to use every available means of reducing their sulphur emissions up to the point where it costs $200 to do so. Beyond that, the firms are better off paying the tax. This $200 green tax thus automatically equates marginal abatement cost across sources of pollution and across firms.

By charging the polluter a fee for the cost it imposes on others, green taxes internalise the pollution externality. By making that fee the same for all sources of pollution, green taxes are cost effective. If the green tax rate is set correctly, so that the tax rate is exactly equal to the marginal external cost of the pollutant, it may also be Pareto efficient, but that is a tougher standard.

Although some real-world policies look like green taxes, they are in many cases not designed to achieve an efficient outcome. This is often the case with taxes where the tax revenues are earmarked for pollution abatement. For example, one UN publication suggests that "a 'green' energy tax could be recycled to industry in the form of grants for energy-saving investments" (UNECE 1998). This encourages firms to install those same energy-saving investments. Firms do neither have the incentive to abate pollution via mechanisms other than energy reduction nor to equate marginal costs across abatement techniques. Other "green taxes" fail to have the proper incentives because they are based on industry-wide average pollution, not the particular emissions from a particular source. If a firm knows it has to pay a tax based on how much its *industry* pollutes, it has little individual interest to spend on abatement itself.

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[13] See also Oates *et al.* 1989.

One environmental policy that may be politically appealing, and that looks a lot like a cost-effective environmental tax, is a subsidy for pollution abatement. In the short run, tax and subsidy policies can achieve identical effects on the environment. However, the tax makes the industry less profitable while the subsidy makes it more profitable. In the long term, with firms being able to enter the more profitable industry, it is entirely possible that a subsidy will result in *more* pollution: Each firm pollutes less due to the subsidy to abate, but the industry contains more firms.[14]

When "green taxes" are not cost-effective, a chief problem is that they are indirect. Rather than taxing each unit of the externality directly, they tax or subsidise some alternative; energy consumption, technology, industry-wide emissions. Of course, there is a practical reason for implementing indirect policies rather than direct ones: pollution itself is frequently difficult to measure.

One market-oriented environmental regulation that has come into favour in the U.S. is tradable permits. The 1990 Clean Air Act caps the total amount of SO_2 that can be emitted by electric utilities, but allows them to trade those emissions among themselves.[15] Such programmes are sometimes called "cap and trade". Because there is a market price for polluting, this policy works in many ways like a green tax. The major difference is that with tradable permits, the regulator chooses the total amount of pollution, and lets the market set the price. With green taxes, the regulator sets the price and the market sets the quantity of pollution.[16]

Setting aside for the moment all of the caveats about what is and is not an "environmental tax", it appears from the public discourse that such policies are increasingly popular. From the evidence, however, that trend is unclear. Since 1994, revenues from environmentally related taxes, fees and charges have hovered around two percent of all government revenues in the OECD countries without much of a

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[14] See Baumol & Oates (1988) for a discussion of how subsidies for pollution abatement can increase pollution in a general equilibrium (long term) setting.

[15] The SO_2 trading provisions of the US Clean Air Act are the largest and most successful implementation of tradable emissions permits, but there are others. In the Los Angeles area, the Regional Clean Air Incentives Market (RECLAIM) assigns each firm from a variety of industries an allotment of NO_x and SO_x emissions, which they are then allowed to buy or sell amongst themselves.

[16] Weitzman's classic paper (1974) demonstrated the importance of this distinction when the regulator is uncertain about the costs of pollution abatement.

trend in either direction.[17] Revenues, however, do not measure the use of market oriented policies. Some regulations are market oriented, but raise no revenue. Tradable permits that are given to polluters and taxes where the revenue is returned are examples. Some so-called green taxes raise revenue, but are not market oriented in the sense that they do not equate marginal abatement costs.

Well-designed government intervention can increase welfare when externalities are present. It should be clear, however, that it is not possible to predict the direction of output and employment of such policies. A corrective tax may thus lead to higher or to lower economic activity as measured by GDP.

5.4.2 The double dividend

Finally, let us turn briefly to the issue implicit in Green Roads to Growth. Are there environmental policies that can improve the environment at no cost? First, we need to be careful about defining the term "cost". Consideration of the cost of a policy is not meaningful without a parallel consideration of benefits. Take the simple example of driving automobiles. An environmental regulation that raises the marginal cost of driving (say a gasoline tax) imposes a cost on an individual driver. But if it also reduces everybody's driving, it confers an even greater benefit on each individual driver in the form of lower pollution. The role of the government is to coordinate the reduction in driving that individuals would not do on their own. If the regulation is designed correctly, the sum of the benefits of cleaner air outweighs the costs of higher gas prices and foregone driving. So every well-designed environmental regulation has net benefits, or to put it differently, no net costs.

In conclusion, the purpose of government regulation is to increase the citizens' welfare, which translates to the benefits outweighing the costs. The costs of environmental regulations (foregone output, increased product prices, etc.) are more easily quantifiable than the benefits (fewer illnesses, clearer skies, protected species). This imbalance between the measurable costs and difficult-to-measure benefits leads to a desire for no-cost or win-win policies. It would certainly be convenient if we could justify incurring abatement costs without having to put a monetary value on environmental amenities.

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[17] See www2.oecd.org/ecoinst/queries.

What is usually meant, however, by "no costs" is that the regulations somehow pay for themselves without considering the environmental benefits. In this subsection we will discuss an idea which gained prominence in 1990s, namely the idea of a "double dividend" of green or Pigouvian taxes (Goulder & Parry 2000, Jaeger 2003, Markandya 2005).

We have seen saw that corrective or green taxation could be used to improve social welfare by internalising the pollution externality. The implicit assumption was that the tax revenue generated was transferred back to individuals and firms as lump-sum transfers, i.e. as transfers which do not depend on the economic behaviour of individuals and firms.

The idea of the double dividend is simply that by "recycling" the revenue from the Pigouvian tax to reduce other distortionary taxes, e.g. the taxation of labour, society would reap a double dividend. The Pigouvian tax would reduce the social cost of the externality and the recycled revenue would reduce the welfare loss (excess burden) of the distortionary tax. This double dividend can indeed be considered a win-win outcome of environmental policy.

The idea of a double dividend appears obvious and straightforward. The thinking has gained considerable political importance, e.g. in the European Commission and in many EU countries. "Green tax reforms" have been introduced or are planned with the alleged objective to lower the taxation on labour and increase employment. As often with a self-evident idea, there is more than meets the eye.

Considering the effects of a green tax and the recycling of tax revenue to lower other distortionary taxes, it is customary to distinguish between two cases (Markandya 2005):

(i) The "welfare double dividend" occurs when the total welfare effect – excluding the effect of the improved environment – increases.

(ii) The "employment double dividend" occurs when the revenue recycling lead to higher employment, because of lower income or payroll taxes or other distortionary taxes.

From an economic viewpoint the welfare double dividend is clearly of greatest interest, while the employment double dividend has been in focus in practical policy making. The employment effect is crucially dependent on the specific organisation of the labour market and whether there is pre-existing unemployment or not (Markandya 2005; see also subsection 5.2.1).

Returning to the welfare double dividend, it is useful to consider the direct and indirect effects of introducing a corrective tax and using the revenue for reduction of a pre-existing distortionary tax:

- The welfare effect resulting from the environmental externality being reduced or alleviated. The positive welfare effects of this can be substantial, but are not the concern of this analysis.
- The *direct primary cost* to the producers or consumers affected by the corrective tax. This can e.g. be costs associated with pollution abatement or substitution of consumption towards a less desired consumption basket.
- The *revenue-recycling effect* when the green tax revenue is used to reduce other distortionary taxes. This effect increases societal welfare.
- The *tax-interaction effect* arises as the green tax typically increases the general price level in the economy and, hence, reduces returns to factors used in production, e.g. labour. This distorts the allocation of e.g. labour and capital. The upshot of the tax-interaction effect is reduced welfare.

The revenue-recycling effect and tax-interaction effect are indirect or derived effects of the green tax; a quantitative assessment of these effects requires a general equilibrium analysis. We now consider the possibility of a (welfare) double dividend (discounted the welfare effect from the externality).

The so-called *weak* double dividend only states that the revenue-recycling effect is positive, i.e. that there is a gain for society by reducing a pre-existing distortionary tax instead of returning the green tax revenue to the individuals in society in the form of a lump-sum transfer. This will generally be the case.

The so-called *strong* double dividend (or just the double dividend) states that the net effect of the direct primary cost, the revenue-recycling effect and the tax-interaction effect is positive. In other words, it requires that the revenue-recycling effect dominates the direct costs and the tax-interaction effect. This is not easily satisfied.

First, environmental taxes are usually narrow taxes on one product or a category of products (e.g. energy). This means that the taxes will have substantial direct primary costs as consumers and producers seek ways to reduce the tax payment, i.e. as they seek to substitute away from products whose prices have increased because of the green tax. In other words, the revenue-recycling effect must to be really large if a (strong) double dividend is to exist.

Second, income and general consumption taxes are broad-based and generally less distortionary than taxes on specific products or activities. This means that the welfare gain from the recycling of tax revenue would likely be smaller than the welfare loss from the direct cost of those affected by the green tax (Goulder & Parry 2000; Salanie 2003, chapter 10).

Third, the tax-interaction effect stemming from higher prices because of the higher green tax will also affect welfare negatively. The size of this effect will depend on a complex interplay of factors in the entire economy.

In the 1990s, a whole literature sought to identify conditions under which a double dividend exists. It is clear from the discussion above that there will be no double dividend in most theoretical models of an economy. In some models the revenue-cycling effect will be smaller than the direct cost; in other models it is smaller than the tax-interaction effect.

There are cases, however, where a double dividend arises. These are essentially "knife-edge" cases, meaning that they are not very realistic in practice. For example, a double dividend can be established if the tax system initially is extremely distorted, and the tax revenue from the green tax is used to reduce the most distortionary taxes. Still, in such a case a general tax reform (without green taxes) would also improve welfare.

It is very hard to empirically examine whether a double dividend from green taxation exists. The problem is that the result will depend on economy-wide general equilibrium effects and these are difficult to trace in statistical analyses. Simulation on large-scale models may suggest that there are positive effects of a green tax reform on employment and production (and welfare), but the effects appear to be small and very sensitive to the specification of the simulation model (Markandya 2005). In total, these results do not suggest that a double dividend can be used in practical policy making. Markandya (2005, p. 1396) writes: "The empirical work is indicative of a small double dividend but, painstaking as it is, a number of the key linkages are left out. Hence policy makers would be justified in treading carefully in this area".

In sum, the conception of a double dividend of green taxes was greeted by enthusiasm in the 1990s, but the enthusiasm somewhat waned when the complexities of the issue became apparent. There is, however, one more common economic argument for environmental policies that can reduce firms' costs without considering

their environmental benefits: subsidies for research and development targeted at pollution abatement innovations. That is the topic of the next section.

5.5 Link III: Innovation and environmental policy

In the simplest case outlined in section 5.4, a well-designed environmental regulation creates all of the efficient incentives. A tax on emissions equal to the external damage caused gives each polluter the incentive to abate until the marginal cost of doing so equals the marginal cost of the pollution to society. And the tax also gives each polluter the incentive to abate in the least costly way, whether it be foregoing output, installing end-of-pipe technologies, changing fuels, redesigning production, or inventing new means of pollution abatement. Since each polluter faces the same tax, the marginal cost of abatement will be equal across all sources of pollution and all firms, meaning that the resulting level of abatement will have been achieved in the least costly way from the perspective of society.

5.5.1 Two market failures

One particular means of abatement, however, poses a particular challenge for policy: investing in research and development (R&D) aimed at discovering new abatement technologies. There are several market failures inherent in all R&D. If a firm invents a new technology for abating emissions, it will reap the benefit of lower production costs. But like all commercial innovations, part of the benefits spill over to others. Other firms can benefit by imitating the innovation or by building upon it with further R&D. Jones and Williams (1998) call this the “standing on shoulders” effect. The R&D costs of innovation are borne by the original firm, but the benefits are enjoyed by many, including perhaps the original firm’s competitors. As a consequence, firms are likely to *under-invest* in R&D, and one solution is for the government to subsidise R&D. Because this problem is not specific to environmental R&D, government policies to promote R&D in general may be economically efficient even without considering their environmental benefits.

An example might be energy efficiency. Consider a firm which invents a new technology that saves energy with potentially great benefits to society. Others will quickly follow if the innovating firm cannot protect its innovation from such bootlegging. This reduces the advantage afforded the initial innovator. No individual firm has incentives to innovate efficiently, and subsidies for R&D or other forms of government intervention aimed at energy conservation may be good public policy. If energy efficiency reduces pollution, then the subsidy might be considered part of

environmental policy, even though its fundamental goal was correction of the R&D spill over problem, and even though the subsidy alone is insufficient to address the externalities associated with energy use. (We discuss the effects of non-environmental policies further in section 5.7.)

A second reason why the private sector may under-invest in R&D involves the uncertainty of research endeavours. R&D projects are typically large and risky. Private financing may be unavailable or expensive. With environment-related R&D ("eco-innovation"), this problem is exacerbated by uncertainty regarding future environmental regulations. Authorities may claim that they are going to cap carbon emissions. If they do so, the price of carbon-based fuels will increase, and firms will have incentives to invent new carbon abatement technologies or alternative energy technologies. If authorities later decide on a less stringent cap on carbon emissions, however, firms' investment in R&D for carbon abatement or alternative energy will have been wasted. The amount of eco-innovation may thus be depressed because of the uncertainty generated by the governments' unpredictability.

Proponents of eco-innovation have a scenario in mind where R&D is underprovided by the free market, and where R&D reduces pollution. Neither is necessarily true, however. There are several ways in which this R&D market failure can work in the opposite direction. First, market R&D may be overprovided. Competitive firms may duplicate each other's R&D efforts, in which case the market generates too much R&D. Firms may also race to discover an innovation yielding a competitive advantage and economic rents. Jones and Williams (1998) call this socially wasteful duplication the "stepping on toes" effect. In this case there is excess R&D, and subsidies would only exacerbate the problem. Similarly, much innovation is aimed at rent-seeking, to replace old technologies with new ones that are only marginally better. If there are rents to be captured by slight innovations, firms may over-invest in R&D, and once again government subsidies for R&D would exacerbate the inefficiency. (This process might be called "destructive creation" in a twist on the old Schumpeterian concept.)

Second, there is no reason to think new innovations will necessarily be cleaner. Suppose a firm invents a new means of manufacturing paper that is much less expensive but generates more pollution. That innovation might be socially desirable if the benefits of lower production costs outweigh the harm from extra pollution. An R&D subsidy that yielded this innovation would be efficient, but environmentally damaging. There are countless examples of innovations leading to more environmental pressure. One example is General Motors' realisation in the early

20th century that adding lead to gasoline reduce engine knock and improve overall engine efficiency. The innovation led to all gasoline being leaded and, hence, gave rise to one of the major environmental problems of the 20th century.

There are theoretical reasons to believe that market-driven R&D is below what would be socially efficient (spillovers, the standing on shoulders effect). And there are theoretical reasons to believe that market R&D is above socially efficient (standing on toes, destructive creation). Whether market R&D is too low or too high is thus an empirical question, albeit a difficult one.

Economists have tried to answer it by focusing solely on the spill over problem. The basic empirical approach treats R&D like any other capital investment, and examines how output increases with the "stock" of R&D. When this analysis is done at the firm level, by comparing different firms with different output levels and stocks of R&D, it reveals the private return to R&D. When it is done at the industry level, it reveals the social return to R&D. Most studies find the social return to be approximately two to four times as high as the private return, suggesting under-investment in R&D. This approach ignores the intertemporal spillover (the standing on shoulders effect) that leads to under-investment and the rent seeking that leads to over-investment. But Jones and Williams (1998) show that these ignored effects roughly offset one another, so that market R&D is generally underprovided.

5.5.2 Government policies

How should the government address the double market failure, i.e. the simultaneous occurrence of an environmental externality and an innovation spillover?

The most common approach is to grant patents to innovators, giving them the sole ability to use their innovation for a period of time. Depending on how broad or long-lasting the patent, this protects the innovator from imitators. However, it replaces one market failure with another: monopoly. By granting a monopoly, the sole right to use an innovation, the government allows the inventor to charge prices above its marginal costs and to earn monopoly rents – another form of economic inefficiency.

Another approach to countering the R&D spillover is to subsidise research. In other words, rather than raising the reward to R&D by granting a monopoly, a government can decrease the costs of innovation by subsidizing R&D. This, however, runs into further problems. First, the R&D spill overs often cross national borders. Small countries do not have incentive to subsidise research by domestic firms if many of

the benefits accrue to foreign imitators. For larger economies this is less of a problem.[18]

A second more daunting problem is figuring out *how* to subsidise research. Governments cannot simply grant funds to firms that promise to use it for R&D, as that would be an invitation to fraud or at least mismanagement. To subsidise R&D, there must be a way to monitor research effort, and that is difficult. R&D is by nature risky, and many research endeavours do not result in productive outcomes despite well-intentioned qualified researchers. It would be difficult for a government funding agency to judge whether an unproductive outcome was due to poor effort, or simply a well-designed risky project with an unfortunate end. It is clearly challenging – or perhaps impossible – for governments to "pick winners" with a high rate of success.[19]

A third problem with government-subsidised R&D is that it may simply crowd out research that would have been undertaken by the private sector without a subsidy. Economists call this "inframarginal" because the government subsidy has no effect on behaviour, but merely pays tax funds to firms for activities they would undertake anyway. It is difficult to imagine how a government could subsidise only R&D that would not have occurred without the subsidy. Government funded R&D that replaces private R&D merely redistributes government tax revenues.

Jaffe *et al.* (2005) nicely summarize the interactions between these two market failures: "Pollution creates a negative externality, and so the invisible hand allows too much of it. Technology creates positive externalities, and so the invisible hand produces too little of it." Direct regulation of emissions is still the most important piece of environmental policy. But this leaves three remaining issues.

First, even where there is in place a direct, cost-effective mechanism for regulating emissions, the market failure associated with R&D still remains. But this is no

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[18] In 2000, the US spent $969 per person on R&D (in $1995), while the UK spent $451, France $528, Germany $645 and Japan $774 (OECD 2002).

[19] One example of such targeted funding is the US ethanol subsidy. Since 1978 the ethanol industry, which uses agricultural products (mostly maize) to make a gasoline additive, or "gasohol", has received a variety of subsidies. These have included over $1 billion worth of direct subsidies for biomass-related projects, loan guarantees for construction of ethanol plants, price guarantees, and tax subsidies of up to $0.60 per gallon. Supporters of these subsidies claim ethanol reduces pollution and American dependence on oil imports. Critics see them as pork for the farm sector. Even the supporters would probably admit the ethanol industry would not exist without government support. The economic question is whether that is because of R&D market failures, or simply because ethanol is an undesirable product.

longer a purely environmental issue, and is a market failure associated with general technology development. Are there reasons why technology policy should be targeted at the environment in particular, picking "winners"? Jaffe *et al.* (2005) suggest that the public-good nature of the environment places it in the realm of government policies, but if the initial direct emissions regulation has fully internalized the pollution externality, that argument is weakened.

Second, direct, cost-effective emissions regulations are rare. Most environmental policies are indirect, are not market based, or perhaps not even present in the case of some pollutants. That places us in the second-best scenario where the technology policy may serve two goals, addressing the R&D spillover and the remaining environmental inefficiency. Correcting two market failures is a difficult and perhaps impossible task for one policy instrument. In this case, one could question whether our best efforts should be aimed at crafting technology policy that would compensate for inefficient environmental policy, or at reforming environmental policy so that technology policy can be directed solely at R&D spill overs.

Third, none of these arguments suggests that environmental policy and technology policy – whether general or targeted at the environment – are substitutes. Rather, Jaffe *et al.* (2005) write that "technology policy can be a costly approach ... if it is used as a substitute for, rather than a complement to environmental policy."

5.5.3 Does eco-innovation make environmental regulation costless?

Again, let us turn to the issue implicit in Green Roads to Growth: Are there policies that would spur environmental innovation and pay for themselves, in the sense that the benefits outweigh the costs even ignoring the environmental component of benefits? The most prominent supporter of this view is Porter & van der Linde (1995). They claim that "properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them". We will discuss this claim in more detail in section 5.5.

It is worth noting here that *market-based* regulations have a particularly strong advantage when it comes to eco-innovation. They provide incentives to innovate where command-and-control regulations do not. Empirical studies of the effects of regulation on pollution innovation are summarised by Jaffe *et al.* (2002). They find that "the empirical evidence is generally consistent with theoretical findings that market-based instruments for environmental protection are likely to have significantly greater, positive impacts over time than command-and-control approaches

on the invention, innovation, and diffusion of desirable, environmentally friendly technologies".

The case of eco-innovation is ultimately just a special case of the standard justification for environmental regulation outlined in section 5.4. Well constructed regulations give polluters the incentive to abate in the least costly way, by equating marginal abatement costs across all methods of abatement: output reduction, end-of-pipe technologies, fuel switching, product redesign, or investment in R&D aimed at innovations in all of the above. This last has been called dynamic efficiency, or dynamic cost-effectiveness, because it implies that firms are choosing the efficient amount of investment in future technologies for pollution abatement.

Is there anything special about dynamic cost-effectiveness relative to trade-offs at a particular point in time? R&D has its own set of market failures, separate from the pollution externalities. These involve spill overs of R&D benefits to imitators or future researchers, duplication of effort by competitors, and rent seeking. None of these is special to eco-innovation. The one exception, perhaps, is that eco-innovation faces twin uncertainties: the inherent uncertainty of all technology investments, and the uncertainty about the nature and stringency of future environmental regulations. To the extent governments are responsible for the latter uncertainty, perhaps they have cause to subsidise R&D aimed at technologies for meeting future standards.

5.6 Link IV: The Porter Hypothesis

The Porter Hypothesis asserts that regulation that improves the environment might also be beneficial to the affected firms and potentially to the entire economy. The hypothesis was first stated in a one-page article in *Scientific American* (Porter 1991).[20] The ideas were developed further in Porter & van der Linde (1995) published in *Journal of Economic Perspectives*. The Porter Hypothesis has given rise to much academic and political discussion, c.f. Palmer *et al.* (1995) in the same issue of the journal.

The Porter Hypothesis is not *one* proposition, but rather a broad set of ideas, which are difficult to spell out in precise terms. The starting point is the individual firm

[20] The idea had appeared in less explicit form in Michael Porter's book *The Competitive Advantage of Nations* from 1990 (Porter 1990).

and its competitiveness. A firm is very competitive if it has low unit costs compared to other firms in the industry or sells products at a premium. Low costs can be the result of low input costs or high productivity. Premium prices can be charged when the firm's products are attractive giving the firm market power. In both cases, competitiveness translates into higher profits.

The Porter Hypothesis states that environmental regulation might improve the competitiveness of affected firms and lead to improved profits – at least once required adjustments have taken place. The improved competitiveness is the result of innovation, which means that existing products are produced more efficiently or that new products are introduced. Using this broad definition of innovation, Porter & van der Linde (1995, p. 98) state that "… properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them". These cost-reducing or profit-enhancing effects are also called "innovation offsets" as technology changes absorb or offset part of the cost increase which would otherwise have occurred.

The Porter Hypothesis points out that environmental policies lead to adjustments in the firms. The adjustments partly offset the costs of theregulation, but also has the potential to affect overall economic and environmental performance. The adjustments imply that the profit of the regulated firm will not decrease as much as in case of no adjustment.[21] Hardly anybody would question this premise. The main disagreements relate to the *scale* of this adjustment (Palmer *et al.* 1995). The Porter Hypothesis states that the firms' profits will actually *increase* when they are subjected to regulation. This proposition is indeed controversial if it is interpreted as being anything but an exception. It implies that the firms do not maximise profits initially, but change behaviour once regulation has been implemented.

Porter & van der Linde (1995) do not state the time horizon of the asserted adjustments, which makes it difficult to evaluate the claim that environmental regulation can increase profits. However, it seems clear that some of the possible innovation offsets will occur only with a lag. Thus, even if the Porter Hypothesis will eventually turn out to be correct, it is likely that the short-term effect on profits will be nega-

[21] The adjustment may require instalment of new capital and thus take time. The net effect of regulation could thus be a smaller ("downsizing effect") but more productive capital stock (Xepapadeas & de Zeeuw 1998).

tive. If regulation leads to a dynamic path with initially lower profits and eventually higher profits, the overall effect on firm performance is difficult to ascertain.[22]

The Porter Hypothesis has generated a lot of policy interest, but it has also brought about a substantial academic literature since 1991. The theoretical literature focuses on rationalisations of the hypothesis whereas the empirical literature seeks to test it mostly by using firm-level data. The literature has recently been surveyed by Wagner (2003) and Roediger-Schluga (2004).

5.6.1 Arguments and theoretical explanations

The original arguments

The very short article by Porter (1991) chiefly stated the claim, which later became known as the Porter Hypothesis. Porter & van der Linde (1995, pp. 99-100, pp. 104-105) provide at least five arguments in favour of the hypothesis:

1) "Regulation signals companies about likely resource inefficiencies" (p. 99).
2) Regulation induces companies to collect information on inefficiencies.
3) Regulation now reduces uncertainty on whether or not regulation will be introduced in the future.
4) Regulation constitutes outside pressure which "forces" innovation in products, technology and markets.
5) Regulation gives adjusting firms a first mover advantage in foreign markets.

We will review and discuss the arguments in turn. Argument 1) points to X-inefficiencies in the firm, i.e. a situation where the firm does not minimise costs. The firm wastes resources and profit possibilities as it could reduce its spending on inputs or produce more with the same inputs. The presumption that firms do not cost minimise is debatable, but information and agency problems may be the underlying factor; see below. Given that X-inefficiencies do exist, it is still unclear whether government authorities can identify the areas of resource waste and how economy-wide environmental policies can be used to target them (Jaffe *et al.* 2003). The counterargument is that some form of "cost pressure" on the firms makes them stomp out X-inefficiencies, even if the pressure is not precisely targeted.

[22] The change in the stock price might reflect the overall change in net discounted profits resulting from

Argument 2) is straightforward: if regulation makes certain inputs or production processes more expensive, then firms will have greater incentives to look for information on how to substitute away from the more expensive inputs and/or change their product offerings. Still, this does not imply that the regulated firms are better off. Furthermore, the collection of information about substitution alternatives is costly and time consuming.

Argument 3) relates to our discussion of private financing of eco-innovation in section 5.4. The profitability of eco-innovation will to a large extent depend on future regulation; uncertainty about future regulation leads to uncertainty about the profitability of investment in such innovation and this makes it more difficult to obtain private financing. If a tightening of the current regulation leads to the expectation of a more stable regulatory environment in the future, then this could ease financing constraints and bring about more innovation.

Argument 4) is essentially the eco-innovation argument discussed as Link III in section 5.5. Regulation might improve the expected profitability of investment in innovation that seeks to reduce the environmental impact of production. Innovation can lead to reduced waste in the production processes, better organisation or new and less polluting products.

Argument 5) assumes that domestic regulation will subsequently be adopted by foreign countries so that domestic firms, which already have adapted to the regulation, will have an advantage in foreign markets in the future. The reasoning underlying the argument of such an international "first mover advantage" is not spelled out in Porter & van der Linde (1995). One question is why firms in foreign countries are unaware that their governments might adopt environmental legislation based on experiences from other countries.

In sum, Porter & van der Linde (1995) consider the management of individual firms and put less emphasis on formal deduction or derivation of the arguments. Agency and information problems or sheer irrationality lead to wasteful and myopic behaviour in many firms. The Porter Hypothesis argues that environmental regulation might help reduce these forms of firm-level slack and lead to less waste and better economic performance. Thus, the Porter Hypothesis also implies a very positive view on the abilities of the same firms to adjust when subjected to environmental

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the regulation.

regulation. This somewhat contradictory view has made the Porter Hypothesis controversial (Jaffe *et al.* 2003). At the same time, the Porter Hypothesis convincingly points at the adjustments taking place in firms when regulated, and these adjustments might take the form of innovations with possible long-term impacts on the firms' costs and product palettes.

Theories rationalising the Porter Hypothesis

The arguments in support of the Porter Hypothesis as presented in Porter & van der Linde (1995) have been subject to much criticism in particular with respect to the arguments' internal consistency. The upshot has been a number of theories seeking to rationalise the Porter Hypothesis within the standard deductive framework of economics (see also Wagner 2003 and Ricci 2004).

Rational X-inefficiency: X-inefficiency need not be logically inconsistent, but can be the result of interaction between fully rational agents subject to information asymmetries. The interests of firm owners and managers are different; the firm owners seek the highest possible profit, while the managers may seek to reduce their work effort. If the managers of a firm know more than the owners about the firm's operations, the managers may leave out cost-reducing steps, which would have been beneficial for the owners (Ambec & Barla 2002, Klein & Rothfels 1999). This will be the case when the remuneration of the managers implies that the managers are worse off when undertaking the tasks of cost minimisation than when "shirking" and not seeking all ways to reduce costs.

Environmental regulation may lead the managers to implement additional cost-saving measures. If the managers' return is linked to the performance of the firm in a non-linear way, the overall effect of the cost of regulation and the induced cost-saving measures may actually be positive, i.e. the economic performance of the firm improves. The net effect will depend on the specification of the model. Interestingly, quantitative regulation may in some cases have a more positive impact on the regulated firm's performance than market-based instruments (Klein & Rothfels 1999).

It should be noted that in this model environmental policies are generally only second best policies. A first best policy would seek to address the underlying information asymmetry which again is the source of the agency problem. Rules on corporate governance and disclosure requirements would more directly address

the information problem. Also among second best policies, there might be other policies which are better from society's viewpoint than environmental policies.

Positive spillovers: The Porter Hypothesis focuses on the effects of innovation on the environment and the economy, and several papers have employed knowledge or productivity-spillovers to elucidate this point. Mohr (2002) presents an infant-industry model argument where a production spillover implies that firms become more productive as the total production volumes increase. It is assumed that a new less polluting technology is available, which for a given level of experience is also more productive than the old technology. Still, in private equilibrium the old technology will be used as the lack of knowledge about the new technology would lead to a production and profit fall. If the government stipulates that the new and less polluting technology must be used, the short term effect may be a loss of output as the accumulated knowledge using the old technology is worthless. The new technology is more productive for a given level of knowledge than the old one, so production will soon overtake the level which could have been attained by the old technology. In other words, the model shows that environmental regulation can lead to a technology switch which benefits the environment and – in the longer term – also increases the production. Mohr (2002) stresses, however, that environmental regulation with such a win-win outcome need not necessarily be optimal from society's point of view – a path with more pollution could be better.

Other papers seek to formalise the ideas of positive externalities or spillovers in innovation processes or in education. Makdissi & Wodon (2002) present a model where positive externalities in education lead to under-investment. An environmental tax may lead to a switch from physical capital to human capital, which would then fully or partly correct the initial education externality.

Environmental policy as a strategic trade instrument: Models of strategic trade policy can rationalise the claim of the Porter Hypothesis that environmental regulation can lead to improved international competitiveness. Simpson & Bradford (1996) consider a model of a duopoly with one firm in each country. An environmental tax (e.g. an effluent tax) can induce the domestic producer to "over-invest" in the strategic variable "innovation" in order to reduce the tax bill. This also changes the marginal cost function as the tax on the one hand increases marginal costs directly, but on the other hand reduces marginal costs indirectly via the increased innovation.

Depending on the shapes of the marginal cost schedules of both the domestic firm and the foreign firm, a domestic environmental tax may increase the market share of the domestic firm. Broadly speaking this will happen when the strategic trade effect dominates the direct cost increase so that marginal costs of the domestic firm decrease in equilibrium. The end result may then be higher domestic production (the strategic trade effect) and lower pollution.[23] This outcome requires that a range of assumptions are satisfied, reflecting complicated interactions between the domestic firm, the foreign firm and the government. Simpson & Bradford (1996) argue that the assumptions are unlikely to hold in most cases and suggest instead that domestic environmental policies should be targeted towards correcting domestic market failures.

5.6.2 Empirical evidence

The relevance and practical-political applicability of the Porter Hypothesis clearly rest on its empirical validation. Indeed since the launch of the Porter Hypothesis there have been hundreds of studies seeking to validate or repudiate the hypothesis. Many different empirical methods have been employed. The large number of studies implies that we can only discuss a few selected studies or otherwise resort to presenting results from survey studies.

Empirical analyses of the Porter Hypothesis face many methodological challenges and most studies address only a small subset of these. Studies compare performance across countries, across sectors and sometimes in a single firm or a few firms. Different methods are employed to measure competitiveness or international competitiveness.

Irrespective of the level of investigation and the choice of variables, it is important to establish the direction of causality: is it regulation affecting economic performance or economic performance affecting the extent of regulation? We would a priori expect economic and environmental performance to be correlated, cf. also our discussion of the Environmental Kuznets curve in section 5.3.

[23] Simpson & Bradford (1996) also show that an environmental tax in excess of the optimal Pigouvian level might increase domestic welfare if the rent from the captured market share exceeds the domestic distortion arising from the “excessive” tax.

5.6.2.1 Case studies

The empirical argumentation presented in Porter (1991) is anecdotal. Porter (1991, p. 96) states that "[t]he strongest proof that environmental protection does not hamper competitiveness is the economic performance of nations with the strictest laws." He goes on to discuss the enviable economic performance of Japan (which at the time of writing had still not entered its decade-long recession) and argues that strict Japanese environmental laws were partly behind the strong performance. It is clear from the discussion above that Porter's "strongest proof" embodies a number of methodological problems; problems related to selection bias, causality and control for underlying factors are ubiquitous.

The empirical evidence in Porter & van der Linde (1995) consists of case studies. They present examples of innovation processes in large manufacturing firms in the USA and argue that the result is that the firms attained better environmental performance and at the same time saved money and/or boosted profits. Ciba-Geigy re-engineered its waste water processes; 3M improved its quality control and avoided wasting adhesives. The latter innovation appears to not be the result of environmental regulation, but rather a continuous search for cost reduction.

Case studies are prone to selection bias problems. It is thus easy to find cases where technical standards and innovation-enhancing regulation have had no or only limited effect. This is e.g. the case for the Californian regulation on vehicle emissions, which stipulates that a certain percentage of cars must be zero-emission vehicles within a certain deadline. The lawmakers have had to extend the deadline several times as no adequate technology to replace the combustion engine has emerged.

Popp (2005) explains why case studies like those in Porter & van der Linde (1995) hold very little information. Payoffs from innovations are uncertain, and firms make two types of errors. They sometimes fail to undertake investments that would be profitable, and they sometimes make investments that turn out to be unprofitable. Before the investment is made, firms have some expectations about its likely return. In some cases, "firms may view a project as only profitable when a regulation is in place, only to find out after completion that the project would have been worthwhile even without regulation. Such cases would qualify as examples of the complete offsets described by Porter & van der Linde."

Case studies have also been used as a basis for estimates of the economy-wide economic effects of environmental regulation. *Cambridge Econometrics* (2003)

scales up the estimated cost savings of "greener business" practices to the entire manufacturing sector in the UK.[24] The calculations are based on 65 non-random cases where environmental specialists have been sent to firms to identify resource waste and inefficient working practices. When weighted and scaled up, the cost savings amount to 1.25-2% of manufacturing value-added. There is no statistical test of whether the cost savings are statistically significant. It is also unclear whether the study fully incorporates the costs of the environmental advisers and the investments needed to attain the environmental improvements.

The advantage of studies of individual firms or specific industries is that it is possible to address the issue of causality in some detail. It is, *inter alia*, important to consider the policymaking process as a regulation decision is often the outcome of a political process or negotiations between policy makers and firms (Roediger-Schluga 2004). The imposed regulation will thus often reflect existing best practice in a sector or technologies in the pipeline of the firms. Roediger-Schluga (2004) shows that this has indeed been the case with respect to the emission standards imposed by Austrian authorities on Austrian chemical firms: new innovations by leading-edge firms have led the authorities to issue regulation after some time. In this case the causality is the opposite of the one suggested by the Porter Hypothesis.

5.6.2.2 Studies on firm-level or industry-level data

Data problems in many cases complicate or rule out econometric analyses on firm-level data of the effects of environmental regulation. Jaffe *et al.* (1995, p. 157) survey 16 studies on firm- or industry-level data and conclude that: "[o]verall, there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined".

Newer studies generally show that there is an insignificant or negative effect of regulation on firm performance (Wagner 2003, Pizer & Kopp 2005). For example, a number of studies considering the link from environmental regulation to *productivity* in US manufacturing have concluded that there is either a negative or statisti-

[24] The heads of the EU environmental protection agencies referred to this study in their 2005 "Prague Statement" in which they argue that further environmental regulation – if appropriately designed – would bring about economic benefits (*EEA* 2005).

cally insignificant relationship (Gray & Shadbegian 2002, 2003). An interesting study from Norway finds a negative relationship using data from some of the country's most polluting industries (Telle & Larsson 2004). The study also shows that environmental policies are effective in the sense that a positive effect is reached if productivity is replaced by a productivity index adjusted for damage from environmentally harmful emissions.

5.6.2.3 Correlations

Porter has been a co-author on a number of studies comparing environmental and economic performance across countries using correlation patterns. Esty & Porter (2001, 2002) find a strong correlation between indices of environmental performance and production levels, but also highlight that there are individual differences as countries have better or worse environmental performance than their level of income would suggest. A major problem of these and similar studies is that they do not address the direction of causality or control for other variables. Simple regressions seeking to control for some background variables appear to erase any partial relationship between environmental regulatory regime and economic growth (Esty & Porter 2001, p. 94).

5.6.2.4 Conclusion

We conclude on the empirical investigation that the Porter Hypothesis has not been confirmed as a frequently appearing phenomenon. Porter & van der Linde (1995) did not expect that either. Few if any studies have found indications of robust positive effects from regulation to the performance of firms, industries or countries. Concerning external competitiveness Mulatu *et al.* (2001) undertake a meta-analysis of a host of studies assessing the effect of environmental regulation on trade flows. Their conclusion is that increased regulation generally leads to reduced trade, but they also find that the effect is strongest in studies considering developing countries.

A possible explanation for the inconclusiveness is that the costs of environmental regulation in almost all cases constitute a minor fraction of the firms' total costs. The productivity, costs or profit of a firm depends on many factors and environmental regulation is therefore likely to have only a small impact on these performance measures. Environmental regulation easily "drowns" in other factors affecting the performance of firms, industries and countries (Wagner 2003). The search for

win-win solutions within the framework of the Porter Hypothesis has not produced many positive results.

5.6.3 Costless environmental regulation?

Clearly the Porter Hypothesis cannot have universal validity. In that case governments would have unlimited possibilities to improve the environment and develop the economy; such a free lunch does not exist. Porter & van der Linde (1995) were aware of this and inject the caveats that only "*well-designed*" or "*social efficient*" forms of environmental regulation "*can have*" offsets larger than 1. In this sense the Porter Hypothesis is tautological. If regulation turns out to affect firms or the economy negatively, the reason must be that the regulation is not well-designed or not targeted to attain social efficiency.

The Porter Hypothesis points to the important aspect that firms do not meet environmental regulation (or other environmental policies) by inactivity. Regulation will be followed by adjustments that will at least partially offset the cost of the regulation. It is possible to set up logically consistent theories where existing market imperfections imply that the offset is above 1. Still, the particularities of these models suggest that environmental regulation leading to improved economic performance must be occurring infrequently. These conclusions from theory have essentially been confirmed in empirical work. The effects of regulation on overall economic performance are small or insignificant and positive effects can at most be found in specific cases. The Porter Hypothesis has from the outset been controversial and the lack of conclusive empirical evidence means that the controversies have remained.

5.7 Link V: Non-environmental policies – International integration

Section 5.3 discussed the Environmental Kuznets Curve, which encapsulates the complex interactions between environmental and economic performance. This section expands on this theme by addressing one particular factor which can affect both income levels and the environment. Increased international integration will affect the economy but also the environment and the relationship between economic performance and the environment is thus the result of an external factor, namely globalisation.

In any discussion of environmental policies and economic performance, it is vital to consider the effect of non-environmental policies on the environmental. Many poli-

cies and extraneous shock affect the environment and the economy at the same time (Markandya 2005). Domestic deregulation, changes of market access rules and removal of subsidies are other examples of policies with the potential to affect environmental and economic performance simultaneously.[25]

In this section we focus on the impact of international integration on the environment and the economy. Globalisation has given rise to heated debates, at the political as well as the grass root levels. Proponents have pointed to possible economic gains and increased opportunities stemming from globalisation. Opponents have argued that globalisation leads to inequality and environmental degradation, especially in developing countries (Borghesi & Vercelli 2003). The focus on globalisation and its effects on the environment and the economy have also led to much academic literature addressing the topic. Recent surveys include Panayotou (2000), Frankel (2003), Copeland & Taylor (2004) and Rauscher (2005).

5.7.1 International integration and the economy

There is no commonly accepted definition of globalisation. We use the term "market opening" or "international integration" when an *individual* country opens its economy toward foreign countries, e.g. by reducing its barriers to trade, capital movements, information exchange and migration. Globalisation is then the process where a large number of countries open their markets, i.e. globalisation amounts to integration at a global scale. Commodity and service trade, and factor movements in the form of capital movements and cross-border ownership are of particular importance.

World production increased 6.5 times in real terms from 1950 to 2004, but the volume of world merchandise trade expanded 24 times in the same period (WTO 2005, p. 31). Global trade consists increasingly of intra-industry trade resulting from vertical specialisation where production has been split in many steps and placed in different countries ("slicing up the value chain"). Trade in finished and semi-finished products is becoming more important (Feenstra 1998).

The developments in international financial markets also point towards increased globalisation. The foreign asset position (accumulated capital flows, capital gains,

[25] Kjellingbro (2005) gives a survey of studies examining the impact of subsidies on the environment. Many subsidies cause harm both to the economy and the environment. See also , OECD 2005.

interests, etc.) of the main creditor nations increased from approximately 6 percent of world GDP in 1960 to 57 percent in 1995 (Obstfeld & Taylor 2002, pp. 24-25). Foreign direct investments have become an increasingly important component of total capital flows and the accumulation of foreign assets (UNCTAD 2005, chs. 1-2).

How does increased openness affect economic performance? Economic theory generally makes the case that liberalisation of international trade creates additional value. The reason is based on the simple counterfactual argument that if no additional value was created, the trading partners would not undertake such trades. A liberalising country can exploit its comparative advantages and economies of scale. Reducing the barriers to international trade implies that the available production resources in the economy can be allocated to more efficient uses than in a closed economy (Krugman & Obstfeld 2003, chs. 2-4).

Beyond possible static efficiency gains, trade liberalisation may also affect the long-term growth rate of the economy. This is the case if trade affects the rate of factor accumulation or the rate of total factor productivity growth. Trade might increase the growth rate if it facilitates "catch up" with more advanced countries (Keller 2002).

Turning now to capital movements, the main advantage of free international capital movements is that absorption and production can be decoupled within a given period. For example, a country borrowing abroad or receiving incoming FDI can spend more on both consumption and investment (Obstfeld & Rogoff 1996, chs. 1-2). International capital markets also allow countries to diversify risks and this would likely lead to higher investment.

The empirical evidence generally supports the optimism of the theoretical literature with respect to the growth effects of international trade. Sachs & Warner (1995) is an early study finding that countries with an open trading regime grow faster than countries with a closed regime. A host of papers refined their analyses, generally finding that the result is robust. Sala-i-Martin (1997) showed that the number of years a country had had an open economy was robustly correlated with growth, irrespective of the methodology for including control variables.

The possible effects of trade on employment are less well researched and the results are uncertain. A recent survey paper concludes that the "effects of trade reform on aggregate employment are muted" (Hoekman & Winters 2005, p. 16). There is some evidence that employment has increased in the long term after trade liberalisation, possibly because of induced higher real wages. The short-term ef-

fects differ from study to study, but are generally small. The "muted" effects and inconclusive evidence found in the empirical literature are in line with the theoretical discussion on employment determination in subsection 5.2.2.

While the main picture is that increased international trade or increased trade openness is positively associated with growth, there are less clear-cut results with respect to the effect on economic growth of opening for international capital movements. Edison *et al.* (2004) survey the literature and find that variables capturing controls on capital movements generally do not help explain economic growth. Their own work suggests, however, that liberalisation is beneficial in high-income countries, but not in less-developed countries.

5.7.2 The environmental effects of globalisation

Globalisation affects the environment in many ways. Some have argued that strict regulations in the developed countries push polluting industries to less stringent countries, which then become pollution havens. This process damages the haven countries' environments, weakens the manufacturing sector in the stringent countries, impedes all countries' ability to set strict standards, and results in a "race to the bottom" in environmental regulations. Others argue that there is very little evidence of industries relocating to take advantage of jurisdictions with lax regulations. Still others argue that well-designed regulations give a country a competitive edge, and increase the strength of regulated industries. Let us consider each argument in turn.

Do industries relocate from jurisdictions with strict regulations to pollution havens? Evidence for this is difficult to document, for several reasons. First, regulatory stringency is notoriously difficult to measure. It involves the strength of laws and the degree of enforcement on many dimensions: permitting, environmental taxes, technology requirements, emissions limits, etc. Second, even if we could measure stringency, the relationship between countries' stringency and their economic output is not one-directional. Regulatory stringency surely affects output, but output also must affect the level of stringency. Countries with a lot of manufacturing may enact more stringent regulations, either because they are richer and environmental quality is a normal good, or because manufacturing pollutes, and regulating that pollution requires strict regulations. Jaffe *et al.* (1995) surveyed the evidence and found that "environmental regulation had little impact on competitiveness". Since then, however, economists have begun to use statistical models that control for the

fact that industry may affect regulations as well as the other way around. This newer work has tended to find evidence of pollution havens.[26]

Another claim sometimes made about environmental regulations in an international context is that countries will compete with each other to attract manufacturing investment by lowering environmental standards – a "race to the bottom." In theory, this could go either way. Countries may compete *not* to attract investment from industries that convey few benefits but large environmental costs. U.S. states have seen this “not in my backyard” (NIMBY) phenomenon with respect to citing hazardous waste facilities and nuclear waste repositories.

A lot of theoretical research has documented situations in which interjurisdictional competition could lead regulators acting in the best interests of their own constituents to set inefficient standards. In these cases, there is need for a federal or international regulatory authority. Examples include pollution that spills across country borders, and therefore the benefits of hosting a polluting manufacturer outweigh the *domestic* costs. Or, if the industry is concentrated and pays rents to outside shareholders, jurisdictions may compete away their ability to capture some of the industry’s rents. This may happen, for example, if EU member countries compete to attract a manufacturer from outside the EU.

In theory, this is thus one of those issues that could lead to a variety of outcomes: Countries could compete efficiently, or there could be market failures leading to overly stringent (NIMBY) or overly lax (race to the bottom) standards. Empirically, however, there is very little work on the subject. Like the pollution haven research, this question is plagued by problems associated with defining stringency. Even more difficult, however, is the issue of disentangling cause and effect. We would like to estimate the degree to which one country’s environmental stringency is a function of its neighbours. However, if there is a strategic competition, the neighbour’s standards are also a function of the first country’s standards. Estimating these two functions simultaneously turns out to be difficult. It is also difficult to sort out the effect of neighbours on each others’ standards from the general effect of regional unobserved characteristics correlated with standard stringency. Do southern states all have low standards because they are competing with one another, or is there some common region-wide characteristic we cannot control for?

[26] The more recent research on this issue is catalogued by Brunnermeier & Levinson (2004).

Moreover, even if we do find that countries' standards are a function of neighbouring countries' standards, that will not tell us whether the standards are too high or too low, only that they may be inefficient.

Three recent papers attempt to overcome these obstacles and measure inter-state regulatory competition by exploiting the Reagan administration's change of policy as a natural experiment in federalism (Millimet 2003, List & Millimet 2003, List & Gerking 2000). In 1981 and 1982 the Reagan administration delegated to state governments responsibility for most air pollution standards. From 1981 to 1984 the US EPA budget fell by 11.5 percent (Millimet 2003), and federal spending on environmental regulations fell sharply relative to state spending. These three papers assume that if regulatory competition results in a race to the bottom, we should see a decline in environmental quality starting in 1981. But none of the three finds evidence that air pollution worsened after 1980, which they interpret as evidence against there being a race to the bottom. However, if inefficient regulatory competition means that local jurisdictions set inefficient standards, then environmental quality still may improve or decline over time. The relevant question is whether interjurisdictional competition and the Reagan decentralization caused regulations to be laxer than they would have been without the decentralization. There are a lot of reasons why air pollution might have increased or decreased during the 1980s, including oil price fluctuations, the 1977 Clean Air Act, and new automobile emissions standards.

Finally, some have argued that countries can gain a competitive edge over trading partners by imposing well-constructed regulations that promote innovation. In one version of this argument, all countries eventually impose strict standards. Industries in countries that take the lead in imposing those standards gain an advantage over industries in lagging countries. Of course, this requires that the leading country governments anticipate the regulations of the laggards, something they may be in no better position of doing than the private sector industries.

The competitive edge gained by environmental regulations may come in the form of strategic trade policy. In Barrett (1994), for example, the national government sets overly strict emissions standard – the costs of compliance exceed the benefits of lower pollution. This raises the domestic industry's prices. Foreign firms, facing less competition, then charge higher prices in turn. But this raises the demand for the domestic industry's goods, and raises domestic profits. This case, however, is sensitive to the assumptions of the particular model. Different assumptions can lead to entirely different outcomes, where it is in the best interests of the domestic

regulator to set standards *below* the level where marginal environmental benefits equal costs (Palmer *et al.* 1995).

5.7.3 Policy implications

Link 5 has important policy implications. First, non-environmental policies – in this case the extent of international integration – affect both economic performance and the environment. Thus, environmental policy cannot be reduced to specific environmental regulation. Second, environmental policies cannot be seen in isolation as they affect the economy in complex ways, e.g. by affecting trade and factor movements.

What are the implications for the environmental policies? Is globalisation undermining environmental regulation? What can be done to reinforce the positive effects/channels of globalisation? And what can be done to counter the negative effects?

An obvious point is that environmental policies will still be needed in a globalized world. The traditional market failures still need to be addressed. The increase in trade across borders also calls for increased international cooperation to tackle the problems on pollution across borders. Moreover, as competitiveness is crucial in the globalized world, the relation between environmental regulation and competitiveness becomes even more important; see also discussion in section 5.5. The question is whether environmental policies strengthen or weaken competitiveness. If the latter is the case, there may be a risk of an increased race to the bottom effect. However, if environmental policies can spur innovation, then well designed policies should be used more actively. Moreover, technologies are diffused more rapidly in the globalized world. Environmental policies should aim to remove the barriers to eco-innovations and eco-efficiencies. A good place to start for the environmental policies is to set the prices “right” in the economy and increase the use of economic incentives in legislation. Finally, if consumer awareness increases in a globalized world, that can create new opportunities for firms. Environmental performance can become important in the overall branding of firms. One consequence will likely be that the business community can be in the frontline of environmental responses.

5.8 Final comments

An important question in environmental economics is whether environmental policies conflict with economic growth (Gardiner & Portney 1994). This paper has considered a number of possible links between environmental policies and the economy. The ultimate objective was to determine whether there could be win-win policies which would improve environmental and economic performance at the same time.

Let us start by stating the obvious: Better environmental performance and economic growth are good things, but that in itself is not an argument for government intervention. Bread and potatoes are also good things, but the market is generally able to provide and allocate these important goods in an adequate way. The existence of a market failure is one of the important arguments for government intervention, e.g. in the form of environmental policy.

The theoretical literature has identified a number of links from environmental policy to economic performance. Externalities can create links between environmental performance and the economy. The double externality problem highlights an additional externality, namely R&D spill overs, which also link environmental and economic performance. The Porter hypothesis argues that environmental policies can help reduce waste in firms and open new markets. Finally, market opening may affect both the economy and the environment.

The policy makers in different countries or constituencies put different weight on different objectives, e.g. environmental performance versus economic progress. A policy proposal must take into account these different priorities. Furthermore, various countries face different problems. Countries differ with respect to income level, trend growth rates, employment rates, unemployment as well as extent and areas of environmental pressure. It follows that the choice of policies should differ across countries, e.g. between countries with high unemployment and countries with a tight labour market.

When assessing an environmental policy proposal, it is important to consider the overall or net effect on the economy. Policies might have direct or “gross” effects that are quite different from the overall or net effects. The main problem here is that complete general equilibrium effects can be difficult to assess precisely, because they depend on the functioning of the entire economy. In practice one would

often resort to using large macroeconometric or computable general equilibrium models (Bergman 2005).

Another issue that should be considered is which policy that would be expected to yield the best results given the political preferences, the structure of the economy and the market failure(s) to be addressed. The most appropriate policy may be policy directly affecting the environment, but it may also be other types of policies. Even among environmental policies, one would have to choose from a range of different policies.

At this stage we should return to our point that the ultimate goal of environmental policies – and other forms of government intervention – should be to increase social welfare. In practice, however, it can be difficult to specify a well-defined social welfare measure, it is complicated to undertake welfare economic assessments and politicians often choose to focus on specific variables like growth and jobs. Increased production resulting from environmental policies may be correlated with social welfare. In other instances, growth enhancing environmental policies might not be socially advantageous. Support to technology or environmental capital equipment might increase production but the resources going into the investment might exceed the expected attained benefits; the opportunity costs are simply too high. In other words, there are cases where growth-enhancing policies will not be in the interest of society.

The empirical literature generally shows a wide range of results of environment policy. It remains controversial whether there are environmental policies that are costless or even beneficial to the firms affected. The bulk of empirical studies suggest that environmental regulation has increased costs, although part of the increase is offset by adjustments within the firms. There is also no evidence that regulation leads to improved international competitiveness to the extent that it shows up in increased trade. These conclusions do not imply, however, that no forms of environmental regulation would bring about lower costs or improved competitiveness as regulation is generally introduced for many reasons.

Empirical studies face a range of methodological choices, which delimit the interpretation of the results. First, the choice of “level” or focus of the study is important since case studies, industry studies and cross-country studies have different strengths and limitations. Second, some studies are mainly descriptive or narrative, while others employ statistical methods which allow formal testing of the relationships uncovered. Third, the choice of “level” and method can reflect data

limitation. Until recently, it was difficult to obtain reliable data on regulation intensity, firm performance etc. at disaggregated levels (Jaffe *et al.* 1995). Improved availability of firm-level data should facilitate detailed econometric studies in the future. Fourth, it is in all cases important that the empirical analysis addresses standard inference issues. The analysis must establish the direction of causality so that it is clear whether it is regulation affecting economic performance, economic performance affecting the extent of regulation or whether there are other factors influencing both.[27] It is important to include a sufficient number of control variables in order to account for other factors affecting e.g. firm performance. It is also important to avoid a possible selection bias, e.g. resulting from missing firms, leading to unreliable results.[28]

The paper clearly showed that win-win policies are generally not easy to find. This is no big surprise. If there were numerous win-win policies with great gains to society, then we would expect them to have been implemented already. Take for example the prospect of over-fishing leading to depleted fish stocks, which again results in an inefficiently low catch of fish. Conservation rules to limit over-fishing have already been implemented in many places and changes to the regulation will at most affect output on the margin. While one should not assume that all socially beneficial policies are carried out already, empirical research suggests that in many cases environmental policies do reflect the "common good" (Oates & Portney 2003). This suggests that proposals claiming the existence of "low-hanging fruits" or win-win policies benefiting the environment as well as the economy should be investigated carefully.

The discussion above does not necessarily mean, however, that there are no win-win policies left. Technology and society at large change continuously and might leave new possibilities or demands for policies improving the environment and the economy. The emergence of new information or new insights could point in the same direction. Finally, environmental policies usually have both winners and losers and win-win policies might have been held up in the policy-making process if

[27] Correlations are problematic in this context as they make it very difficult to determine the direction of causality.

[28] In this context one should be careful when interpreting case studies as the selection is likely to be biased, in particular because firms going out business and firms not be established will seldom appear in a case study. Essentially case studies invite the researcher to choose the case confirming prior opinions.

the potential losers have sufficient political influence (Oates & Portney 2003, Leveque & Nadai 1995). Changes to the policy-making process could thus make possible the implementation of win-win policies which had hitherto been stalled in the political system.

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Part III

Case study # 1

PART III-VIII. Each of the six case study parts consists of a case study paper followed by two opponent notes.

6 Case study paper no. 1: Innovation, technology and the global knowledge economy: Challenges for future growth

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6.1 Abstract

This paper discusses the role of knowledge, technology and innovation in economic growth within the context of the "Green roads to growth" project. It summarizes the current state of the art in this area, illustrates this with selected graphs and tables based on published statistics and raises issues for discussion. The main focus is on the big shift of our understanding of economic growth that has taken place in recent decades, exemplified by emergence of terms such as "the knowledge-based economy", "the ICT revolution" and "innovation", which - although not an entirely new issue – did not get much attention a few decades ago. Particular emphasis is placed on reviewing the new micro-evidence on innovation and the knowledge-based economy that has emerged in recent years. However, since extensive micro-evidence on innovation and knowledge-based growth is available only for a limited number of developed economies, we also consider other types of indicators (that are available for a larger set of countries), and present a synthetic overview of the differences in performance across different parts of the globe. Finally we summarize the main trends and discuss the challenges posed by these for future growth, sustainability and policy.

6.2 Introduction

It is difficult to find an issue that is more central to policy makers' agenda than how to achieve economic growth. Indeed, it is generally acknowledged that economic

[29] I am indebted to Martin Srholec for assistance in producing many of the empirical illustrations used in this paper and to Mario Pianta and Jørgen Rosted for useful comments and suggestions. Remaining errors and omissions are my own responsibility.

growth is seen as essential for the realization of important policy objectives, such as income, welfare (including the environment) and – last but not least - employment. The ability of a country to foster economic growth and, hence, realize other important policy objectives is what is often termed the "competitiveness" of a country (Fagerberg 1988, 1996, Fagerberg, Knell and Srholec 2004). Therefore it comes as no surprise when policy makers in the European Union want to make Europe the most competitive region in the global knowledge-based economy (the Lisbon Agenda). What this means is simply to get the European Union on a growth path that is consistent with the realization of important policy objectives.

Although this may sound simple enough experience tells us that getting there may not be just as simple. In fact, the EU has not come very far in realizing the ambitious goals of the Lisbon agenda, and concerns have been expressed on to what extent the political steps taken in order to do so are really appropriate. This reminds us of the important insight that any policy aimed at raising long-term growth has to be based on a thorough understanding of the factors behind growth and the concrete circumstances into which the policy is going to be implemented. In the next sections we discuss the first of these issues in a bit more detail. Focus will be on the big shift of our understanding of economic growth that has taken place in recent decades, exemplified by emergence of terms such as "the knowledge-based economy" (which seems to be on everybody's lips these days), "the ICT revolution" and "innovation" (which - although not an entirely new issue – did not get much attention a few decades ago). Particular emphasis is placed on reviewing the new micro-evidence on innovation and the knowledge-based economy that has emerged in recent years and the conclusions that can be drawn from this on how knowledge-based growth works at what the scope for policy may be.

However, extensive micro-evidence on innovation and knowledge-based growth is only available for a limited number of developed economies. To arrive at a more coherent picture of global dynamics we therefore broaden the scope to include other types of indicators that are available for a larger set of countries, and present a synthetic overview of the differences in performance across different parts of the globe. Finally we discuss the challenges posed by these current trends for future growth, including the issue of sustainability. As discussed already by the classical political economists two centuries ago, growth may be of two different kinds: A mere expansion of activity without a change in methods of production, or it may involve a change in the latter as well. While the former inevitably sooner or later

will be constrained by limited natural resources, the latter may arguably escape the resource constraint – at least for the foreseeable future - by getting more out of less and changing the resource base. Indeed, without continuing technological and organizational change, growth will be impossible, because of the constraints posed by limited natural resources. Therefore innovation is key to sustainable growth and economic development on a global scale.[30]

6.3 Perspectives on growth: From mechanization to knowledge[31]

Intuitively, most people easily accept the idea that knowledge and economic development is intimately related. However, this is not the way different levels of development used to be explained by economists. From the birth of the so-called "classical political economy" – a term invented by Karl Marx - two centuries ago, what economists have focused on when trying to explain differences in income or productivity is accumulated capital per worker. Similarly, differences in economic growth have been seen as reflecting different rates of capital accumulation. This perspective arguably reflects the important role played by "mechanization" as a mean for productivity advance during the so-called (first) industrial revolution, the period during which the frame of reference for much economic reasoning was formed. Closer to our own age Robert Solow adopted this perspective in his so-called "neoclassical growth theory" (Solow 1956). The theory predicted that, under otherwise similar circumstances, investments in poor countries (e.g. those with little capital) would be more profitable than in the richer ones, so that the former would be characterized by higher investment and faster economic growth than the latter. As a consequence of this logic, a narrowing of the development gap (so-called

[30] Innovation is also important for employment. The introduction of new products (product innovation) is commonly acknowledged to have a clear positive effect on employment. But it has been argued that process innovation, due to its cost-cutting nature, may also displace jobs. However, such differences (in employment effects) between different types of innovations, while distinguishable at the level of the individual firm or industry tend to become more blurred at the level of the overall economy. In fact, many economists go so far as to argue that the savings in costs, following a process innovation in a single firm or industry, by necessity will generate additional income and demand in the economy at large, which will "compensate" for any initial negative effects of a process innovation on overall employment. The issue remains highly controversial, and we will not discuss it in further depth here. For a good, up to date overview of the literature on innovation and employment, see Pianta (2004).

[31] Some of the text in this section draws on my paper "Knowledge in space: What hope for the poor parts of the globe?, presented at a conference organized by EC, OECD and NSF-US on Advancing Knowledge and the Knowledge Economy in Washington January 10-11, 2005, forthcoming in D. Foray and B. Kahin.

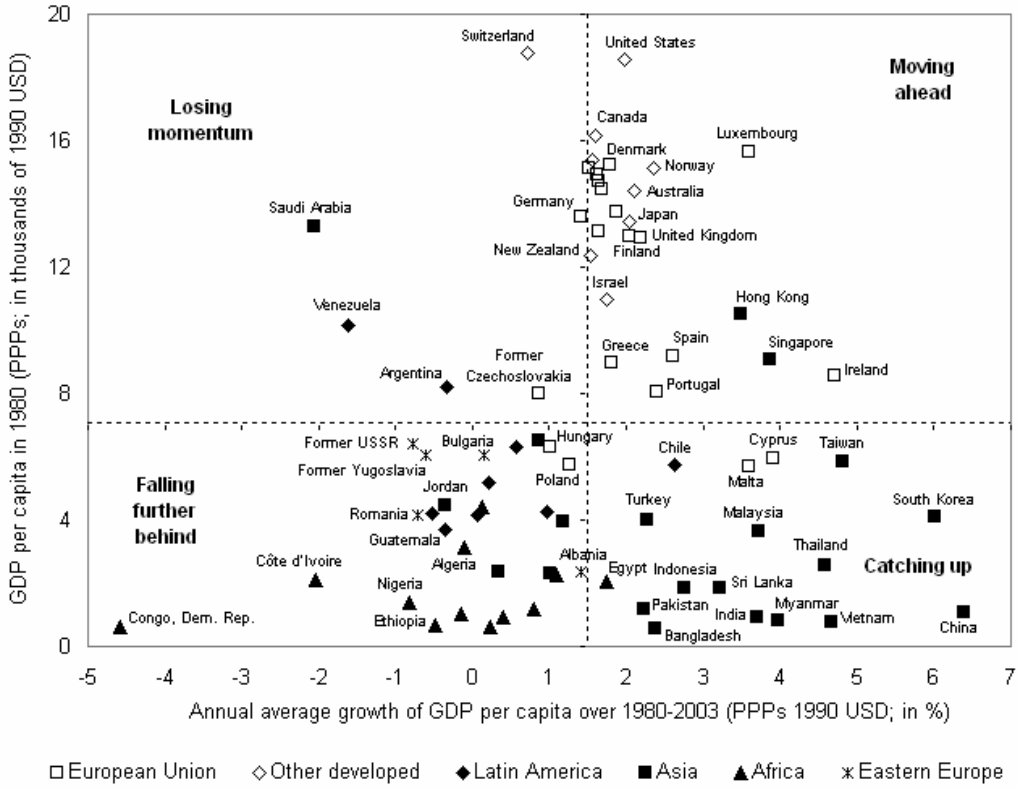
"convergence") should be expected. Based on another argument borrowed from the classical political economists (reflecting their opposition towards mercantilist politics and feudal privileges), such convergence was by many economists deemed all the more probable; the less the state interfered with working of the "free" market. This gave birth to a particular approach to development policy, termed the "market friendly" approach associated, advocated by international agencies such as the IMF and the World Bank (see, for instance, World Bank 1993).

The prediction that global capitalist dynamics would be accompanied by a convergence in income and productivity between initially poor and rich countries was an attractive one in many respects. It represented a liberal and optimistic view on global economic development. As long as governments did not interfere excessively in the working of markets, and limited itself to certain basic tasks, a happy ending was expected to be within sight. However, it is rare to see a prediction that is so completely rejected by the evidence as this one is. In fact, the history of capitalism from the industrial revolution onwards is one of increasing differences in productivity and living conditions across different parts of the globe. According to one source, 250 years ago the difference in income or productivity per head between the richest and poorest country in the world was approximately 5:1, while more recently this difference has increased to 400:1 (Landes 1998). But in spite of this long run trend towards divergence in productivity and income, there are many examples of (initially) backward countries that – at different times – have managed to narrow the gap in productivity and income between themselves and the frontier countries, in other words, to "catch up". Japan in the decades before and after the Second World War and the "Asian tigers" more recently are obvious examples.

This diversity in performance across countries on different levels of development is not limited long historical periods (centuries) but is even more characteristic today. As an illustration of this Figure 1 plots growth in GDP per capita (horizontal axis) versus its level (vertical axis) for a large sample of countries during the last quarter of a century. In this way four quadrants emerge. Up to the left you have initially rich countries that grow slowly ("losing momentum"), down to the right initially poor countries that grow fast (e.g. "catching up"). If the global economy is on a converging path, the great majority of countries will cluster in these two quadrants. But this is not the case, the majority of countries clearly belong to the remaining quadrants; up to the right initially rich countries that continue to move ahead of the others ("moving ahead") and down to the left poor countries that grow slowly ("falling behind"). As is evident from the graph the latter group consists to a large ex-

tent of African countries (joined by some Latin American and Asian ones and some former members of the USSR or its sphere of influence in Eastern Europe).

Figure 1: Convergence vs. divergence in GDP per capita over 1980-2003



Source: GGDC (2005)

Table 1 illustrates this tendency towards divergence in a more substantive fashion by reporting data for levels of growth in GDP per capita for major players in the global economy. It should be noted that the means reported in the table are population weighted to avoid an unwanted influence of small countries (which dominate in terms of mere numbers but not in terms of population or GDP) on the reported statistics. As is evident from the table the performance of low-income economies differs greatly. While China and some other Asian economies catch up at a rapid

rate, countries in Eastern Europe and the CIS[32] and African countries hardly grow at all (fall behind). However, there are also signs of divergence between more advanced economies recently, with United States doing somewhat better in terms of GDP per capita growth than its counterparts in Europe. The latter difference, it might be noted, is even more striking in GDP growth since employment is developing more favourably in the United States than in the European Union.

Table 1: GDP per capita by regions over 1980-2003 (in PPPs, population weighted)

	GDP per capita (in thousands of 1990 USD)			Average annual growth (in %)		
	1980	1990	2003	80-90	90-03	80-03
European Union (25)	11,994*	14,358	17,784	1.9*	1.7	1.8*
O/w EU-north	14,176	17,046	20,415	1.9	1.4	1.6
EU-south	11,048	13,849	17,350	2.3	1.7	2.0
EU-new members	6,386*	6,686	8,611	-0.3*	2.0	1.2*
United States	18,577	23,201	29,208	2.2	1.8	2.0
Japan	13,428	18,789	21,373	3.4	1.0	2.0
Asian Tigers	5,306	9,975	17,120	6.5	4.2	5.2
China	1,067	1,858	4,429	5.7	6.9	6.4
Asia (other developing countries)	1,510	1,924	2,834	2.5	3.0	2.8
Latin America	5,781	5,351	6,051	-0.8	1.0	0.2
East Europe and CIS	6,199	6,510	5,246	0.5	-1.6	-0.7
Africa	1,672	1,581	1,646	-0.6	0.3	-0.1
World	4,678	5,417	6,821	1.5	1.8	1.7

*Note: *) Data is missing for Slovenia, Estonia, Latvia and Lithuania.*

Source: GGDC (2005)

How to explain this diversity in patterns of development? Is it related to a superior ability to develop and/or exploit knowledge in the successful countries, as many perhaps would suspect? As noted in the introduction, theoretical work for a long time tended to ignore the role of knowledge in development (Fagerberg 1994). This was not only caused by the fact that economists' focus for historical reasons was elsewhere. It also had to do with a particular view on knowledge that came to dominate economics, that is knowledge as a so-called "public good" or a body of information, freely available to all interested, that can be used over and over again

[32] The Council of Independent States (CIS) consists of former Soviet Union member states.

(without being depleted). Arguably, if this is what knowledge is about, it should be expected to benefit everybody all over the globe to the same extent, and hence cannot be invoked as an explanation of differences in growth performance. Hence, following the logic, the real reasons behind such differences must rest elsewhere. Moreover, if everybody benefits to the same extent, why should anybody care to provide it? For a long time many economists found this question so perplexing that they chose to ignore knowledge altogether (i.e., regard it as a factor that is alien to economic reasoning, or "exogenous" as it is conventionally expressed).

More recently economists such as Paul Romer put an end to this practice by suggesting that knowledge, in the above "public good" sense, is a by-product of investments that firms undertake in order to develop new products and services (Romer 1990). The reason why, following this view, firms find it profitable to do so is that intellectual property rights (patents etc.) give them sufficient protection to secure a healthy private return on their investments. Hence, following this approach, how intellectual property rights are catered for (including legal and institutional aspects) may have a very important impact on the economy . The social returns are, at least on average,[33] assumed to be even higher, enhancing the pool of public, freely available knowledge, and spurring growth. If such pools of knowledge can be assumed to be "national" in character, models based on this perspective (so-called "new growth theory") might yield predictions consistent with the observed long-run tendency towards divergence in GDP per capita (with large countries - with large "national" knowledge stocks - in a particularly good position). However, such an assumption would be difficult to justify, given the perspective on knowledge underlying the approach (a body of information). Indeed, the logic of the argument clearly suggests that such freely available knowledge would not be bound to (geographical) context and hence should be expected to benefit all countries.

Should we accept that knowledge is not an important factor behind the vast differences in income across different parts of the globe? Or is there something fundamentally wrong with the way knowledge is conceived by the theoreticians? We put our bets on the latter. When Robert Solow and others started to model growth more

[33] Since new technology displaces old technology, and hence makes investments made in the latter obsolete, social returns may also in some cases be less than (the sum of) the private returns (see Aghion and Howitt 1998). We will not discuss this possibility further here,

than fifty years ago, there was not a lot of work available on knowledge and innovation in firms. However, during the last two decades we have seen a proliferation of work in thin area, with several big surveys, numerous case studies and a lot of interpretative work, and we now know a good deal more about how firms search for, develop and use new knowledge. Surprisingly, this new "knowledge on knowledge" does not seem to have been exploited much by the theoreticians in their attempts to construct models of knowledge-based growth. Although innovation is now generally recognized as key to growth, formal models of growth, in particular, typically embody very abstract assumptions on how innovations are brought about, which arguably are not of much help for policymaking. Policy makers are therefore struggling with how to transform these new insights on growth into workable policies, and the European Union's Lisbon/Barcelona process may in fact serve an illustration of this.

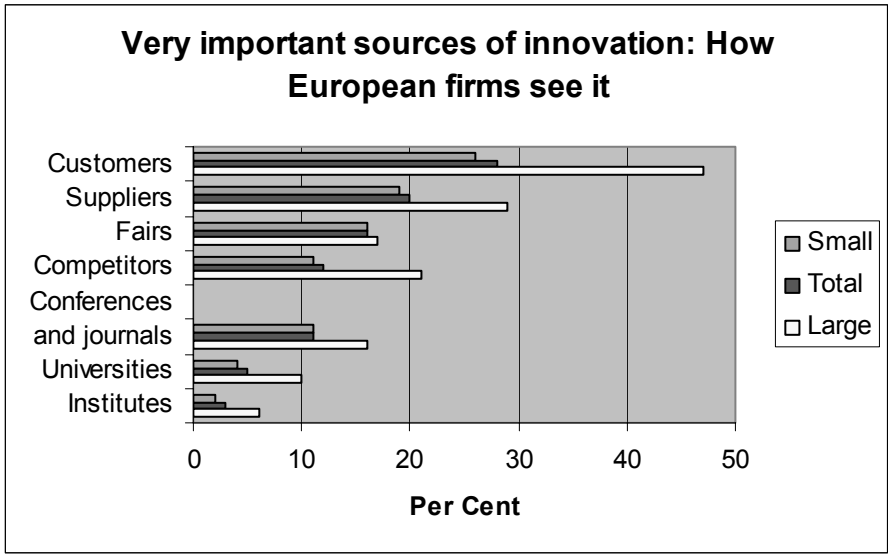
6.4 Understanding innovation based dynamics: Conceptual framework and empirical evidence

During the last two decades innovation has increasingly become a central focus for policy makers. The reason for this is the central role innovation is assumed to play for income and employment growth (and quality of life more generally). It is increasingly recognized that high quality science and R&D is not sufficient for the realization of important social objectives. New ideas, important as they may be (with potentially far-reaching consequences), have little economic and social impact unless carried out into practice. This – carrying new ideas out into practice – is what innovation is about, and that is why it so important.

For a long time this seemingly innocent step – carrying new ideas out into practice – was not seen as very significant. The major focus, among policy makers and academics, was on the process prior to the first attempt of commercialisation of a new idea, e.g., science and research (within large public and private sector organizations). As long as investments in science and R&D were kept at a high level, it was assumed that the derived social and economic benefits would follow. This perspective on innovation - which later became known as "the linear model " (Kline and Rosenberg 1986) - has typically been used to legitimise large public investments in science and R&D. It continues to be an influential view, particularly among policy makers. For instance, this type of reasoning concurs well with the recently announced EU policy of raising its expenditure of R&D to the 3% of GDP level.

However, although few would deny that science and R&D play important roles in long run economic social and change, the exact nature of these relationships has been subject to considerable controversy. Partly this had to do with the problems in identifying empirically the links between investments in science and R&D and the assumed economic benefits. Another source for raising new questions about innovation comes from a diverse body of empirical research on innovation processes in firms. Although some of it dates way back, this research has been especially vibrant in recent years, particularly in Europe (the so-called Community Innovation Survey – CIS). The CIS survey, now in its third version (Eurostat 2004), shows that, apart from internal sources, interaction with users is the most important source of innovation for firms followed by contacts with suppliers, participation at fairs/exhibitions and impulses from competitors (Figure 2). Contacts with the public R&D infrastructure (universities and research institutes) are generally considered to be of much lesser importance. Although there are some differences in results across countries and/or industries, the ranking of the various sources in terms of their importance is remarkably robust. The biggest difference is actually between firms of different sizes; large firms consistently value external sources of innovation more highly than do small firms.

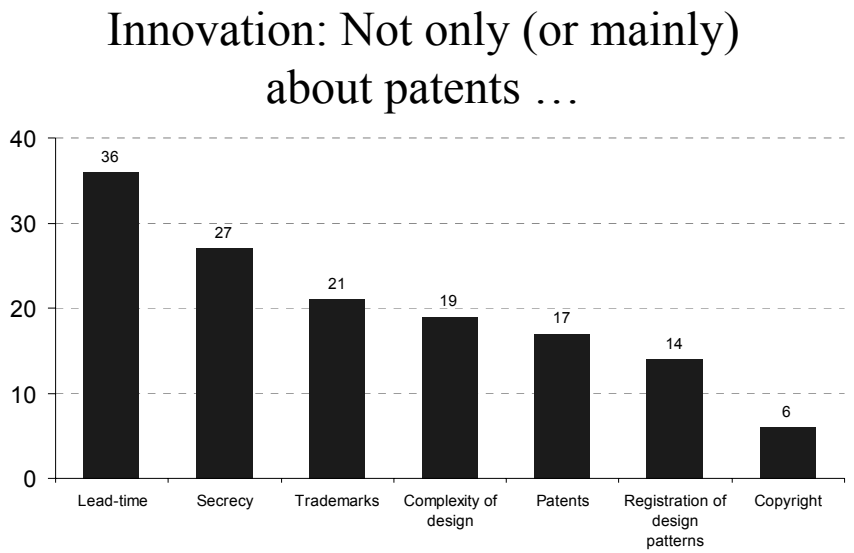
Figure 2. The Community Innovation Survey: Evaluation of external sources of information used in innovation



Source: Eurostat (2004)

This is not to say that universities do not have an important role to play in a knowledge-based economy, but according to firms the most important impacts are of an indirect nature, such as through the supply of highly educated and skilled personnel. Admittedly, these findings may seem to be at odds with the widespread expectations among university administrators these days of substantial future incomes to universities from direct involvement in innovation activities (through intellectual property rights - IPRs). However, available evidence from the US, which spearheaded this movement, indicate that for most universities that have followed this trajectory, establishing an IPR system has in fact been a pure financial loss (Mowery 2004). Arguably, the type knowledge on which much recent discussion of this subject focuses, e.g., codified information that is patented and traded in markets (or not patented and hence provided for free), is only one among several types of economically relevant knowledge (albeit an important one). In fact, there is now a large body of research showing that firms generally do not regard patenting as the most important way to protect their knowledge (Foray 2004, Granstrand 2004, Figure 3 below). This does not imply that there may not be segments within certain sectors or industries that are different in these respects (the biotechnology industry is the prime example) but the general picture is a different one.

Figure 3. The Community Innovation Survey: How to appropriate the benefits innovation



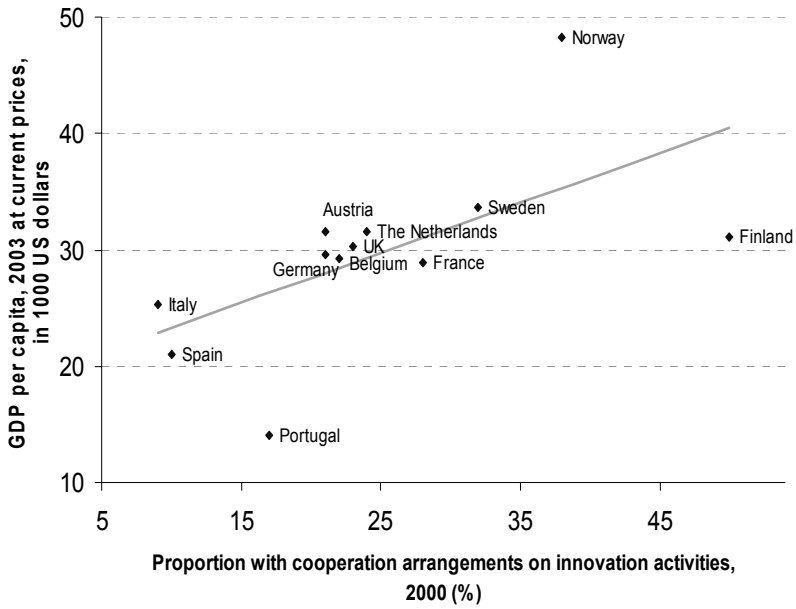
Source: Eurostat

The truth of the matter is that in most areas of knowledge, there is a long way from scientific discoveries to commercial exploitation. Lags of several decades or more are not uncommon (Rogers 1995, Fagerberg 2004). Technological activities of firms

seldom take abstract scientific principles as point of departure and search for commercial applications (although that may happen). The general pattern is that of a perceived need among customers, a problem that needs to be solved, which generates a search for relevant knowledge. Research emphasizes that, in most cases, firms only have imperfect knowledge on the relevant options in front of them, and that they tend to be myopic, searching, internally at first, then in the neighbourhood of their existing competence/network (Nelson and Winter 1982, Dosi 1988, Cohen and Levinthal 1990, van der Ven et al. 1999). Consistent with this, as illustrated in Figure 2 above, the most highly valued external sources are typically customers and suppliers.

The finding that innovation does not only depend on firms' own (internal) efforts, but also on interaction (and knowledge sharing) with external actors, such as customers and suppliers, led during the 1990s to the formulation of a new approach ("systems of innovation", see Lundvall 1992 and Nelson 1993), which explicitly attempts to take the systemic (or recurring) character of such patterns of interactions more thoroughly into account. This system approach, in its various versions, has become popular among policy makers and analysts, among other things due to its flexible structure (which means that it can easily be adapted to different settings/issues) and the fact that it offers a handy framework for accumulating knowledge about the links between the public R&D infrastructure, policy initia-

Figure 4: Innovation-cooperation pays off



Source: Own calculations based on Trendchart Innovation Scoreboard 2 and Eurostat (2004)

tives/support schemes and firm behaviour. Although it has been argued that (perhaps because of this flexibility) the approach lacks precision when it comes to making statements on causality and providing policy advice (Fagerberg 2003, Edquist 2004), the correlation between the extent of innovation-cooperation and GDP per capita is very strong, indicating that innovation-cooperation pays off (Figure 4).

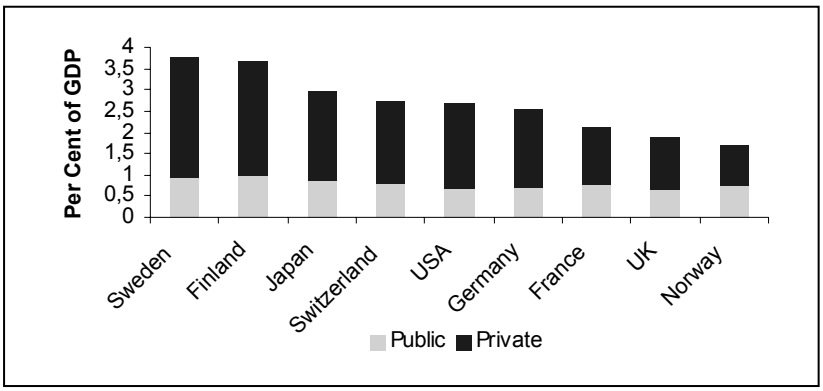
What much recent work in this area boils down to is that some of the popular folklore surrounding the innovation phenomenon, focusing for instance on the construction of technologically very demanding devices, based on scientific breakthroughs, occurring in big laboratories with the help of very advanced and expensive equipment etc., may be a bit one-sided. Albeit some innovations are of this sort, many are not, including a lot of those that matter economically. In fact, innovation is not limited to certain so-called high-tech industries, but flourishes in other industries as well, not to speak of services (von Tunzelmann and Acha 2004, Miles 2004), although the factors that matter for innovation (and consequently the available policy options) may vary somewhat from one sector to another (Malerba 2004). Although some innovations may be spectacular technological breakthroughs, the bulk of innovation in modern societies consists of relatively small improvements and it is probably a safe bet that the cumulative impact of these is as great (or greater) than that of the more “radical” or “revolutionary” ones.

Moreover, a key lesson from modern innovation research is that not only technological innovations of the product and process type, which are what people often use to focus on, matter but that organizational innovations are very important as well. In fact, many of the most important innovations throughout history have been of the organizational kind such as, for instance, the new distribution system that accompanied the development of mass production in the US a century ago, or how Toyota and other Japanese companies reorganized the entire value chain in the car industry in the period following the end of the Second World War (Bruland and Mowery 2004, Fagerberg and Godinho 2004, Lam 2004). Although some organizational innovations have followed in the wake of technological breakthroughs, and have been shown to be of critical importance for the commercial exploitation of such advances, organizational innovation may also be an important impetus to growth in its own right (the Japanese experience in the car industry is arguably an example of this).

Thus we now have relatively extensive evidence from several countries, based on surveys of innovation activities of firms, that consistently shows that what generally matters most for successful innovation is not so much the link with basic sci-

ence, big public laboratories or universities, or IPRs for that sake, but close interaction with users (demand), suppliers and competitors (Granstrand 2004, Smith 2004, von Hippel 2005). These lessons may raise important questions for policy. Arguably, in many cases the policy discourse tends to focus too much on the resources available for innovation, e.g., R&D, rather than innovation as such, which – if anything - should be the prime target for policy. For instance, a well-known concern among policy makers has been that of too little investments in R&D compared to other countries. But such comparisons tend to forget that these figures may reflect differences in specialization patterns, since R&D intensities differ a lot across industries, and countries for various reasons specialize (and distribute their R&D) differently across industries/sectors. In fact, there are much larger differences across countries in R&D efforts than in GDP per capita (which are what matters most in the end). Arguably, it is not obvious that it would be a good idea to regard the industrial structure of a country as obsolete, just because it is not high R&D. As pointed out by von Tunzelmann and Acha (2004), there may be a lot to gain economically from investing in innovation (including R&D) in industries with more modest R&D requirements. On the other hand, it is perfectly possible that there may be industries (or industrial segments) for which the prospects are far from promising, so that a gradual reorientation would be more than justified. However, to be able to deal with such issues in a constructive manner, a relatively detailed analysis of a country's innovation system – its strength, weaknesses as well the external challenges with which it will be confronted – would be required. Concentrating all the attention on a specific number – R&D as a percentage of GDP – may be of little help in this regard.

Figure 5. Cross-country differences in R&D: Private, not public



Source: Trendchart Innovation Scoreboard 2002

It is also important to keep in mind that differences in aggregate R&D intensities across developed economies are mostly due to differences in private, not public investments in R&D (which tend to be more equal across the developed world). Private investments in R&D, on the other hand, depend on a number of factors, such as for instance the strategic orientation of management, the costs, the perceived risk, the demand for new, innovative products or services and the extent to which R&D is deemed necessary to be able catering for this demand. Hence, innovation and R&D are jointly decided. If demand is failing or risk considered too high (which may in some cases amount to the same thing), innovation projects will be abandoned (or not started), and the same applies to the associated R&D investments. Focusing exclusively on the amount of R&D investment, instead of innovation and the wider set of factors that influences it may in fact not be so fruitful.

6.5 The global knowledge economy and the ICT revolution

In some sense growth has always been knowledge-based, so one might think that what we have witnessed is more a shift in perspective than in the way the global economy works. There is some truth in this statement but we shall argue that there is more to it than that. Since extensive micro-evidence on innovation and knowledge-based growth of the type considered above is available for a limited number of countries only, we will in this section broaden the scope to include other types of indicators, available for a larger set of countries that in various ways reflect the roles that knowledge and innovation play in the economy. The first broadly available indicator that we will consider is patenting in the United States. There are a few things to note here. First, in contrast to what is often taken for granted, patents reflect invention not innovation. The great majority of inventions never reach the innovation stage, and many innovations are never patented. Hence, patenting is only a very partial measure of innovation, with a clear bias towards (potentially) valuable codifiable knowledge that is easy to copy/distribute and hence may depend on legal protection for its realization. Second, since patent systems differ across countries, comparative analyses are commonly restricted to patenting in one single country (due to its share size the US market is normally preferred).[34]

[34] It is generally acknowledged that the propensity of American residents to register inventions in their own national patent office (USPTO) is higher than that of non-residents, and that this creates an upward "home country bias" in the statistics (that needs to be corrected for to allow for international

The patent data reported in Table 2 illustrate several important trends. The first is the rapid increase in patenting over time. This increase is especially evident for ICT patents, the number of which increased by a factor of five during the last quarter of a century (compared to a mere doubling for total patents). This clearly reflects the crucial role played by innovation and diffusion of ICTs during this period, as well as the important role played by patenting in the ICT industry.

Table 2: Patents granted at the USPTO by regions (per million people)

	Total patents			ICT patents		
	1980	1990	2004	1980	1990	2004
European Union (25)	32.0	40.6	55.0	4.6	7.1	17.2
O/w EU-north	52.2	65.4	88.1	7.6	11.8	28.2
EU-south	7.7	12.2	15.9	1.1	1.6	3.6
EU-new members	2.5	2.0	2.0	0.2	0.2	0.4
United States	163.7	189.7	286.2	27.5	39.9	122.7
Japan	61.1	158.1	277.5	15.1	57.2	146.9
Asian Tigers	1.7	14.2	135.7	0.2	2.6	69.5
China	0.0	0.0	0.4	0.0	0.0	0.1
Asia (other developing countries)	0.0	0.0	0.2	0.0	0.0	0.1
Latin America	0.3	0.3	0.6	0.0	0.0	0.1
East Europe and CIS	1.6	0.7	0.7	0.2	0.1	0.2
Africa	0.2	0.2	0.1	0.0	0.0	0.0
World	14.0	17.2	26.0	2.4	4.0	11.3

Note: The "home country advantage" of United States in the USPTO patents is adjusted according to an estimation method proposed by Archibugi and Coco (2004, p. 633).

Source: OECD (2005a).

The second important trend is the almost total lack of patenting in the US market by developing country firms. This does, of course, not imply that such firms do not innovate at all but that in most cases the innovations they undertake are not patented (or patentable), as will be the case for many minor innovations. Among the developed countries, the US performance is of course impressive (but difficult to

comparisons based on the USPTO data). Following Archibugi and Coco (2004) we adjust for this bias by taking into account information on US and Japanese patents registered at the European Patent Office (EPO). The assumption is that since Europe a foreign market both for American and Japanese inventors there should no bias in the propensity to patent for inventors from these countries in the European market (while data for European inventors in the European market will be biased of course). The formula used is the following (see Archibugi and Coco 2004, p. 633):

$$\textit{Adjusted US patents at the USPTO} = (JAP_{USA} * USA_{EPO}) / JAP_{EPO}$$

where JAP_{USA} represents patents granted to Japanese residents in the United States, while USA_{EPO} and JAP_{EPO} capture patents granted to American and Japanese residents at the EPO.

interpret given the lack of assured comparability). However, what is even more striking is the very rapid growth in Japanese patenting in the US market, with a level in 2004 on pair with the US performance (total patents) and clearly above the US for ICT patents. Patenting by the Asian Tigers (Korea, Taiwan, Singapore and Hong Kong) grew even faster, from an almost negligible level to a level well above the European average. Thus for what it is worth, the data seem to confirm the leading role played by US – and increasingly so – Japanese firms in the global knowledge economy, with European firms lagging considerably behind, recently overtaken by Asian Tiger firms as well. This appears to confirm the widespread worry that Europe is not adapting well to the challenges posed by innovation-based growth (Fagerberg, Guerrieri and Verspagen 1999).

Does this picture withstand scrutiny? For this purpose we report in Table 3 data for three related indicators; R&D expenditure, production of scientific articles and ISO 9000 certifications in the last decade or so. Compared to patents R&D clearly is a broader indicator, reflecting efforts/capabilities of relevance for invention, innovation and absorption of technology/knowledge.

Table 3: Technological capabilities: Selected indicators

	R&D expenditure ¨ (% of GDP)		S&E articles (per million people)		ISO 9000 certifications (per million people)	
	1993	2003	1991	2001	1993	2003
European Union (25)	1.8	1.8	366	496	83	539
o/w EU-north	2.2	2.3	517	649	141	453
EU-south	1.0	1.1	201	362	11	860
EU-new members	0.9	0.8	115	181	1	322
United States	2.5	2.6	767	704	8	143
Japan	2.8	3.2	319	452	3	438
Asian Tigers	1.7	2.3	75	316	12	274
China	0.7	1.3	5	14	0	75
Asia (other developing countries)	0.5	0.6	7	9	0	14
Latin America	0.5	0.6	15	31	0	23
East Europe and CIS	0.9	1.1	5	66	0	37
Africa	0.5	0.5	9	7	1	5
World	1.7	1.8	90	106	8	91

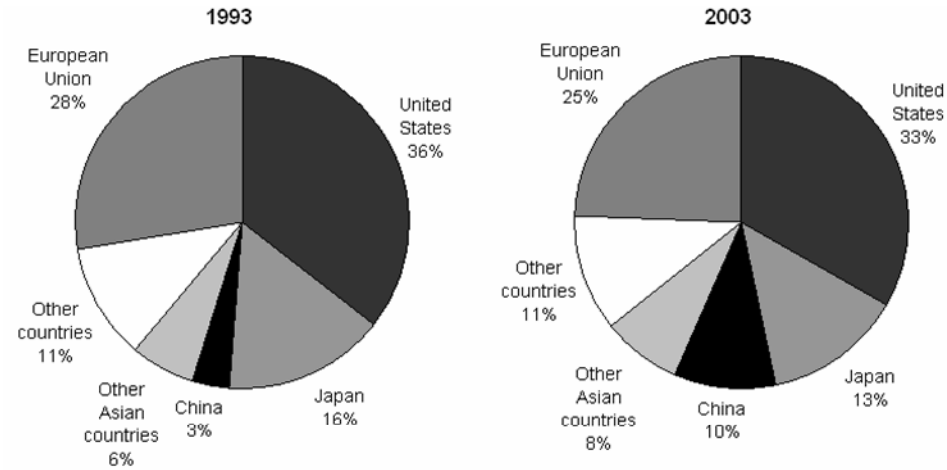
Note: Data on R&D refer to the nearest year available to 1993 and 2003.
Source: OECD (2005b), RICYT (2005), NSF (2005), ISO (2004).

Hence it may be seen as a reflection of what is commonly called "technological" or "absorptive" capacity, e.g., the ability to not only develop but also to identify, acquire and use new knowledge (Kim 1997, Cohen and Levinthal 1990). Consistent with this it has a much more egalitarian distribution across countries than patents.

The rapid increase in Chinese R&D is especially noteworthy (Dahlman and Aubert 2001). But also Japan and the Asian tigers increase their R&D efforts significantly over the last decade. As in the case of patenting, the dominating R&D performers are the US, Japan and the Asian Tigers, but this time with Japan in a comfortable lead (as a percentage of GDP). Europe is, again, lagging behind the frontier. However, Europe is doing better in science (articles), on pair with Japan in fact, but still below the United States. Europe is also doing well on ISO 9000 certifications, especially in the South. Japan too is performing reasonably well on this dimension.

Hence the picture that suggests itself is one of a high performing US, a highly sophisticated and productive (but slow-growing) Japan and a number of other Asian economies rapidly catching up both technologically and economically. Europe on the other hand appears increasingly to stagnate and lag behind along most dimensions. It is important to note that the share size of some of these rapidly growing Asian economies is bound of to have an important impact on the global knowledge economy. As shown in Figure 6 below, today about one third of global R&D is done in Asia, about the same as in the USA and well ahead of the EU (one quarter). China alone stands for about one tenth of global R&D (and rapidly increasing).

Figure 6: Concentration of R&D expenditure in the world economy (in PPPs)

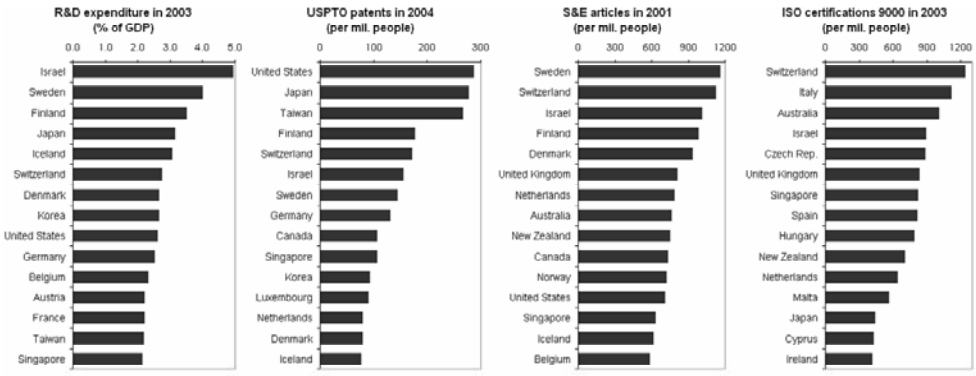


Note: Data on R&D refer to the nearest year available to 1993 and 2003. The group of other Asian countries also includes Asian Tigers. Source: OECD (2005b).

However, Europe consists of many different countries, so to better account for this diversity we include in Figure 7 the fifteen highest-ranking countries along the four indicators considered above. It is interesting to note that the countries with the best performance generally are small countries, several of which are European. Four small countries in particular generally obtain a high rank; Finland, Israel,

Sweden and Switzerland. This is particularly so for scientific publications and R&D. For patenting the US, Japan and Taiwan are the frontrunners but immediately followed by the above "gang of four". The ranking on ISO 9000 indicators tends to deviate a bit from the other indicators but two of these four small countries are among the four top performers in this case too. Hence the relatively mediocre rating for Europe on the indicators considered here is not the result of a uniform pattern. Primarily it reflects the performance of the larger European economies.

Figure 7: Top 15 countries by selected indicators of technological capabilities



Note: Data on R&D refer to the nearest year available to 1993 and 2003.

Source: OECD (2005ab), RICYT (2005), NSF (2005), ISO (2004).

Tables 4 and 5 contain information on another important aspect of technological capability, what is often termed "human capital", e.g., the level of education of the population/labour force. As is evident from table 4, enrolment in secondary schooling has been high for most developed economies for a long time. Historically, enrolment rates have been much lower in the developing part of the word, but have recently started to rise there as well. However, despite this increase, enrolment in secondary education is still low in Africa and parts of Asia.

There are much larger differences in tertiary enrolment. The first thing to note is the very special position of the United States. If we go back 25 years, more than half of the relevant age group in the US was enrolled in tertiary education, compared to less than one quarter in Western Europe. Although the United States continues to be in the lead in this area, over time the differences between the US and other developed economies have been reduced, and the level of tertiary enrolment has increased in most countries. But tertiary enrolment continues to be at a very low level in many developing countries in Africa and Asia (including China).

Table 4: School enrolment by regions (gross enrolment ratios)

	Secondary schooling			Tertiary schooling		
	1980	1990	2002	1980	1990	2002
European Union	82	92	121	23	32	60
o/w EU-north	87	97	139	24	36	61
EU-south	75	90	106	23	33	60
EU-new members	83	84	103	18	21	56
United States	91	93	94	56	75	83
Japan	93	97	102	31	30	51
Asian Tigers	75	87	90	14	31	67
China	46	49	70	2	3	16
Asia (other developing countries)	31	42	56	6	8	14
Latin America	42	49	89	13	17	27
East Europe and CIS	95	92	93	37	42	54
Africa	21	29	37	4	5	9
World	49	55	70	13	16	26

Note: Averages weighted by country's population.

Source: USAID (2004) and World Bank (2005).

The fact that US enrolment rates were so much higher than elsewhere a few decades ago transforms into a much higher share of population with completed tertiary education today (Table 5). This puts the United States in a unique position; around one third of its labour force has completed tertiary education, compared to around one sixth of the labour force in Japan and the Asian Tigers and one tenth of the labour force in the European Union. To the extent that contemporary technological progress is skill-biased (Acemoglu 2002, Pianta 2004), the unique position of the United States in this regard may explain some of the superior performance of the US economy when compared to other developed economies recently. However, in many developing economies the level of skills is still much lower. For instance, in China only one of every fifty members of the labour force (over 25 years of age) has completed tertiary education. This together with relatively low enrolment rates indicate that for China and other countries in a similar situation the skill-level of the labour force will continue to be low for many years ahead.

ICT is a much-heralded factor in economic growth, epitomized by the protagonists of the so-called "new economy" perspective on growth and development. Although the popularity of the concept "new economy" faded somewhat after the crash of the Internet bubble, the ICT revolution is a real phenomenon that should not be taken lightly. Not only has it created powerful new industries (and unbelievably rich

Table 5: Share of population with completed schooling (in %; age over 25)

	Secondary schooling			Tertiary schooling		
	1980	1990	2000	1980	1990	2000
European Union	15	18	18	5	7	10
o/w EU-north	19	21	20	5	7	11
EU-south	9	12	13	3	5	9
EU-new members	12	17	18	5	7	10
United States	47	24	22	18	27	30
Japan	15	16	17	9	13	15
Asian Tigers	17	29	30	6	8	15
China	6	14	14	1	2	2
Asia (other developing countries)	5	7	8	2	3	4
Latin America	5	7	8	4	6	8
East Europe and CIS	n/a	n/a	n/a	n/a	n/a	n/a
Africa	2	4	7	1	2	3
World	9	11	12	3	5	6

Note: Average weighted by country's population.

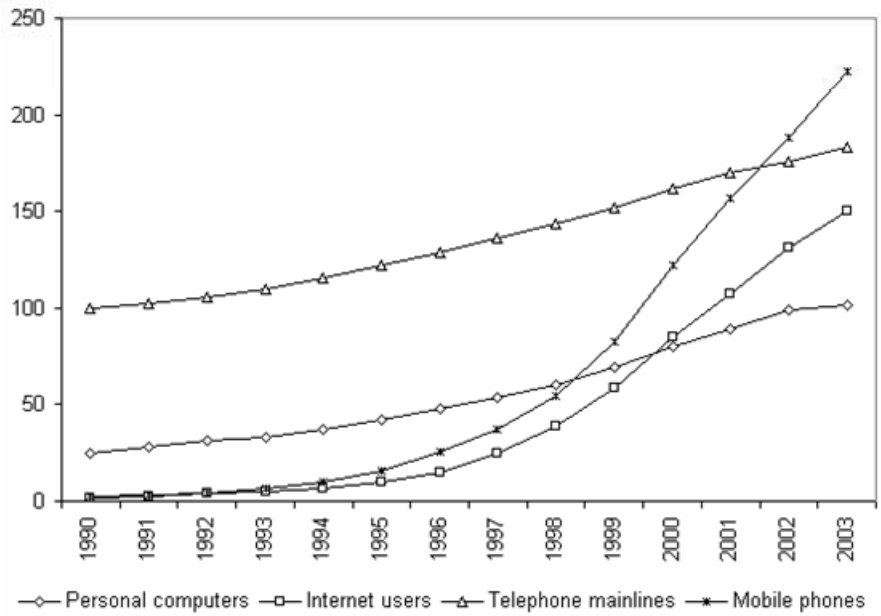
Source: Barro and Lee (2000).

industrial tycoons) but it has also revolutionized "how things are done" in many if not most areas of economic and social life. In fact the latter is what is meant by a technological revolution (Freeman and Louca 2001). Although the new industries that emerge are important drivers of growth in their own right, the major economic effects arguably come through the diffusion and application of ICTs throughout the economy and the continuing improvements that follow in the wake of these processes. Therefore, the extent to which a country manages to benefit from the ICT revolution will not primarily depend on its ability to develop into a competitive location for production and export of ICT products, which after all not every country can succeed in doing, but on the ability of the country to successfully diffuse and apply ICT technology throughout the economy. Thus, if one is interested in the relationship between ICT and economic growth, especially in a comparative perspective, it is very instructive to look at diffusion rates for major ICT products, which is the approach adopted here.

Figure 8 illustrates the ongoing character of the ICT revolution by comparing diffusion rates for an "old ICT" – mainline telephony – with three new technologies that emerge from the ICT revolution; PCs, the Internet and Mobile telephony. As is evident from the graph mainline telephony – which was invented more than a century ago – continue to diffuse at a relatively rapid rate. In the beginning of the 1990s

there was one telephone per ten people in the world at large, in 2003 the density of mainline telephones had increased to one per six persons. One should perhaps have expected that the speed of diffusion, as indicated by the slope of the graph, would be much higher for the new ICTs, and this clearly applies for both mobile telephony and internet use (which have developed very rapidly from an almost negligible level ten years ago). In fact the spread of mobile telephony has now surpassed that of the older technology (mainlines) and Internet use is not far behind. But, interestingly, the diffusion of PCs, an arguably much more costly (and demanding) technology compared to, say, mobile telephony, has been much slower. Still there is less than one computer per ten persons in the world at large. This indicates that diffusion of ICTs still has a long way to go.

Figure 8: Diffusion of ICT technologies in the world economy (per 1,000 people)



Source: ITU (2005) and World Bank (2005).

Table 6 reproduces the same indicators for major countries and regions of the global economy for the most recent year available (2003). This shows that ICTs are very unevenly distributed across the global economy. Diffusion rates in Africa are only a small fraction of those in the developed part of the world. This applies to all ICTs but is most evident for PCs and the Internet. But as in other areas there are important differences within the developed world as well. In general the US is in the lead in the diffusion of new ICTs, especially PC and Internet technology, closely

Table 6: Indicators of ICT diffusion by regions in 2003 (per 1,000 people)

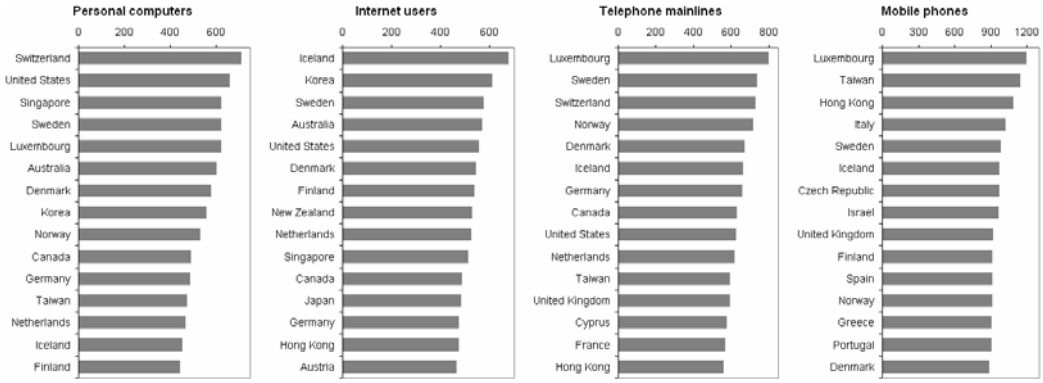
	Personal computers	Internet users	Telephone mainlines	Mobile phones
European Union	324	366	520	817
o/w EU-north	429	440	604	809
EU-south	197	274	458	960
EU-new members	161	258	325	614
United States	660	556	621	543
Japan	382	483	472	679
Asian Tigers	526	533	550	862
China	28	63	209	215
Asia (other developing countries)	17	32	59	75
Latin America	68	90	169	233
East Europe and CIS	69	53	216	199
Africa	14	15	29	60
World	101	113	186	228

Source: ITU (2005) and World Bank (2005).

followed by the Asian Tigers and – at a certain distance – Japan and the European Union. However, the Europan Union is doing better than the US in the diffusion of mobile telephony, in which it is second only to the Asian Tigers. Interestingly, mobile telephony is the only major ICT technology that has caught on in the poorer part of the world. In Africa for instance, although still at a low level, there are four times as many mobile telephone users than PC or Internet users.

As with other types of statistics these overviews may mask important differences within the aggregates. We therefore plot in Figure 9 the indicators for the top fifteen countries along each of the four indicators considered above. It is interesting to note that although the United States is relatively high up on the list for diffusion of PC and Internet technology (but not mobile telephony) the position of the country is by no means exceptional. In fact it is joined as being among the world leaders in ICT use not only by the Asian Tigers (as might be expected from the evidence considered above) but also by a bunch of smaller European economies. In fact on every indicator in Figure 9 about one half of the top fifteen performers are small European countries such as, to mention some prominent examples, the Nordic countries, Luxembourg, the Netherlands and Switzerland. Hence, the relatively modest performance of the European Union as a whole in the diffusion of some core ICT technologies when compared to, say, the USA and some Asian economies, is primarily caused by developments in the larger member countries.

Figure 9: Top 15 countries by indicators of ICT diffusion in 2003 (per million people)



Source: ITU (2005) and World Bank (2005).

Another important aspect of the ICT revolution may be its relationship with knowledge (Foray 2004). According to some analysts the exact relationship between growth and knowledge has changed due to ICTs, making knowledge more footloose and hence challenging the competitive positions of well-established locations for economic activity in Europe and elsewhere, favouring poorer economies and giving a strong impetus to "convergence" in productivity and income in the global economy. This is an important issue for which "hard" evidence is hard to come by (and which we consequently will not venture into in great detail here, see Ernst, Fagerberg and Hildrum (2002) for an extended discussion). However, while it is true that knowledge codification has been on the increase for centuries, and that this continues at an accelerated rate in the present ICT era, much economically relevant knowledge is not of this form. For a firm to profit from knowledge, whether through exploitation of existing or creation of new knowledge, what is required is the ability to combine many different kinds of knowledge/capabilities, of which some may not be codified and have little to do with science or technology in the received sense. For instance, it has been shown that relevant skills in combination with the ability to undertake adequate organizational changes are of critical importance for being able to profit from new ICTs (Bresnahan, Brynjolfson and Hitt 2002). Hence, although the ICT revolution has affected economic growth in a major way, and is likely to continue to do so for a considerable period of time, it is in itself not likely lead to increased convergence in productivity and income across the globe. In fact, the effect may just as likely be the opposite one if current trends towards a very uneven distribution of ICTs globally (the "digitial divide") are not reversed.

6.6 Summing up the argument – implications for policy

This section will sum up some of the "stylized facts" that emerge from the analysis. Are there groups of countries emerging that position themselves quite differently with respect to the growth of the global knowledge-based economy? What are the possible implications of this with respect to growth and convergence? Are the policy initiatives that have been developed in Europe, such as those originating from the Lisbon/Barcelona summits, appropriate in this new situation? And what about the longer term (and the need for a transition to a sustainable growth path)?

However, let us first delve into what is implied by the term "knowledge-based economy" and the extent to which it raises new challenges and opportunities for economic growth at the country level. In short, based on the evidence considered in this paper, can we affirmatively decide the extent to which there is something fundamentally new to "the knowledge economy" or if it – alternatively - is "old wine in new bottles"? If pressed on the subject I would say yes to the former and no to the latter. As pointed out previously knowledge has always been important for economic development but the way it operates today is new compared to situation, say, a century ago. This change is the combined effect of several important trends, some of which have gone on for a long time and some that are more recent. First it is the rise of innovation as an organized activity within firms. A century ago devoting resources to R&D and innovation was very rare. Today leading companies realize that without it they will not survive for long. This process of change started in Germany a century ago, continued in the US from the Second World War onwards (Nelson and Wright (1992) and has since spread to most of the globe. Hence as a global phenomenon it is fairly recent. The second important trend is the rise of what we may term a supportive R&D (or innovation) infrastructure – and a corresponding policy field - at the regional and/or national level, what is today commonly studied under the heading of "systems of innovation" (Edquist 2004). This is clearly a post-Second World War phenomenon (and in most countries much more recent than that). Third it is the massification of higher (tertiary) education, which started in the US after the Second World War and then spread to other developed countries. In most countries this is a very recent phenomenon, the full consequences of which have not yet been felt. And finally it is the ICT revolution, which has made it possible to create knowledge infrastructures that make it possible to search, combine and recombine knowledge and information much quicker and efficient than before. As is evident from the diffusion statistics surveyed above this process is still at an early stage.

The evidence considered in this paper clearly illustrates the dynamic character of the emerging knowledge-based economy along all the four dimensions mentioned above; innovation, R&D infrastructure, higher education and ICT. The rapid growth of patenting worldwide, the catch-up in R&D expenditure as well as GDP per capita in several (previously poor) Asian economies, the massification of higher education and the rapid spread of new ICTs throughout the global economy all testify to the strength of this dynamics. However, this is not a process that benefits every country in the world to the some extent. On the contrary the available evidence seems to suggest that for some time now differences in GDP per capita between the dynamic (mostly rich) and less dynamic (mostly poor) parts of the world have been in increasing, and that this emerging divide is also mirrored in indicators of innovation, R&D infrastructure, higher education and ICT. However, this is not merely an increasing "north-south" divide, since some initially poor countries in Asia, China in particular, manage to catch-up. Moreover, there diverging tendencies at work within what we like to think of as the developed world, with in particular the European Union performing less well than, say, the United States and parts of Asia. These tendencies understandably worry policy-makers in the EU who have launched several policy initiatives to revitalize the growth and competitiveness of the European economy.

The chief policy goal that European policy makers have agreed on is to try to raise R&D investments towards the three percent of GDP target. However, although high R&D investment is an important indicator of a thriving knowledge-based economy, it does not follow that increasing R&D without changing anything else would necessarily change much. What is needed is a more holistic policy approach based on a solid understanding of the factors that induce (or hamper) R&D and innovation. Since interaction with users (and user competence) has been shown to be perhaps the most important factor behind successful innovation, one recommendation might be to explore the possibility for intervening on the demand side, which arguably should be within reach given that politicians actually control around half of GDP in many European countries (somewhat less in others but still a big chunk of overall demand). The challenge in that case would be how to transform the big spenders among the public sectors, such as education, health, communication, energy provision (in some countries) etc., into powerhouses for innovation. More generally, what would be needed is a transition to an experimental economy; in which experiments with new solutions/technologies would be the normal state of affairs, not the exception. Arguably, such an economy would generate more innova-

tion, and higher R&D expenditure in the private sector. This would, however, also necessitate a tolerance among policy-makers and the general public for the failures that inevitably would accompany any transition to a more experimental policy framework.

Finally, what about the sustainability issue? Is the knowledge-based dynamics (or innovation based growth) discussed here really sustainable in the long run? This is a challenging question and it is difficult (if not impossible) to answer it with any degree of "certainty". However, what can be said is that if there is a sustainable growth path for the global economy, it is probably this one. Economic growth in the traditional sense requires increased use of non-renewable resources and is therefore likely at some stage to be constrained by resource scarcity. Innovation – and knowledge-based growth – is about mobilizing the knowledge, creativity and courage of the population to envisage new solutions that save resources and satisfy needs in new and better ways. Knowledge-based growth – what is sometimes termed "the innovation machine" - is a wonderful device to bring us closer to that aim. But firms and entrepreneurs need to be convinced that the new solutions they eventually come up with are likely to have a market, otherwise they will be reluctant to enter into the relevant search processes. Arguably, this is where politicians may have their main chance, e.g.; by providing motive, encouragement and direction to search processes that might otherwise have been prematurely abandoned (or never started). And a good place to start might well be with the public sector's own needs (Fagerberg, Guerrieri and Verspagen 1999)!

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7 Opponent note no. 1a: Innovation, technology and the global knowledge economy: Challenges for future growth

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Knowledge, innovation and technological change - in particular the emergence of Information and Communication Technologies (ICTs) - are deeply affecting the evolution of advanced economies. This opponent paper reviews the paper Innovation, technology and the global knowledge economy: challenges for future growth by Jan Fagerberg, discussing the concepts for analysis, reviewing and integrating the evidence and providing suggestions for a policy discussion.

7.1 General Comments

The paper *Innovation, technology and the global knowledge economy: Challenges for future growth* is an excellent assessment of economic change resulting from knowledge and innovation. It offers a powerful interpretation of the role of knowledge as a source of growth and a solid conceptual framework for understanding innovation. It provides a comprehensive picture of the indicators of current technological change and of the patterns of growth that are shaping advanced economies.

Fagerberg's paper rightly emphasises the role of knowledge as a social process and the importance of cooperation in innovation performance, showing the limited relevance of intellectual property rights and patents in the strategies used by firms to appropriate the benefits of innovation. In terms of funding the creation and diffusion of knowledge, the role of public policies emerges as a stable source across advanced countries, while national differences are mainly the reslts of different industrial stuctures and business strategies.

The empirical patterns shown by the different science, technology and education indicators reported in the paper offer a complex picture with strengths and weakenesses of each country and regions in particular activities, from the funding of R&D to the outcome in terms of scientific papers or patents, to the diffusion of knowledge in the education system, to the use of ICTs. This comprehensive picture could lead, however, to a more focused assessment of the position of EU countries with regard to the Lisbon strategy and to possible policy priorities.

The major limitation in Fagerberg's paper is the lack of analysis of the impact that such processes have on the economy, society and the environment. Key issues that may deserve attention include the effects on the quality and sustainability of growth, on jobs, skills, work organisation, wages and income distribution. Little discussion is also devoted to policy issues.

These themes appear to be of major relevance for assessing the present and potential role of knowledge and innovation in a scenario of sustainable growth. Therefore this paper concentrates on identifying additional conceptual questions and on providing a complementary review of the available literature and assessment of the effects that innovation and a knowledge-based economy, as well as policies associated to the Lisbon Agenda, could have on such fields in Europe. I would suggest the themes pointed out below as relevant ones to integrate the Green Growth discussion.

7.2 Key themes on growth

7.2.1 Divergence in growth

The evidence provided in Figure 1 of Fagerberg's paper clearly shows the extent of the divergence since 1980 in GDP per capita among the countries of the world. The ability of rich countries to continue to show high growth rates has largely relied on knowledge, innovation and the power to appropriate the benefits from them. The resulting lack of convergence and the impoverishment of Eastern Europe and Africa, however, represent serious challenges for the social and environmental sustanability of the current model of growth. The rise in world inequalities could be considered as a danger for the sustainability of current growth.

7.2.2 Is growth properly calculated?

Growth in GDP can be the result of economic processes with very different knowledge content, employment effect and environmental impact. In order to assess the contribution of growth to a sustainable quality of life, more information has to be obtained on such dimensions of growth.

The emergence of both the knowledge economy and of environmental issues have challenged the traditional definitions of GDP and of its growth as an appropriate indicator of economic progress.

A large part of the production, accumulation and transmission of knowledge remains outside market processes that lead to sales of goods and services, or the public provision of education services that is reported in GDP on the basis of its cost of production.

A growing literature has discussed the importance of knowledge and ICT-related improvements in the quality of goods and services and has led to the use of hedonic prices for ICT goods, that have heavily affected the rapid growth of the US economy in the past two decades. While this is far from being a satisfactory solution, the question is open on how to account for quality improvements in GDP data.

A more radical departure from GDP has come with non monetary indicators such as UNDP's Human Development Index (and the associated indicators on gender, poverty, etc.) that take into account GDP per capita alongside education and life expectancy indicators, two dimensions that are based on the rate and extent of creation and diffusion of knowledge in society (UNDP, various years).

Other alternatives to GDP have taken into account in particular the environmental effects and have maintained a monetary evaluation. They include the Index of Sustainable Economic Welfare and the Genuine Progress Indicator. Most of these indicators show that after the mid-1970s the continuing growth of GDP per capita has not been matched by a parallel growth of well-being that has generally stagnated, or has declined in some countries. (Gadrey and Jany-Catrice, 2005). Finally, the ecological footprint is a different measure of the ecological impact of current development expressed in terms of the area of the planet's surface supporting a country's economy. Some of these data could usefully supplement the data of Table 1.

7.2.3 Can growth become less material-intensive?

For rich countries, many indicators suggest that growth is becoming less dependent on large use of raw materials. The increasing weight of services, including those related to ICTs, and the fall of manufacturing share in GDP have led advanced countries to reduce their use and imports of raw materials and basic products (such as steel, etc.) per unit of GDP. However, for small European countries in particular, this "structural change" can be the result of a process of specialisation in R&D and knowledge-based activities, immaterial parts of manufacturing activities (R&D, training, finance, and marketing) and private and public services.

For most of manufacturing, however, the material-intensive activities do not disappear; they are just relocated to countries where labour costs and environmental protection are lower. In this case, an improvement in the sustainability of growth in small rich European countries can be associated to a concentration of production with intensive use of materials in industrialising countries, with a possible net worsening at the global level.

7.3 Key themes on knowledge and innovation

7.3.1 The direction of knowledge development and innovation

While Fagerberg's paper provides comprehensive evidence on the rate of growth of knowledge and innovation, there is little attention to its direction, in particular to their nature and content and their likely impact on sustainable growth. Technology, pushed and pulled by market incentives and public policy goals, may evolve either in the direction of greater concentration of knowledge and wealth, protection of intellectual property and monopoly market power, centralised control, or in the direction of greater diffusion, access, empowerment, leading ultimately to greater environmental and social sustainability.

Some evidence on these opposite directions could be drawn from available data. For example, a breakdown of R&D by field of research could shed light on a country's priorities. Data on patenting in controversial fields (nuclear energy, genetically modified organisms, etc.) could be contrasted with patterns of invention in environmentally-friendly fields. Moreover, the Community innovation surveys provide data on the share of innovations introduced by EU firms with the aim of reducing the use of material, energy, etc.

7.3.2 The diversity of innovation strategies

Within the narrower field of business innovation, the orientation of innovative efforts in firms and industries is also worth considering. While constraints on its direction are heavy, coming from the technological regime, shaping the opportunities for innovation, firms do have room for selecting alternative strategies concentrating either on price competitiveness (and mainly process innovations) or on technological competitiveness (and mainly product innovations). Different innovative strategies are likely to have different impacts on growth and the environment; they are also likely to have different impacts on jobs, skills and wages.

7.3.3 The effects of innovation on jobs

The impact of innovation on the *quantity* of employment, defined in terms of the number of jobs created or lost, can be assessed at the firm and industry levels.[35] The most direct employment impact of innovation is found in the firms that introduce them, and the evidence available suggests that firms innovating in products, but also in processes, grow faster and are more likely to expand their employment than non-innovative ones, regardless of industry, size or other characteristics. However, firm level studies cannot identify whether the gains of innovating firms are made at the expense of competitors, or whether there is a net effect on aggregate industry. Industry level studies can identify the overall effect of technological change within a sector, accounting for both the direct impact in innovating firms and the part of the indirect effects that operate within the industry.

The evidence shows that in European industries in the 1990s employment generally decreased as a result of weak demand expansion, high wage dynamics, and weak product innovation; a higher intensity of innovative expenditure contributed to job losses due to the prevalence of labour saving process innovations. Weak growth and the pressure towards cost-based competition in most industries has resulted in the emergence of technological unemployment in Europe. Innovation appears to have a net job creating effect in those manufacturing and service industries showing high demand growth and an orientation towards product innovation, while new processes result in job losses. The overall effect of innovative efforts depends on the countries and periods considered, but in general is more positive the higher demand growth, the importance of highly innovative industries (both in manufacturing and services), and the orientation toward product innovation. In open economies, countries with an economic structure of this type are likely to receive a disproportionate part of the employment benefits of innovation; countries with stagnant economies and less innovative industries are likely to experience serious job losses due to technological change.

[35] Key works on innovation-employment issues include Freeman and Soete (1987,1994); Freeman and Louçã (2001); Vivarelli (1995); Vivarelli and Pianta (2000), Pianta (2005).

7.3.4 The effects of innovation on skills

The impact innovation has on the quality of jobs has been assessed by studies on the skill biased nature of current technological change. Such studies move from a view of labour markets in equilibrium, disregard the overall effects of innovation on the amount of jobs created and lost, and focus on the relative importance of skilled and unskilled jobs.

The impact of technology on skills has long been at the centre of disputes. The industrial revolution (as Marx pointed out) was based on a process of mechanisation that led to the deskilling of artisans; such a model - machines incorporating human knowledge and making it possible to use cheaper and less qualified labour - has dominated the production system for over a century (Braverman, 1974), and it may still be found in parts of manufacturing and in low skill services. The technologies of the late XX century, on the other hand, have increasingly required the employment of workers with greater skills, matching the increasing supply of highly educated labour.

Skill levels - usually (crudely) measured with educational levels or blue/white collar occupations - experience a general increase, according to a large number of recent studies that have pointed to the skill biased nature of current technological change. The dominant findings of the econometric literature on skill bias in industries, firms and individuals, using direct measures of technological change, is that the diffusion of technologies has a strong skill bias effect, while it has a less evident effect on wage polarisation (Chennells and Van Reenen, 1999; other reviews are in Sanders and ter Weel, 2000 and Acemoglu, 2002). In this wave of studies the diffusion of information and communication technology is considered as a key factor accelerating the upskilling process.[36]

However, when skills are defined more carefully, the relationship with computerisation is more controversial. Looking at aggregate US employment, Howell (1996)

[36] Berman, Bound and Griliches (1994) and Autor, Katz and Krueger (1998) have opened the way for this literature, finding that, across US industries over long time periods, R&D and computers have been associated to faster upskilling of the workforce. Another possible explanation for the decline of unskilled workers is the increase in international trade with countries specialised in low skill labour. Berman, Bound and Machin (1998) compared the effects of trade with that of technological change, finding that the latter accounted for most of the fall in demand for less skilled workers in the United States.

found that major shifts in the skill structure took place between 1973 and 1983, with little variation in the 1980s, when diffusion of ICTs accelerated.[37]

7.3.5 The effects of technology on work organisation

Technological and organisational innovations have always evolved in parallel in the introduction of new technologies. But which is the main pattern in the way work is organised?

An interesting overview is provided by the third Survey on European Working Conditions (European Foundation for the improvement of living and working conditions, 2001). The survey has interviewed 21,500 workers in all EU countries and has found that the number of people working with computers (at least one quarter of the time) has increased only marginally from 39 per cent in 1995 to 41 per cent in 2000, while those using computers all the time are 19 per cent. Little change has taken place over that period also in the workers' perception of their skills: 8 per cent regard the demands of the job as too high for their skills and 11 per cent as too low. However, work intensity has increased, as the share of workers reporting working at very high speed during at least one quarter of their time has increased from 48 per cent in 1990 to 56 per cent in 2000 (this is closely correlated to health problems and injuries at work). The share of workers which have control over their pace and methods of work has remained high and stable at about 70 per cent between 1995 and 2000, while only 44 per cent (including self-employed) have control over their working time (European Foundation for the improvement of living and working conditions, 2001).

The opposing processes of deskilling and upskilling emerge again in research addressing organisational innovation. Studies on several countries collected in Adler (1992) find that both processes take place as a result of different strategies of firms, suggesting that "the use of new technologies will in general be more profitable when entrusted in to more highly skilled employees" (id:3) with broader roles, greater competences and continued learning. However, it has been argued that

[37] A study by Howell and Wolff (1992) has identified jobs characterised by cognitive skills (typical of technical staff), interactive skills (typical of supervisory staff) and motor competences (typical of manual workers) in US industries between 1970 and 1985. The main effect of industry level spending on computers and new investment has been a greater demand for high cognitive skill workers, leading to a more complex picture of the technology-skill relationship.

"there is a fundamental contradiction between the potential of computerization to enrich working life and increase productivity and the development of the technology in the pursuit of authoritarian social goals" (Shaiken, 1984:5) as management has often introduced new technologies and shaped work organisation with the primary aim to increase control over workers (see also Noble, 1984).[38]

The increased productivity resulting from new technologies and organisations has often taken the form of the intensification of work, with firms pressuring workers to produce more effort in their activities. In studies on the UK and Australia, Green (2004) has found that computer usage is strongly associated to higher effort levels. Part of the explanation is the increased possibility to monitor work through ICTs, the weakening (or absence) of trade unions and overall changes in social relations and attitudes to work that may lead to greater commitment and effort.

While the analysis of organisational innovation and its impact on the quality of employment may lead to several different directions, the available evidence suggests that innovations in technologies and in organisations can represent complementary factors, as firms pursue a strategy of change; conversely, when firms face downsizing and restructuring, they can become alternative paths for adjustment.

7.3.6 The effects of innovation on wages

As technological change reshapes the quantity and quality of jobs across firms, industries and countries, wages are bound to reflect such an evolution. As in the case of skills, research has largely investigated the relative dynamics of wages, focusing on the polarising effects of innovation. Surprisingly little research, on the other hand, has addressed the impact of innovation on the absolute levels of wages, on their relation to profits and rents, and on the associated changes in work hours and prices.

Studies on innovation and wage polarisation found that wages tend to be higher and grow faster in industries with higher technological opportunities, and for

[38] Organisational change has been investigated in a survey of, carried out in 1993 and 1996 by The number of non managers using computers - an indicator of diffusion of new technologies - and the adoption of new work practices emerge with a strong association to productivity and wages in US manufacturing plants (Black and Lynch 2000). Several European studies (Caroli and Van Reenen, 2001 on France and Britain; Greenan, 2003 on France; Piva and Vivarelli, 2002 on Italy) have shown that organisational innovation is more important than technological innovation in shaping changes in occupational structure and skills.

workers with higher education or using computers at work (for reviews see Chennells and Van Reenen, 1999; Sanders and ter Weel, 2000; Acemoglu, 2002).

However, many of these results can identify a spurious correlation, as more competent and educated workers are likely to receive higher wages, and equally likely to make an above average use of computers and new technologies. Moreover, wages are exposed to competition from international trade and to changes in the sectoral composition of the economy (Addison and Teixeira, 2001).

The relationship between innovation and wages may run also in the opposite direction. Kleinknecht (1998) has suggested that low wages and high labour market flexibility eliminate a major incentive for introducing innovation in firms. The Dutch experience of wage moderation and extreme flexibility in labour market arrangements has indeed led to extensive job creation, especially in small and medium-sized firms, often in part time employment, but this was made possible by low productivity growth. According to Kleinknecht (2003), in the 1980s and 1990s the rate of increase of GDP per working hour in the Netherlands has been half that of the European average, raising questions on the viability of such a model in the longer run.

7.3.7 The relevance of macroeconomic contexts and policies

Considering the complexity of the issues, explanations of the changing wage structure have to consider, besides the role of technology, the growth of aggregate demand, the competitive pressures on firms and industries, the dynamics and quality of labour supply, in the context of specific labour market institutions and social relations. While technological change does have a major impact on absolute and relative wage levels, it has an even stronger influence on the distribution of the productivity gains made possible by new technologies. The relationship between innovation and wages has therefore to be investigated in the context of macroeconomic distributional patterns, of industry-level sharing of productivity gains, of broad changes in social relations and trade unions activity, of national wage and welfare policies.

Europe and the US do represent opposite patterns in this regard. The Unites States has experienced faster growth of population, labour supply and GDP than Europe, with the expansion of new sectors based on product and service innovations, in more competitive labour markets where less regulation on minimum wages and

union power are found. This has resulted in a faster growth of new jobs (compared to Europe) at the top and bottom end of the skill structure and this polarisation has been amplified in terms of wage inequalities by the lower regulation of US labour markets. Conversely, in Europe greater competitive pressure and slower growth have favoured changes in process technologies and organisations that have reduced low skill employment while creating few new jobs; at the same time wage polarisation has been mitigated by the stronger European rules on wage setting and employment protection.

Developments in the US have been described as a 'low road' (Howell, 1996), as firms have searched for lower labour costs through cuts in wages and in permanent staff, use of part time and temporary workers, anti-union practices, relocation to low wage production locations and inflows of low wage foreign workers.

Such strategies are now increasingly found in Europe too. In fact, the decline of the traditional model of full time, life time, waged (and unionised) employment is a major process of change in all advanced economies, with firm strategies and governments policies leading to a rapid growth of flexible, temporary, part time, subcontracted work.

At the same time, social dynamics is leading to new waves of labour militancy in many countries, with demands for higher wages, a reversal of the 'precarisation' of work, renewed welfare protection, shorter working time (in some European countries), greater training and life long learning, more meaningful jobs and the development of socially useful activities carried out in the 'third sector' of non profit organizations.

In parallel, the sustainability of growth has been at the centre of increasing social concerns and mobilisations, with demands not just for the protection of the environment and nature, but for a rethinking of the priorities of growth in several fields, from agriculture to transport, from industrial materials to emissions, from the military to biotechnology industries.

In order to respond to these broad social and environmental demands, a combination of technological, organisational, institutional and social innovations could be developed in the context of the Lisbon Agenda.

7.4 Key policy themes

In the perspective outlined by the Lisbon Agenda, five key principles for policy are discussed here, focused on the specific ways innovation is supported and oriented by public action, and emerges as a force for change in industries and in the economy; specific labour market or environmental policies are not considered here. Such policies have to be developed at the appropriate level; actions by national governments need be integrated at the regional, European and global level, overcoming some of the limits of traditional national policies implemented in the past.

1. The first principle is the recognition that an *active, targeted innovation policy* is required in order to help shape the types of economic activities that a society would like to engage in, and the way they are organised on the basis of the opportunities offered by new technologies. Three perspectives could inform such policy.

First, policy should reconstruct a fertile relationship between *knowledge, research and innovation*. A recognition is needed that all innovative efforts are based on a wide pool of common, accessible knowledge, largely in the public domain, sustained by continued basic research and largely funded by public sources. In the past two decades policies for the privatisation of knowledge (such as stricter rules on intellectual property rights and incentives to universities and public research centres to market their inventions) have proven not to be appropriate and effective in speeding up the diffusion of knowledge and innovation, spreading more widely and evenly its benefits. The return of a major commitment of public funds to research and the recreation of large and accessible pools of knowledge, both basic and applied, are necessary conditions for a sustained innovative performance in the economy and for the successful development of new economic and social activities in leading edge technology fields.

Second, innovation policy should focus on *employment friendly innovations*. The distinction between product and process innovations plays an important role in shaping the economic and employment outcomes of technological change and should inform policy in this field. Supply-side incentives and funds for innovation should introduce a clear focus on the type of innovative activities more likely to result in new products, rather than in labour-displacing new processes. Policies of indiscriminate financial support for supply-driven innovation by firms have led to major direct losses in employment.

Third, greater attention should be paid to the *role of users* in sustaining and orienting the innovation process. So far, the evolution of most ICT activities has been driven by the design of suppliers rather than by the requirements of the users, resulting often in a limited expansion of new activites and in a unrealised potential of the new technologies. The "technology push" that in past decades has created countless innovations in ICTs appears now as a straitjacket for the expansion of economic activities based on ICTs, as what is lacking now are, on the one hand, the coordination and coherence of organisational, institutional and social innovations and, on the other hand, the operation of a "demand pull" able to launch the growth of new large markets for new goods and services (some of these issues are addressed in High level expert group, 1997). This "demand pull" should rely not so much on old-style public procurement, but rather on new schemes "empowering the users", that might accelerate the development of markets for new goods and services, able to address existing specific social needs. In such a view, public procurement should abandon untargeted demand-led schemes and foster a selective public expenditure focused on ICT new products and systems (policies and rules supporting adoption of Linux based ICT systems in the public sector of several countries are examples).

2. The second principle for a new approach to innovation policy is the need for targeting industries and activities (often ICT-related) with the highest potential for growth and employment, for learning and ability to create new products and markets for unmet demands. Specific policy tools, operating both on the supply and demand sides, include a long-run strategy for repositioning the economy in the international division of labour; the provision of infrastructures and framework conditions for new sectors, new markets and new products; organizing private and public sector demand with incentives and procurement; action on regulatory and competition aspects, opening access for new producers; managing the contraction of declining industries, not just through income support policies, but with new activities.

3. A third principle is to *expand education and learning* throughout the economy - in schools, universities, in continuing education and on the job - in order to accelerate social change and support the demand for higher skills coming from innovative economies, industries and firms. Again, a large commitment of public funds is needed in this policy, as education is a major tool for spreading knowledge and supporting research activities, avoiding the simplistic request for an educational

system closer to the short-term needs of firms. Incentives could be provided to firms and individuals (higher wages, tax deductions, etc.) to expand their competences and "human capital", in a comparable way to what happens with incentives to firms to expand their physical capital. Moreover, specific actions may be required for the problems of the low skilled and for assuring access to education to less favourite social groups, immigrant communities and less developed regions.

4. The fourth principle is the need for taking seriously the *systemic nature of innovation* and the role of *national innovation systems*. This implies a strong coherence between industrial, technology, labour market, learning and macroeconomic policies, that all too often are developed and implemented in isolation from one another, responding to very different pressures and constraints. The large literature on innovation systems has pointed out the key role played by close, effective, sustained and long term interactions between firms, universities and research centres, the financial sector, and government bodies. In such a perspective, a wave of institutional innovations, consistent with the new nature of technological change, may be required in order to reap all the benefits promised by the diffusion of ICTs.

5. The fifth principle is the need for policies on the *distribution of the productivity gains* resulting from technological change. Policies need to address not just the achievement of productivity gains, but also their distribution and the resulting economic and social effects. Over the past decades, innovation has mainly benefited firms and consumers, in the form of higher profits and lower prices, in a context of increasing pressure on firms from increasing international competition and from investors demanding high financial returns. Workers have seen job losses, increasing inequality, frequent reductions in real wages, more insecurity, work intensification, and often increased working time. The result has been an increasingly uneven distribution of incomes, made worse by the reduction of resources available for social redistribution through the tax system.

The Lisbon Agenda and the associated policies could incorporate some of these perspectives, leading Europe towards a "high road" where knowledge and innovation are the basis for a growth model based on high productivity, competitiveness, redistribution and sustainability, in the context of increasing democratic participation.

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8 Opponent note no. 1b: Innovation, technology and the global knowledge economy: Challenges for future growth

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8.1 Fagerberg's questions and answers

Fagerberg's paper addresses four questions: (1) Is there anything new about "the knowledge-based economy? (2) Do some countries distinguish themselves from the others? (3) What are the policy challenges? (4) Is EU pursuing the right goals?

First Fagerberg's reflections on each of these questions are presented. Following this the same questions are discussed based on FORA's research, analysis, and policy advice (see chapter 7).

8.1.1 Is there anything new about "The Knowledge-based Economy?

This question has been discussed for more than a decade and the essence of the discussion is well put by Faberberg saying that *in some sense growth has always been knowledge-based, so one might think that what we have witnessed is more a shift in perspective than in the way the global economy works.* Fagerberg finds that there is some truth in this statement but argues that there is more to it than that and even say that: "T*he big shift of our understanding of economic growth has taken place in recent decades"* (p. 90-91).

Fagerberg focuses on four trends characterizing the knowledge-based economy. The first is the rise of innovation as an organized activity within firms. The second important trend is the rise of what we may term a supportive R&D (or innovation) infrastructure. Third it is the massification of higher (tertiary) education. And finally it is the ICT revolution (p. 108-112). Based on indicators for these trends Fagerberg concludes that: *"The evidence considered in this paper clearly illustrates the dynamic character of the emerging knowledge-based economy along all the four dimensions mentioned; innovation, R&D infrastructure, higher education and ICT"* (p. 114).

Among the four trends characterizing the dynamics of the knowledge-based economy Fagerberg puts most attention on innovation which is more than just R&D investment: "*During the last two decades innovation has increasingly become a central focus for policy makers. The reason for this is the central role innovation is*

assumed to play for income and employment growth (and quality of life more generally). It is increasingly recognized that high quality science and R&D is not sufficient for the realization of important social objectives" (p. 97).

Even if it seems like Fagerberg has a very straight forward answer to the question whether there is anything new about "the new economy" you have to press him: "*In short, based on the evidence considered in this paper, can we affirmatively decide the extent to which there is something fundamentally new to "the knowledge economy" or if it – alternatively - is "old wine in new bottles"? If pressed on the subject I would say yes to the former and no to the latter"* (p. 113).

8.1.2 Do some countries distinguish themselves from the others?

Fagerberg looking upon three regions finds that regions scoring high on indicators for the four trends also have a high growth, and that there are differences among the regions. The U.S, the four tigers (Korea, Taiwan, Singapore, and Hong Kong) and sometimes Japan are performing better than Europe on the selected indicators.

To obtain a more detailed picture Fagerberg also lists the fifteen highest ranked countries along the four trends. This indicates that in particular three small European countries obtain a high rank; Finland, Sweden and Switzerland. The bad ranking for Europe is therefore not uniformly distributed among all countries. In fact the bad performance reflects the performance of the larger European countries.

8.1.3 What are the policy challenges?

The policy challenges for EU are illustrated by lower rankings compared to the U.S. and the tigers on all four indicators: Innovation, including R&D infrastructure, tertiary education and ICT. However according to Fagerberg it is not enough to focus on these rising trends, it is also necessary to have a better understanding of the nature of innovation. Innovation in general is important. However, the focus should be on both radial and incremental types of innovation. *Although some innovations may be spectacular technological breakthroughs, the bulk of innovation in modern societies consists of relatively small improvements and it is probably a safe bet that the cumulative impact of these is as great (or greater) than that of the more "radical" or "revolutionary" ones (p. 101).*

There are several sources of innovation and Fagerberg argues that more attention should be given to firms' interaction with the users "*since interaction with users (and user competence) has been shown to be perhaps the most important factor*

behind successful innovation" (p. 114). The focus on users in the innovations process is generally linked with incremental innovations, because individuals typically relate their needs to existing solutions or combinations of these.

8.1.4 Is EU Pursuing the right goals?

Fagerberg argues that: "T*he chief policy goal that European policy makers have agreed on is to try to raise R&D investments towards the three percent of GDP target" (p. 114).* And this is not the right goal to pursue according to Fagerberg. A holistic policy approach is needed.

The holistic policy approach should be based on the four rising trends (innovation, R&D infrastructure, tertiary education and ICT) coupled with a focus on interaction with users.

A new mind set is needed in order to create powerhouses for innovation. This should lead to an experimental economy. And Fagerberg argued that a good place to start experimenting is with the public demand.

8.2 The four questions once again

FORA has conducted research and analysis on the challenges of the emerging global knowledge economy and has designed industrial and business policies for the Danish Ministry of Economic and Business Affairs. The result of this research and analysis is the platform for the following attempt to address Fagerberg's four important questions.

8.2.1 Is there anything new about "The Knowledge-based Economy?

What is the fundamentally new about the knowledge-based economy is the shift in the nature of competition from competition on price/quality to competition on innovation. Competition on innovation requires capital investment and more qualified labor than competition on price/quality does. However, innovation also requires less tangible factors/imaginary factors such as knowledge, creativity and new ideas.

The imaginary production factors behind innovation account more and more for the differences in growth between countries and not capital deepening as previously. Decomposition of economic and productivity growth taking into account reallocation, quality, and quantity effects, supports this (Sørensen and Fosgerau, 2000). The contribution to labor productivity from multifactor productivity (MFP) has been

increasing, when comparing this decade with the previous (Jorgenson, Ho and Stiroh, 2002; Stiroh, 2002; Triplett and Bosworth, 2003). This new growth pattern leads OECD to conclude that there is something new in "the new economy" (OECD, 2001).

Nevertheless, this needs further explanation. MFP is the residual that is left after accounting for labor and capital accumulation, and therefore besides the contribution of innovation to productivity, MFP also captures measurement failures. On the other hand still more literature shows an increasing impact on growth and productivity from other factors than traditional capital deepening.

Increased labor quality has been linked with productivity growth (Jorgenson, 2004; OECD, 2002h). Higher and higher education is a common goal for countries' investments.

International knowledge spillovers have been related to an unclear link between investments in R&D and higher growth rates. Countries with high investment rates exhibit higher income levels, more than higher growth rates (Klenow and Rodriguez-Clare, 2004).

ICT has been related to increased productivity growth (Jorgenson, Ho and Stiroh, 2005; OECD, 2003a; Stiroh, 2002; Triplett and Bosworth, 2003). ICT capital deepening has been rising and ICT explains a part of the contribution from MFP.

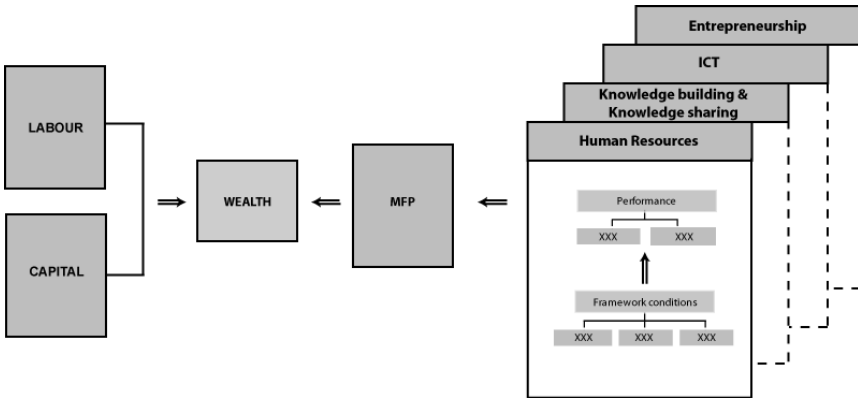
Complementary workplace reorganization, introduction of new products and services carried out in relation to ICT investments are found to increase MFP when compared with only investing in ICT (Bresnahan, Brynjolfson, and Hitt, 2002; Pilat, 2004). In addition firms that adopt these innovations tend to use more skilled labor (Katz and Kruger, 1998; Machin and Van Reenen, 1998; Skaksen and Sørensen, 2005)

Entrepreneurship has been linked to productivity growth (Audretsch and Thurik, 2000, Brandt, 2004; OECD, 2003b; Scarpetta, Hemmings and Woo, 2002). Besides productivity growth entrepreneurship is not surprisingly linked to job creation (OECD, 2002a).

As mentioned earlier, FORA has conducted research and analysis on the increasing importance of the imaginary factors and the adherent challenges of the of the global knowledge economy, and has designed industrial and business policies for the Danish Ministry of Economic and Business Affairs. The methodology behind FORA's research builds on the classic growth framework, where the accumulation

of factor (capital and labor) and MFP determine wealth creation. It is central to the methodology that four innovation drivers of growth and productivity lead to higher wealth through their contribution to a higher MFP. The four identified innovation drivers are human resources, knowledge building, ICT and entrepreneurship (figure 1).

Figure 1: The FORA model



The four drivers are all related to a countries innovation capacity by being preconditions for innovation.

Highly qualified knowledge works are essential to the activities of the other drivers of innovation. Knowledge building and knowledge sharing help to address opportunities or the creation of them. ICT supports knowledge building and knowledge sharing. Entrepreneurship enables the introduction of new goods, services and ways of organizing outside existing firms. Management and organization provides the proper support for organizing resources and optimal strategy.

A number of complex yet coherent activities described by the four drivers are generally believed to have a positive effect on productivity (MFP).

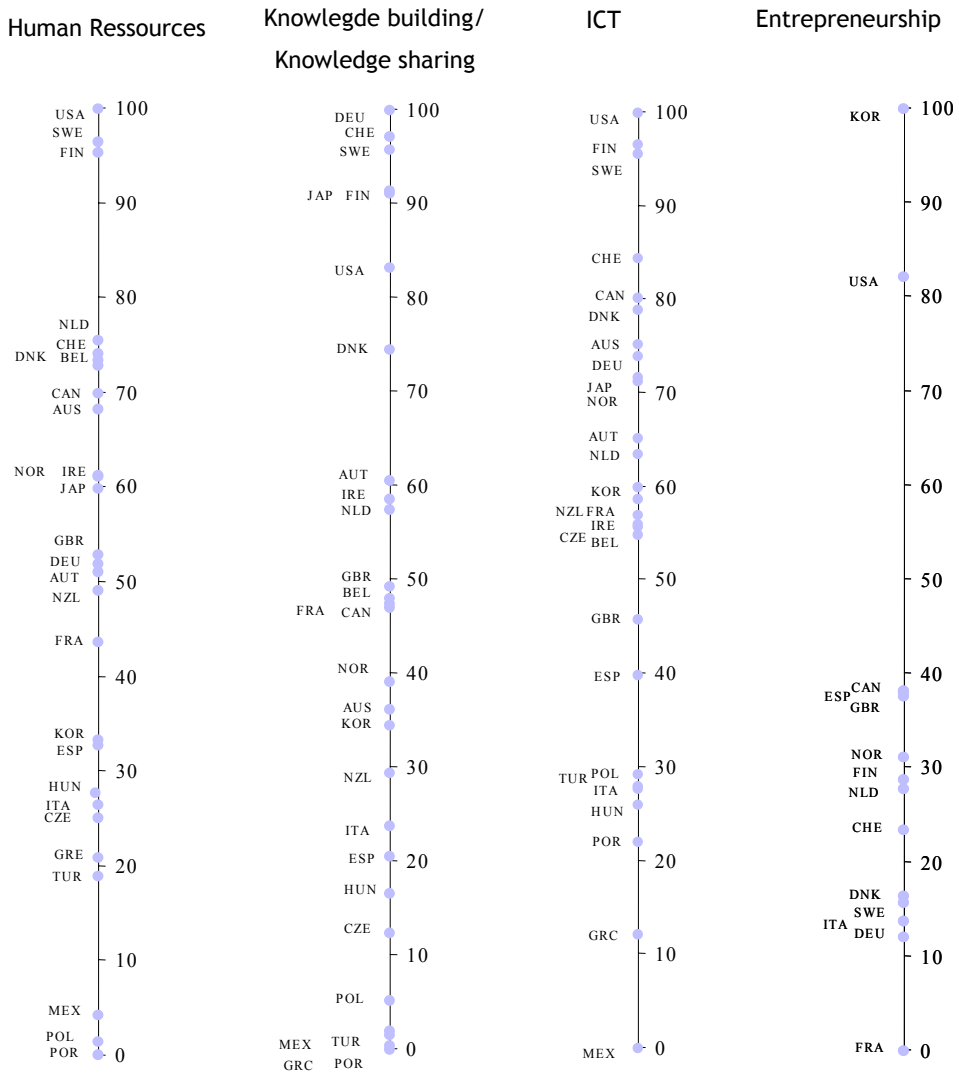
For each of the four drivers FORA has identified a number of performance indicators. There is a link between the acceleration in MFP and the four drivers and this explains most of the differences in long-term growth between the OECD countries (FORA 2004, a, b, c, d; OECD, 2001).

That most of the growth differences between OECD countries in the last decade can be explained by their innovation capacity is the reason why we conclude there is something new in the knowledge economy and it has significant policy implications.

8.2.2 Do some countries distinguish themselves from the others?

Based on the performance indicators we can assess how countries differ in innovation capacity with respect to each of the four drivers (figure 2.)

Figure 2: Performance rank for each of the four innovation drivers



Source: Own calculations; Data (FORA, 2005a). The four performance indices consist of a total of 31 compiled indicators.

The figure above illustrates different OECD countries' position on each of the four drivers where the best performing countries is assigned the value 100. The differences reveal that the countries' rank shifts, depending on which of the four factors that is viewed.

The U.S. stands out in terms of entrepreneurship but is also doing well with respect to human resources and ICT. Also the rest of the English speaking countries are

doing well on most of the drivers. Japan scores high on knowledge building but is behind on the other drivers. Korea stands out in terms of entrepreneurship, but is behind on the other factors. We do not have data for the three other tigers but other sources illustrate that they score relatively high on most of the factors. The Nordic countries are doing well on most of the factors except for entrepreneurship.

The rest of the European countries differ greatly with a few countries ranking relatively good at a single factor i.e. Switzerland on knowledge building. All Central European countries are falling behind with respect to entrepreneurship.

It is not straight forward to summarize the results but it seems that the English speaking countries, the Asian tigers, the Nordic countries and maybe Switzerland outperform the other European countries. There are important and interesting differences in the way to success. Some countries are strong in entrepreneurship but weak in human resources and knowledge building, and therefore do not realize the full potential of the knowledge base economy. Other countries like the Nordic ones are strong on three of the four drivers but not in entrepreneurship, and therefore fail to realize the potential. This raises the hypothesis that a country needs to be strong on all four drivers to realize the full potential of the knowledge-based economy.

8.2.3 What are the policy challenges?

The differences in performance among the OECD countries give some insight in the policy challenges. To gain a deeper insight you need to know more about which policy areas affect the innovation capacity. Is it possible to identify relevant policy areas? And how does policy affect the four drivers?

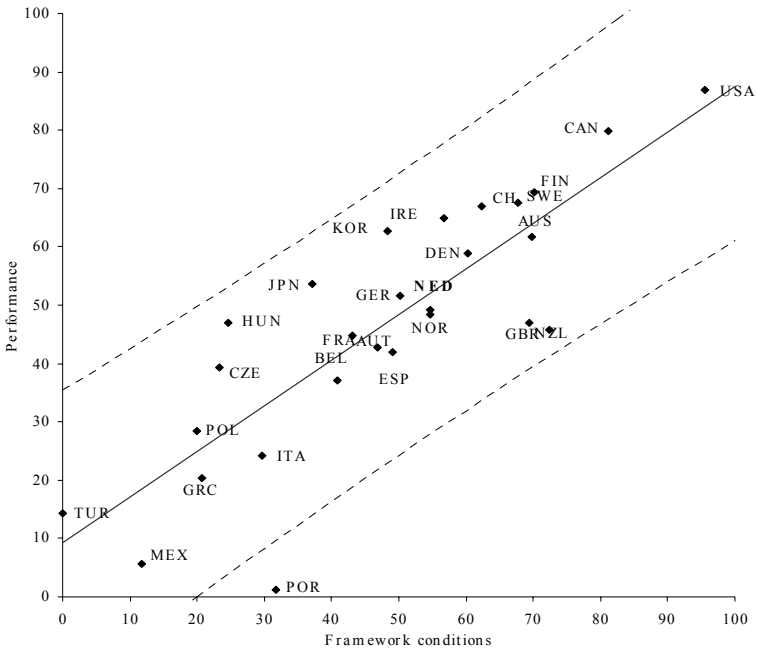
FORA's research goes one step further than identifying forces behind growth differences in identifying not only a set of performance indicators as shown in the previous section, but also a set of condition or framework indicators for each of the four drivers (FORA, 2005 a,b,c,d).

The identified framework conditions are a quantification of policies and factors related to the four drivers believed to have an effect on the performance indicators. The underlying foundation of this approach is that linking indicators related to the framework conditions with the indicators of performance will allow for new policy insights.

The separation also allows for going from the very highest level and down to specific policy areas to gain a better understanding of what is going on. It gives policy

making a depth and breadth to be able to compare framework conditions and performances conditions. This research shows that there is a significant positive relation between the performance indicators and the framework conditions (Figure 3.). The relationship is robust to changes in weights, methods of normalization, inclusion and exclusion of countries and indicators.

Figure 3: Correlation between performance and framework conditions



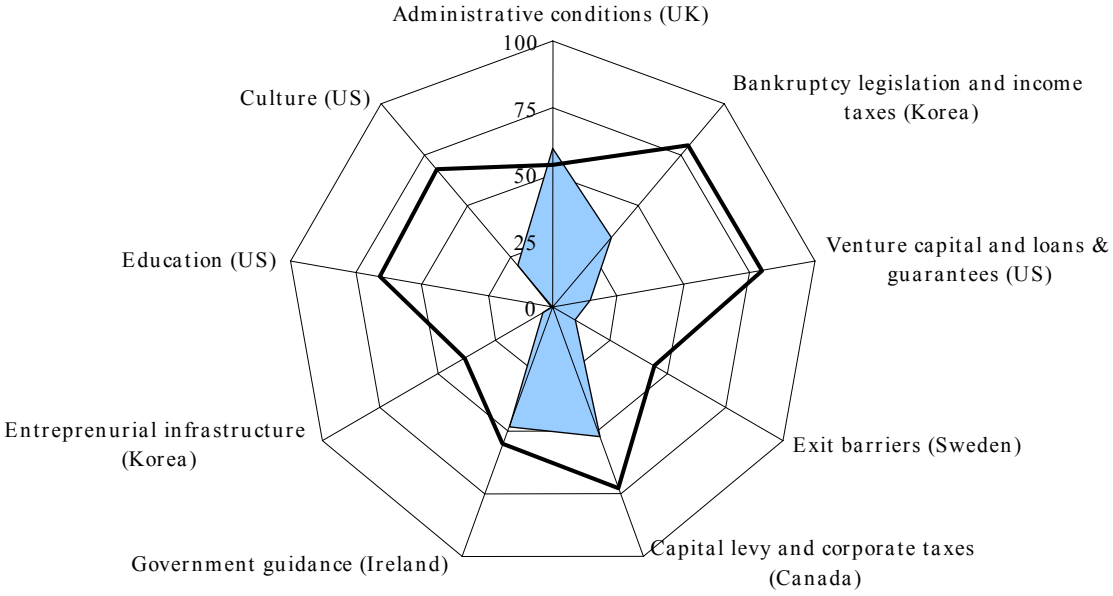
Note: The correlation is 0.85. The dotted lines show the 95% confidence interval. We find that all 27 OECD countries are located within the two error bars except for Portugal, which has a very bad performance. Source: Own calculations; Data (Fora, 2005). The four framework condition index consists of a total of 150 compiled indicators, while the performance index consists of a total of 31 compiled indicators. The framework conditions are based on 37 policy areas for nurturing innovation capacity.

The FORA model allows for benchmarking. For each driver one might pick the best performing countries and look for patterns in the policy design. If the best performing countries have a similar pattern in their policy design one could use this pattern as a benchmark. Careful investigations of the framework conditions in the best performing countries can give some insight to policy challenges in the knowledge-based economy. The benchmark process can be seen as comparative economics where one tries to learn from the best performing countries in order to build a stronger innovation capacity.

Framework conditions can be content dependent and therefore framework conditions cannot be transformed uncritically from one country to another. But used

carefully this kind of benchmark exercise can give important policy inspirations (see figure 4).

Figure 4. The Framework indicators for entrepreneurship: The Danish case.



The best performing countries on entrepreneurship are US, Korea and Canada (FORA, 2005). According to the benchmark model Denmark is weak in several important policy areas especially venture market, bankruptcy, education, culture and taxes. Denmark can take the framework conditions in the best performing countries as a benchmark for policy consideration and make detailed peer reviews of the framework condition in these countries. For each policy area it must be evaluated if the framework conditions in the best performing countries can function in a Danish context.

Besides building a strong innovation capacity another challenge is to enhance the success possibilities for innovations. According to Fagerberg user-driven innovation is a way to enhance the success of innovations. The research of FORA confirms this observation. FORA has conducted studies of user-driven innovation in the electronics-, medico-, and fashion industry and compared the experiences in Danish firms with best practice in the worlds most advanced firms (FORA 2005b).

FORA's research on user driven innovations distinguishes between recognized user needs and non-recognized user needs. The former can be identified by traditional

marketing tools and usually gives inspiration to important incremental innovations as pointed out by Fagerberg. To investigate non-recognized user needs demands much more advanced and systematic studies, where firms have to draw upon disciplines and methods from anthropology, ethnography, sociology and market psychology. Understanding and evaluating non-recognized user needs sometimes leads to quit new concepts and more radical innovations see examples in (FORA 2005b).

8.2.4 Is the EU pursuing the right goals?

Fagerberg argued that the EU's one-sided R&D goal is not the right goal to pursue. It is hard to disagree on this point.

Innovation and a strong innovation capacity is the right goal to pursue. Innovation depends on the four drivers. However, it must be kept in mind that the challenges confronting countries are different. Hence different policy is needed. However, one challenge seems common for most EU countries; entrepreneurship.

Given the different challenges EU cannot tailor-make a goal and a policy fitting all countries but for each driver there is both a national dimension and an EU-dimension. Up till now the EU has failed to make this separation and has not designed an innovation strategy for the EU dimension. This is probably one of the reasons for the rather poor performance of most EU countries.

8.3 Postscript

Fagerberg's paper is written in the context of the "Green roads to growth project". It is argued that the knowledge-based growth is associated with less pollution and this could be right. However, the western world is not likely to reduce its material consumption. Outsourcing means that production just changes to new places and the same do pollution. The knowledge-based economy will not in itself solve environmental challenge much more is needed.

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Part IV

Case study #2

9 Case study paper no. 2: What trade-off between knowledge-based growth and the environment?

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9.1 Abstract

Protecting the environment is essential for the quality of life for current and future generations. The policy challenge is to combine this essential concern with promoting the continuation of economic growth. The main determinants of growth were changing during the 1990s due to the rise of the knowledge-based economy. The knowledge-based economy poses challenges for countries to strengthen their innovative capacity in order to secure long-term growth. This paper explores the relationship between knowledge-based growth and environmental indicators. This exploration suggests that knowledge-based growth is not in conflict with the environment, so the trade-off between growth and the environment therefore no longer exists. Consequently, growth-oriented policies should be aimed at stimulating the four drivers of knowledge-based growth: Entrepreneurship, knowledge building and knowledge sharing, use of information technology, and exploitation of human capital. However, pro-environmental policies are still needed to protect the environment. Knowledge-based growth does not remove all pressures in the economy as it only occurs in parts of the economy. These environmental policies might be aimed at stimulating environmental research in prioritised areas based on a cluster approach and at ensuring that environmental regulations spur innovation. These policies can thereby stimulate firms to produce environmental technologies, competitiveness and ensure a positive relation between improving the environment and generating growth.

KEYWORDS: Knowledge-based growth; innovation; environmental regulation.

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9.2 Introduction

The Lisbon Strategy sets out for the European Union to be "[...] the most competitive and dynamic knowledge-based economy in the world". This growth should be created on an ecologically, economically and socially sustainable basis. A challenge for policy makers is to enhance economic growth and create jobs while at the same time protecting the environment. *"Can environmental policies underpin the EU goals of improving economic growth, environmental quality and employment – all at the same time?"* is a central question for the open international Forum "Green Roads to Growth".

The answer would be a straightforward "*no*" in the classic growth paradigm based on factor-accumulation and mass production. A more intensive use of factors (resources) will lead to a higher pressure on the environment through for example higher emissions. Economic growth will consequently have detrimental effects on the environment through its accumulation of factors of production and externalities. Environmental policies will similarly impede economic growth by imposing limitations on firms' abilities to produce in an efficient manner thereby reducing their competitiveness.

However, a new growth pattern is emerging. Growth in the 1990s broke the well-known pattern of "catching-up" of the 1960s and 1970s, where countries that lagged behind in terms of labour productivity and GDP per capita gradually closed the gap vis-à-vis the leading country (OECD, 2003a). After stalling during the 1980s, the convergence process appears to have reversed during the 1990s in the largest OECD economies. GDP per capita grew faster in the United States than in Japan and the large EU member countries. A few countries (Ireland, Korea, Australia, Norway, New Zealand and Canada), in contrast have seen GDP *per capita* rising faster than in the United States allowing them to narrow the income gap.

This new growth pattern is caused by a shift in the relative importance of the main drivers of growth. Factor accumulation has played a key role in creating wealth in the post World War II period and has been the focus of most policy making in OECD countries. However, it appears that a new source of wealth has been dominating in the high-growth countries in the 1990s due to the rise of the "knowledge-based economy".

The knowledge-based economy shifts the nature of competition from competition on price/quality to competition on innovation and innovative capacity. Competition

on innovation and on price/quality both requires capital investment and a more qualified labour force. However, innovation also requires intangible assets such as knowledge, creativity and new ideas. Compared to an industrial-based economy, a knowledge-based economy is associated with a better environment, assuming that there is an increase in the intangible factors of the production, as growth mainly comes from a better utilisation of factors of production through innovation.

The intangible factors pushing innovation increasingly account for differences in growth between countries. Taking into account reallocation, quality, and quantity effects, the decomposition of economic and productivity growth supports this new development (Jorgenson, Ho and Stiroh, 2002; Stiroh, 2002, Triplett and Bosworth, 2003, Sørensen and Fosgerau, 2000). The unexplained part of the growth process (i.e. multi-factor productivity) generates most of the differences in growth among OECD countries during the 1990s. This new growth pattern leads the OECD to conclude that there is something new taking place in the global economy (OECD, 2001).

Multi-factor productivity (MFP) used to be coined as 'a measure of our ignorance' or the Solow residual (Solow, 1957). The Solow residual was the unexplained part of the growth process that was explained by exogenous technology shocks. The change from large scale to knowledge-based production has increased the relative importance of the residual factor in countries with high growth, making this factor endogenous and, consequently, responsive to policy changes. It is now seen as a better utilisation of resources. Economic growth theories have also adapted to this change by introducing the concept of endogenous growth driven by investments in knowledge and research (Romer, 1994).

The new patterns of growth do not only impact wealth generating policies, but also the links between the environment and economic growth. Growth generated by factor accumulation has a preponderant negative effect on the environment, and trade-offs between economic growth and the environment is therefore a key part of the political agenda, whereas this potential trade-off is so far unexplored for the knowledge-based growth.

The purpose of this paper is to explore the relationship between knowledge-based growth and indicators for the environment in order to discern if countries that are adapting to knowledge-based growth are doing so in detriment to the environment. Furthermore, the objective of this paper is to propose various policy options that ensure both economic growth and a sustainable environment.

The paper shows that knowledge-based growth is no panacea, but knowledge-based growth does not have the negative side-effect on the environment as previous growth patterns. The trade-off between growth and the environment consequently no longer exists.

The paper is based on FORA's extensive research and analyses on the challenges of the emerging global knowledge-based economy. The research follows the lines of the growth study performed by the OECD from 1998 to 2001. The result of our extensive work serves as a platform for discussion and the operationalisation of knowledge-based growth. Data related to the environment have been obtained from the Environmental Sustainability index (ESTY, Levy, Srebotnjak, and Sherbinin, 2005) and the OECD Environmental Data Compendium (2004). This paper does not address job creation, an important point in the Lisbon Strategy. For example, the consequences from skill-based growth and outsourcing are not addressed.

The relationship between the environment and economic growth stages has previously been addressed within the literature on for example Environmental Kuznets Curves (EKC) (Grossman and Krueger, 1995, and Kuznet, 1955). This research attempts to fit a universal yet reduced form of the pollution-income relationship (Haubaugh *et al*, 2002) and leaves no space for differences in innovative capacity structures. Our multi-dimensional approach allows us to draw more effective policy implications from the data and the research. EKC literature also focuses on the change from a manufacturing to a service production, whereas the knowledge-based growth examined here covers both service and manufacturing.

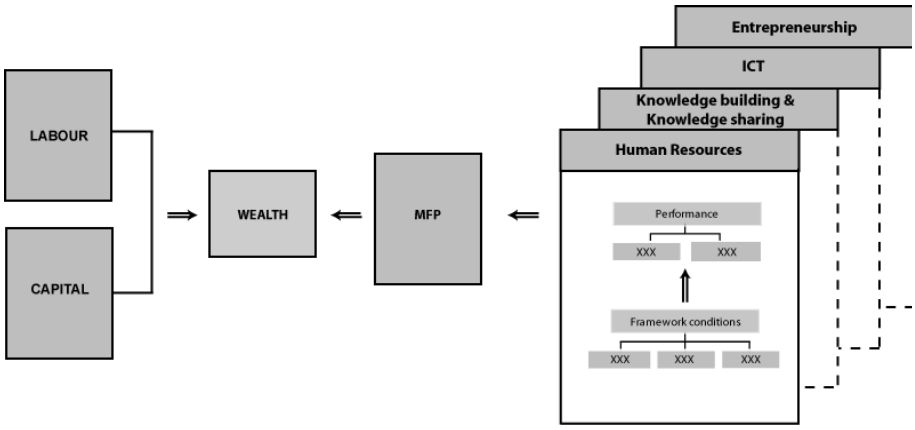
This paper begins with a short introduction to knowledge-based growth and FORA's model for wealth creation. It then illustrates how countries differ in innovative capacity with respect to the four drivers of innovation and addresses the policy challenges. Next, the methods that are used for data collection and analysis are described. Subsequently, the results of the analysis of the relationship between innovative capacity and the environment are presented. Following this, the paper proposes a discussion of growth friendly environmental policy based on regulation, government demand and strategic government investments in R&D, and concludes.

9.3 FORA's model for wealth creation in the knowledge-based economy

The methodology behind FORA's research builds on the classic growth framework, where factor accumulation (capital and labour) and MFP determine wealth creation. The central concept of this methodology is that four "innovation drivers" of growth

and productivity lead to higher wealth creation by contributing to a higher MFP. The four identified innovation drivers are entrepreneurship, ICT-use, knowledge building and knowledge sharing, and human resources (Figure 1).

Figure 1: FORA's framework



The four drivers are all related to a country's innovative capacity as they are preconditions for innovation.

Highly qualified and skilled workers are essential to the other drivers of innovation, and each driver is mutually reinforcing to innovation. Knowledge building and knowledge sharing help address opportunities or create them. ICT supports the drivers of knowledge building and knowledge sharing. Entrepreneurship enables the transformation of resources into new goods and services, new markets, new ways of organizing or new materials. Management and organisation provide the proper support for organising resources and optimal strategy.

FORA has identified a number of performance indicators for each of the four drivers. In doing so, the link between the acceleration of MFP and the four drivers became apparent and explained most of the differences in long-term growth among OECD countries (FORA, 2004, a, b, c, d; OECD, 2001 – see chapter 7).

That most of the growth differences between OECD countries in the last decade can be explained by their innovative capacity is the reason why we conclude there is something new in the knowledge-based economy, and that it has significant policy implications.

However, a qualification must be made. MFP is viewed as equal to the residual factor, after accounting for labour and capital accumulation. Hence, on the one

hand, the residual captures the contribution of innovation to productivity, but it can also capture measurement failures. On the other hand, the majority of the literature shows that there are other factors besides traditional capital deepening that have had an increasing impact on growth and productivity, for example: increased labour quality (Jorgenson, 2004, OECD, 2002); ICTs (Jorgenson, Ho and Stiroh, 2005, OECD, 2003a, Stiroh, 2002, Triplett and Bosworth, 2003); entrepreneurship (Audretsch and Thurik, 2000, OECD, 2003b, Scarpetta, Hemmings and Woo, 2002), and the complementary reorganisation that accompanies ICT use and the introduction of new products and services.

Building on various OECD studies, FORA has conducted extensive research in each of the four drivers of growth. The research efforts have resulted in four in-depth studies (FORA, 2004a, b, c and d). Collectively, the four reports introduce a comprehensive framework for carrying out an extensive analysis of a country's innovative capacity for productivity growth. The framework has been used both in Denmark (FORA, 2005a) and in the Netherlands (FORA, 2005b).

9.3.1 FORA's framework

The identification of *two sets of separate indicators* for each of the four drivers is a central premise for FORA's approach to research. *Performance indicators* represent a number of complex yet coherent activities that are generally believed to have a positive effect on productivity (MFP). *Framework condition indicators* represent a quantification of the policies and factors related to the four drivers and are believed to have an effect on the performance indicators.

FORA's framework goes beyond a traditional benchmarking analysis that ranks countries on a number of relevant indicators for each of the growth drivers (e.g. World Economic Forum's Competitive Index).

The underlying foundation of this approach is that interlinking (interdependent) indicators related to the framework conditions and performance will allow for new policy insights. The separation also allows for a better understanding of the growth process by analysing at an overall level and at the level of specific policy areas. This broad and in-depth approach enables policy makers to compare framework conditions and performances.

In the following section, the four drivers will be briefly explained. The focus is on the performance drivers, since the objective of this study is on the relationship

between economic performance and the environment. The framework conditions are mentioned because they illustrate a clear foundation for policy judgement.

9.3.1.1 Entrepreneurship

First illustrated by Schumpeter, entrepreneurship's positive effects of providing new products and processes to the market have been recognised. However, how to define and how to measure entrepreneurship is still being hotly debated. Entrepreneurship is not a single event, but a process that transforms an innovative idea into a firm, which might fail, grow or remain a small business. FORA's model focuses on two parts of this process - *entry* and *creation of high growth firms*. Analyses show a direct link between these two parts of the entrepreneurial process and productivity growth (Audretsch and Thurik, 2000, Scarpetta *et al,* 2002, OECD 2003a, and Brandt, 2004a).

No single agreed paradigm exists for the framework conditions for entrepreneurship, but many important contributions to the literature have been made (Aldrich, 2000). The differences between various contributions are often semantic. The essence of the various papers is that a new firm is created by a combination of three factors: *opportunities*, *skilled people* and *capital*. These three factors are then combined with the necessary condition of a *market clearing* (possible benefits of creating a new firm outweighing the associated costs) and finally *culture* (Gabr & Hoffmann, 2005). Both performance and framework conditions are quantified.

9.3.1.2 Use of Information Communications Technology (ICTs)

Corporate ICT-use has a significant impact on productivity. Studies show that the manufacturing of ICT (hardware and software) as well as an increased use of ICT help explain the persistently high productivity growth rates in the United States throughout the 1990s (Jorgenson, 2001 and OECD, 2003). However, ICT manufacturing is not a prerequisite for seizing the benefits of ICTs (Jorgenson, Ho and Stiroh, 2005, Stiroh, 2002). A large potential lies in the sophisticated use of ICTs in the development and use of new work processes and new business models (Porter, 2001). As such, the composite index for ICT-performance compares companies' abilities to integrate ICTs into innovative work processes and new business models.

The framework conditions for ICTs builds on OECD analysis, which identified four factors that affect the ability of enterprises to seize the benefits of ICTs (OECD, 2002b). In its simplest form, it depends on *access to ICTs* and *skills and organisa-*

tion. The growth of the internet can create additional benefits by creating access to high quality *digital content* developed by both private firms and government agencies. Finally, access to ICTs, skills and organisation, and content might not necessarily be enough to seize the potential if firms do not *trust the technology* or *on-line security* (OECD, 2003*c*).

9.3.1.3 Knowledge building and knowledge sharing

In advanced industrial countries, the exploitation of scientific discoveries and new technology has been the principal source of economic growth. However, growth does not only depend on the introduction of new products, processes, services and systems, but also on their subsequent diffusion throughout the economy (OECD, 2004). FORA's model consequently defines performance as : 1) the ability to create and build new knowledge by developing new products, processes, services and systems, and 2) the ability to collect, share and diffuse knowledge (both domestically and internationally) throughout the economy.

Considerable academic and business literature exist on framework conditions affecting knowledge building and knowledge sharing. The National Innovation System (NIS) Theory provides the building blocks for FORA's framework related to this driver (Lundvall, 1992). For the purposes of assessing the factor determining national performance in the build-up and subsequent diffusion of knowledge, the NIS framework is quantified into four main areas (*public research*, *financing*, *co-operation between knowledge institutions and the private sector,* and *interaction with customers, suppliers and competitors*).

9.3.1.4 Human resources

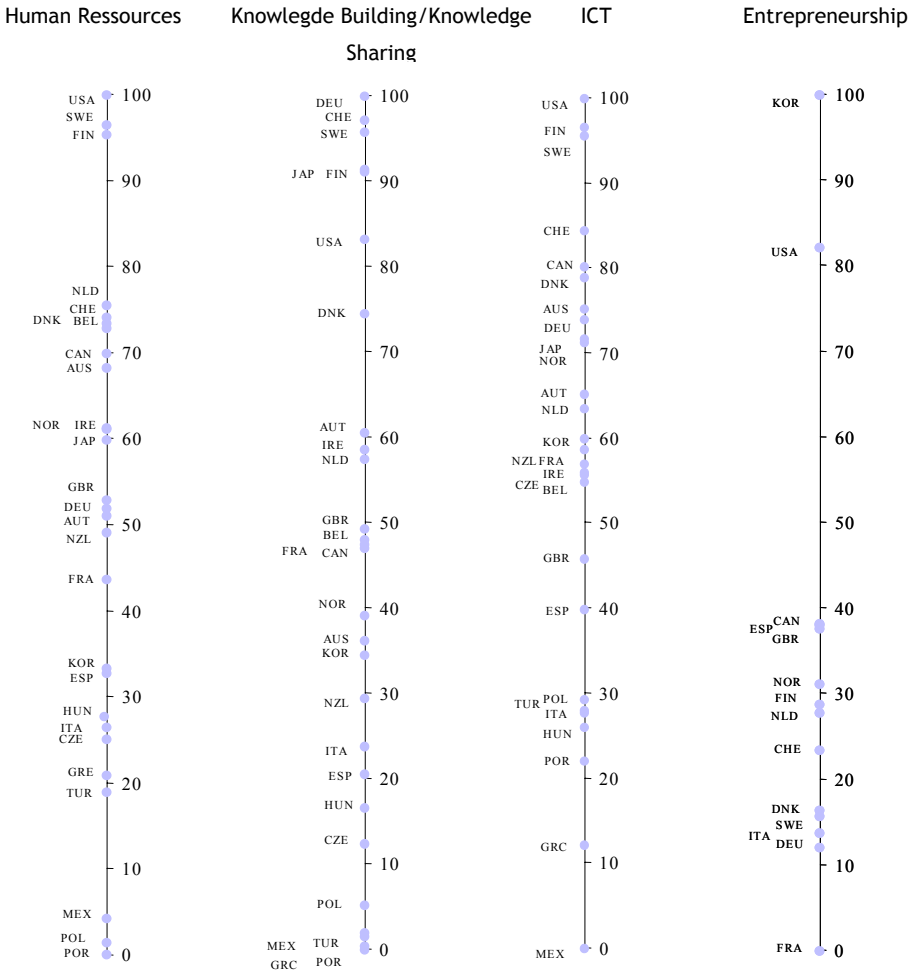
Human capital has long been recognised as a key engine of growth (Barro, 2000; Bassanini and Scarpetta 2001). New research shows that it is not only the *level of human capital* but also the *organisation and management* of the "knowledge workers" that are important to growth. Therefore, work should be organised to fully exploit the collective competences of knowledge workers. (Mckinsey, 2002; Caroli and Reenen, 2001).

While no theory exists on the optimal framework conditions for human capital, the FORA model identifies a number of broad areas that could be important (FORA, 2004a). These areas cover *basic and higher education*, *life-long learning* and *organisational and management structures.*

9.3.2 Innovative capacity differences between countries

Based on the performance indicators, it can be illustrated how countries differ in innovative capacity with respect to each of the four drivers (figure 2.)

Figure 2: Performance rank for each of the four innovation drivers



Source: Author's calculations based on FORA data (2005a). The four performance indicators consist of a total of 31 compiled indicators.

The figure above illustrates the relative positions of different OECD countries measured by each of the four drivers. The best performing countries are assigned the value of 100. The differences reveal that country rank shifts, depending on which of the four factors is measured.

The United States stands out in terms of entrepreneurship, but is also doing well with respect to human resources and ICT-use. Generally, other Anglo Saxon coun-

tries are doing well on most of the drivers. Japan scores high on knowledge building/sharing, but is behind on the other drivers. Korea stands out in terms of entrepreneurship, but lags behind on other factors. No data for the three other economic "tigers" (Singapore, Hong Kong and Taiwan) is currently available, but other sources indicate that they would score relatively high on most of the factors. The Nordic countries are doing well on most of the factors, except for entrepreneurship.

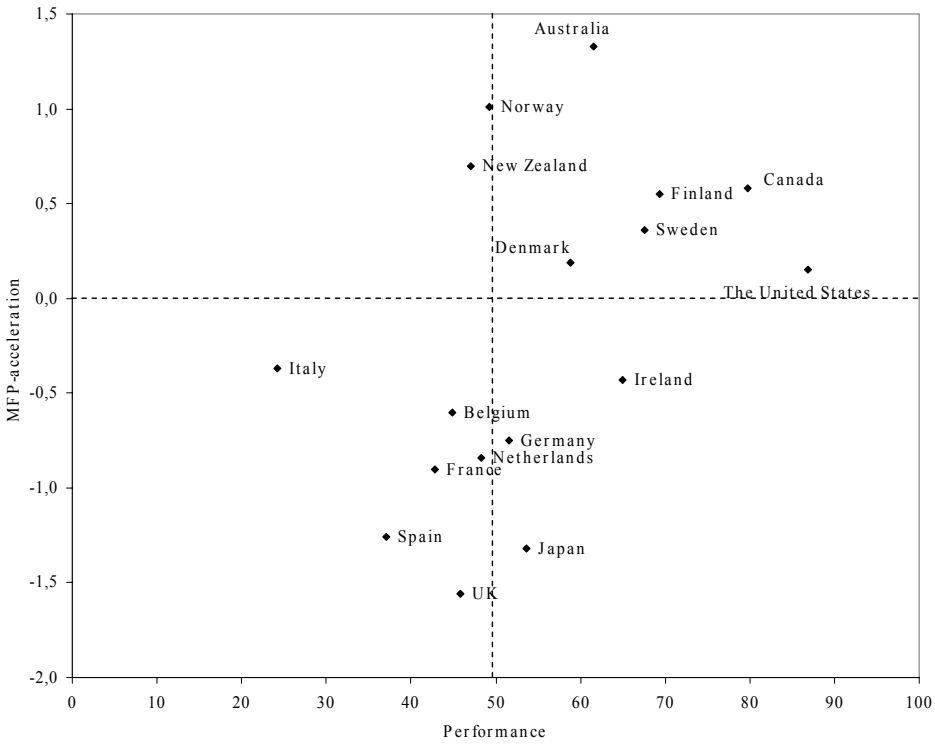
The rest of the European countries differ greatly. Several countries rank relatively well for single factors (i.e. Switzerland on knowledge building/sharing). All central European countries are falling behind with respect to entrepreneurship.

It is not easy to summarize the data. However, it seems that the Anglo Saxon countries, some Asian tigers, the Nordic countries and maybe Switzerland outperform the other European countries. Yet there are important and interesting differences in the way each country has achieved success. Some countries are strong in entrepreneurship but weak in human resources and knowledge building; these countries are not realising the full potential of the knowledge-based economy. Other countries, for example the Nordic countries, are strong on three of the four drivers but not in entrepreneurship, and therefore, they also fail to realise their full potential. This evidence leads to the hypothesis that a country needs to be strong on *all four* drivers in order to realise the full potential of the knowledge-based economy.

FORA finds that with a few exceptions a higher innovative capacity has materialised into growing contributions to MFP, leading to higher wealth creation (FORA, 2005a). This is central to FORA's analytical approach. MFP comparisons might be problematic because of the various measurement problems. Using MFP acceleration instead of MFP level or changes can remove some of the measurement problems (OECD, 2005). Comparing innovative capacity and MFP acceleration supports FORA's conclusions; that higher innovative capacity has materialised into growing contributions from MFP (Figure 3).

Continued improvements in data collection and verification will undoubtedly lead to a more coherent correlation between MFP growth and overall performance.

Figure 3. Correlation between changes in MFP-growth (1980-90 and 1990-2002) and the overall performance index



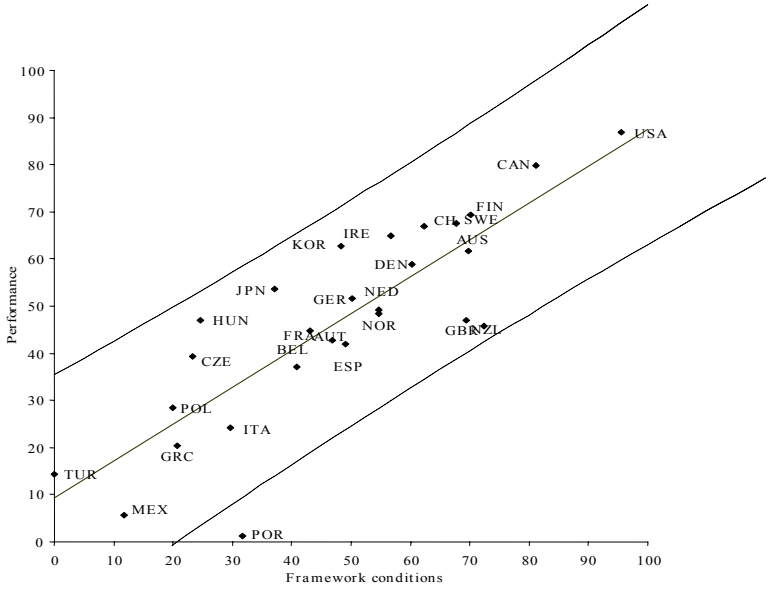
Note: Correlation 0.46; t-value equals 2.1; Based on a factor analysis human resources, knowledge building and knowledge sharing are each assigned the weight 0.2, while the driver for entrepreneurship is assigned the weight 0.4. See FORA 2005a for further details about the performance index at www.foranet.dk. Source: OECD's Productivity database and Author's calculations.

9.3.3 The policy challenges

The differences in performance among the OECD countries give some insight into the policy challenges that governments face when pursuing a knowledge-based economic growth. To gain a deeper insight you need to know more about which policy areas affect the innovative capacity. Is it possible to identify relevant policy areas? And how can policy affect the four drivers?

This research illustrates that there is a significant positive relationship between the performance indicators and the framework conditions (Figure 4.). The relationship is robust to changes in weights, methods of normalisation, and the inclusion and exclusion of countries and indicators (FORA 2005a).

Figure 4: Correlation between performance and framework conditions

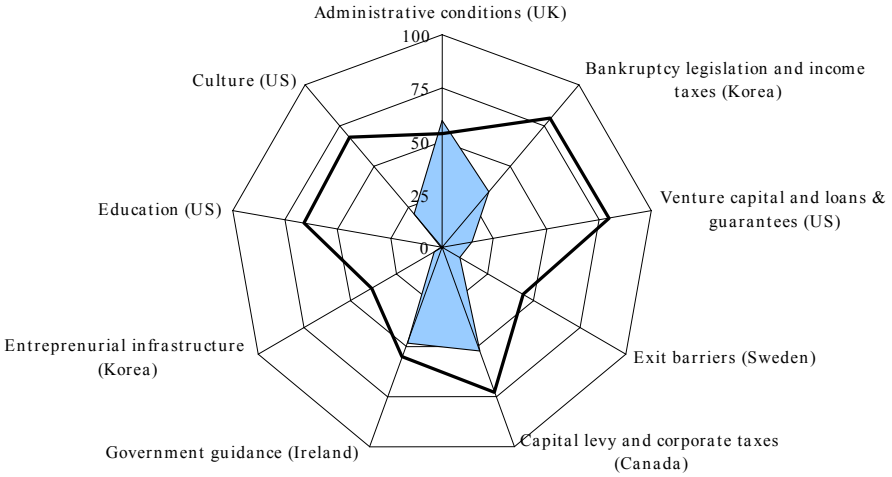


Note: The correlation is 0.85. The dotted lines show the 95% confidence interval. All 27 OECD countries are located within the two error bars except for Portugal, which has a very bad performance. Source: Author's calculations; Data (FORA, 2005).

The FORA model allows for benchmarking. For each driver, one could pick the best performing countries and look for patterns in policy design. If the best performing countries have a similar pattern in their policy design, one could use this pattern as a benchmark. Careful investigations of the framework conditions in the best performing countries can give some insight into the policy challenges of the knowledge-based economy. The benchmarking process can be seen as comparative economics where one tries to learn from the best performing countries in order to build a stronger innovative capacity in other countries.

Framework conditions can be context dependent and, therefore, not readily transposable from one country to another. But if used carefully, benchmark exercises of this type can bring forward important policy insights (see figure 5).

Figure 5. The Framework Indicators for entrepreneurship: The Danish case.



Source: Author's calculations. Data: FORA (2004e)

Note: The spider diagram illustrates how framework conditions are prioritised among the top-3 countries (Korea, US and Canada) – the black line. The relative importance of a given policy areas is determined by the average value of the top-3 performance countries, as illustrated by the black line combined with a check of the correlation between the policy area and the performance indicators. The Danish position is illustrated by the blue area. The best-performing country for each of the policy areas is shown in () following the name of the policy area.

The best performing entrepreneurial countries are the United States, Korea and Canada (FORA, 2005). According to the benchmark model, Denmark is weak in several important policy areas, especially in the following areas: venture capital markets, bankruptcy, entrepreneurship education, entrepreneurial culture and taxes. Denmark can take the framework conditions in the best performing countries as a benchmark for policy consideration and make detailed peer reviews of the framework condition in these countries. For each policy area, it must be evaluated if the framework conditions in the best performing countries can function, or if they should be modified to fit a Danish context.

Besides building a strong innovative capacity, another challenge is to enhance the success possibilities for innovations. User-driven innovation is a way to enhance the success of innovations. FORA research confirms this observation. FORA has conducted studies of user-driven innovation in the electronics, medico, and fashion industry comparing the experiences of Danish firms with the best practices of the world's most advanced firms (FORA 2005b).

Innovation and a strong innovative capacity are important to attain economic growth and prosperity. Innovation depends on the four drivers. The question is whether countries adapting to, and pursuing, knowledge-based growth implement policies that are in conflict with the environment and sustainable development?

9.4 Data and computation methods

The quantification of FORA's framework, including sub-indexes and indicators requires a large amount of data. A total of 210 indicators have been used in compiling the performance and framework conditions.[40] These data include all OECD member countries, except for Iceland, Luxemburg and Slovakia, which are excluded due to lack of data. Most data come from 2002-2003.

Data on the environment are obtained from the 2005 Environmental Sustainability Index (ESTY, Levy, Srebotnjak, and Sherbinin, 2005) and the OECD Environmental Data Compendium (2004).

No agreed method for constructing composite indices exists. Our approach is based on the *Handbook on Composite Indicators* developed by the OECD and the Joint Research Centre in Ispra (Giovanni, Hoffmann, Nardo, Saisana, Saltelli and Tarantola, 2005). The approach ensures a high quality of the composite indicator by following a specific procedure when constructing it.

All indicators are normalised using distance from the best and worst performer. The normalised indicators take the values between 0 (laggard) and 100 (leader). No imputation of missing values is attempted. Equal weights are applied.

The main weakness in this approach is the weighting system used, but no direct solution exists to the selection of weights. Therefore, the results are tested using a new sensitivity technique developed by FORA in co-operation with the OECD, where weights are assigned randomly to each of the normalised indicators (OECD, 2005). In this paper, the calculation was repeated 10,000 times and weights were drawn randomly from a uniform distribution for each of the indicators. This exercise gives a distribution of possible values for each country, which is then used in the analysis. The randomly assigned weights vary between 0 and 1 for each indicator, therefore the technique indirectly tests for the robustness of the possibility of excluding an indicator.

[40] A full discussion of the indicators can be found in FORA (2005a).

9.4.1 Constructing the knowledge-based-growth index

This paper builds on the performance indicators for each of the four drivers of growth (human resources, knowledge building and sharing, ICT and entrepreneurship) in FORA's framework. The normalised performance indicators for each of the

Figure 6: Overview of FORA's index for knowledge-based growth

Index for Knowledge-based Growth	Entrepreneurship	*Firm entry rates*, average rate from the two-year period, 2000-2002 (New firms in% of existing firms), Eurostat
		Entrepreneurial activity (TEA) average from 2000-2002, Global Entrepreneurship Monitor, GEM
		Share of young firms with more than 60% growth rates in turn-over in a three year period, 1999 – 2003 (FORA, 2004d)
		Share of young firms with more than 60% growth rates in employment a three-year period, 1999 – 2003 (FORA, 2004d)
	Human Resources	*Share of employees in high-skilled jobs*. International Labour Organisation (ILO) database (laborsta.ilo.org) and "Measures of Skills from Labour Force Surveys - An Assessment", Table 1a. OECD (2002).
		Private sector researchers per 10 000 labour force. STI Scoreboard OECD (2003).
		Adult literacy skills. "Literacy in the information age", Table 2.1. OECD (1999).
		Delegation of authority within companies. "The Global Competitiveness Report 2002-2003", Table 10.13. WEF (2003).
		Employees are managed by objectives. European Survey on Working Conditions. SIBIS (2000).
		Worker motivation. "World Economic Yearbook", Table 3.2.07. IMD (2003).
	Use of ICT	Number of workers using PCs at work, OECD (2003).
		Number of PCs per office worker. IDC, Eurostat, US Bureau of Labour Statistics and ILO.
		Percentage of businesses with ten or more employees using the Internet. STI Scoreboard, Figure B.4.4.1. OECD (2003).
		Percentage of business with ten or more employees that have Internet access. STI Scoreboard, Figure B.4.4.1. OECD (2003).
		Internet purchase and sales. STI Scoreboard, Figure 4.6.1 OECD (2003).
		Business assessment of the extent to which the Internet is used for marketing purposes. WEF, Table 8.04.
		Business assessment of the extent to which the Internet has contributed to lower inventory costs. WEF, Table 8.01.
		Business assessment of the application of wireless e-business application among customers and suppliers. WEF, Table 8.05.
		Share of companies that use the Internet for financial services.
		Share of companies that use the Internet to monitor markets and competitors.
	Knowledge Building and Knowledge sharing	Number of companies having introduced new or significantly improved products or processes. Community Innovation Survey (CIS-III). Data covers the period from 1998 to 2000.
		Extent to which new products and processes are developed from the WEF survey (2001)
		Extent to which companies develop new designs from the WEF survey (2001)
		Extent to which innovation drives revenue growth from the WEF survey (2001)
		Number of patents in "triadic" patent families in the US, Japan and Europe. STI Scoreboard, Table A.11.2. OECD (2003).
		Import of foreign technology. STI Scoreboard. OECD (2002).
		Business assessment of the application of new technology. Table 3.02. WEF (2003).
		Number of companies with co-operation arrangements on innovative activities with other enterprises or institutions. CIS-III. Data covers the period from 1998 to 2000.

four drivers are aggregated into four sub-indexes – one for each driver. The four sub-indexes are then weighted into one single index – labelled FORA's Index for Knowledge-Based Growth (KBG). Data were obtained from various sources, seen in Figure 6.

9.4.2 Construction of an environment Index

In aiming to operationalise environmental degradation, the pressure-state-response framework (OECD, 1993) and the driving force-pressure-state-impact-response framework (Eurostat, 1999) provide good starting points. The first framework simply states that human activities exert *pressures* on the environment, which can induce changes in the *state* of the environment. Society then *responds* with environmental or economic policies and programmes. The second framework, which builds on the first framework, states that driving *forces* such as industry and transport produce *pressures* on the environment, such as pollution emissions, which degrades the *state* of the environment, leading to *impacts* on human health and ecosystems and causing society to *respond* with various policy initiatives.

However, these frameworks often become controversial when quantified. Measuring the environment is controversial. A few attempts exist such as the Environmental Sustainable Index (ESI) (Esty *et. al*, 2005). The ESI is a composite index tracking a diverse set of socioeconomic, environmental, and institutional indicators that characterize and influence environmental sustainability at the national scale. ESI offers policymakers with a quick overview of countries relative performance and provide a useful mechanism for benchmarking environmental performance based on the "Pressure-State-Response" policy model.

The ESI is our staring point for our analysis. An often quoted alternative is the ecological footprint (Chambers, Simmons and Wackernagel, 2001). The ecological footprint focuses to a large extent on consumption as it is defined as *the aggregate land and water area in various ecosystem categories that is appropriated (or claimed) by that nation to produce all the resources it consumes, and to absorb all the waste it generates on a continuous basis, using prevailing technology.* This focus on consumption makes it less relevant for our analysis of growth so we chose ESI as a starting point for the analysis despite that ESI has been criticised (Wackernagel, 2001 and Esty *et al.* 2005; Appendix H).

Further analysis only focusing on the pressure component is also attempted in order to focus our analysis on the direct link between current economic growth and the environment. The ESI index incorporates pressure, state and response. Both

the state and the response are not directly linked to economic growth. The state reflects history more than the current growth. The respons, a measure of institutions, reflects policy choices and income level more than current growth.

Figure 7: Overview of environmental pressure index

Index for Environmental Pressure	Air Pollution	Coal consumption per populated land area, 2005 Environmental Sustainability index
		Vehicles in use per populated land area, 2005 Environmental Sustainability index
		Emission of SOx pr. Capita, OECD Environmental Data Compendium 2004
		Emission of NOx pr. Capita, OECD Environmental Data Compendium 2004
	Greenhouse Gas	CO2 emissions,
		Emission of CH4 pr. Capita, OECD Environmental Data Compendium 2004
		Emission of N2O pr. Capita, OECD Environmental Data Compendium 2004, OECD: Demographic Indicators and own calculations
		Emission of HFCs pr. Capita, OECD Environmental Data Compendium 2004, OECD: Demographic Indicators and own calculations
		Emission of PFCs pr. Capita, OECD Environmental Data Compendium 2004, OECD: Demographic Indicators and own calculations
		Emission of SF6 pr. Capita, OECD Environmental Data Compendium 2004, OECD: Demographic Indicators and own calculations
	Ecosystem Stress	Annual average forest cover change rate from 1990-200, 2005 Environmental Sustainability index
		Acidification exceedance from anthropogenic sulphur deposition, 2005 Environmental Sustainability index
	Waste and Consumption Pressure	Waste recycling rates, 2005 Environmental Sustainability index
		Generation of hazardous waste, 2005 Environmental Sustainability index
		Industrial waste (kg/1000 USD GDP), OECD Environmental Data Compendium 2004
		Municipal waste (kg/cap.), OECD Environmental Data Compendium 2004
		Nuclear waste (t./Mtoe of TPES), OECD Environmental Data Compendium 2004
	Water Stress	Industrial organic water pollutant (BOD) emissions per available freshwater, 2005 Environmental Sustainability index
		Fertilizer consumption per hectare of arable land, 2005 Environmental Sustainability index
		Pesticide consumption per hectare of arable land, 2005 Environmental Sustainability index
		Percentage of country under severe water stress, 2005 Environmental Sustainability index 2005 Environmental Sustainability index
	Natural Resource Management	Productivity over fishing, 2005 Environmental Sustainability index
		Salinized area due to irrigation as percentage of total arable land,
		Percentage of total forest area that is certified for sustainable management, 2005 Environmental Sustainability index

Environmental pressures are measured with the sub-indexes: air pollution, greenhouse gas, ecosystem stress, waste and consumption pressure, water stress and natural resource management. Each sub-index consists of several indicators (see Figure 7). Most of these indicators come from the ESI framework. However, data on

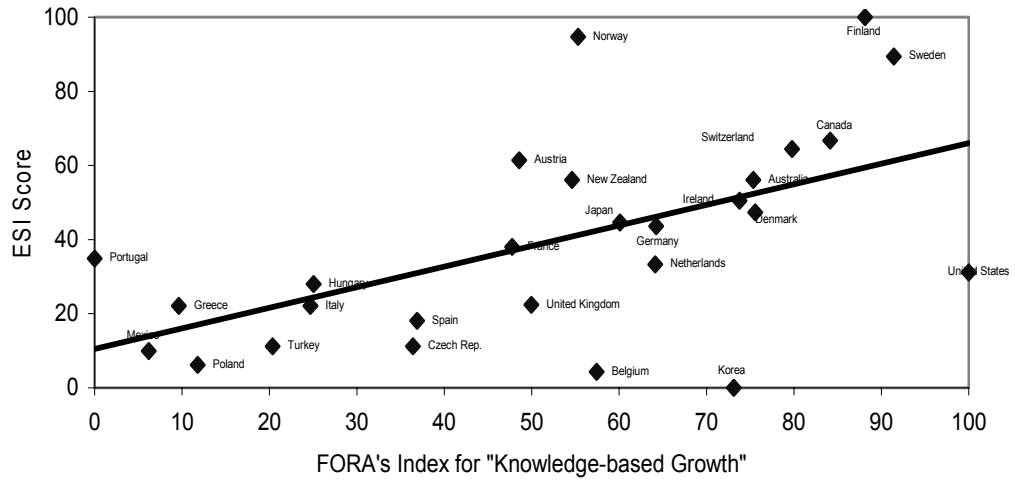
greenhouse gas are included in the environmental pressure index and additional variables from OECD's work on sustainability are included in the sub-indexes. Data in the ESI framework on emission relative to populated land area are substituted with data on a per capita basis instead. In this analysis, there are more variables in some of the sub-indexes when compared to the ESI framework.

More "serious" environmental problems might exist than the ones measured by the selected indicators such as soil erosion and urban pollution. The indicators included in the pressure index are not meant to reflect all environmental problems, but reflect the environmental problems that are clearly perceived to be linked to economic growth.

9.5 Results

The overall ESI score and FORA's index for Knowledge-Based Growth show a high correlation using a simple correlation test although a few outliers exist (Figure 8). A few countries (the United States, Korea and Belgium) have a much lower ESI score than expected, and a few countries (Norway and Portugal) have much higher scores than expected.

Figure 8: Links between ESI and knowledge-based growth



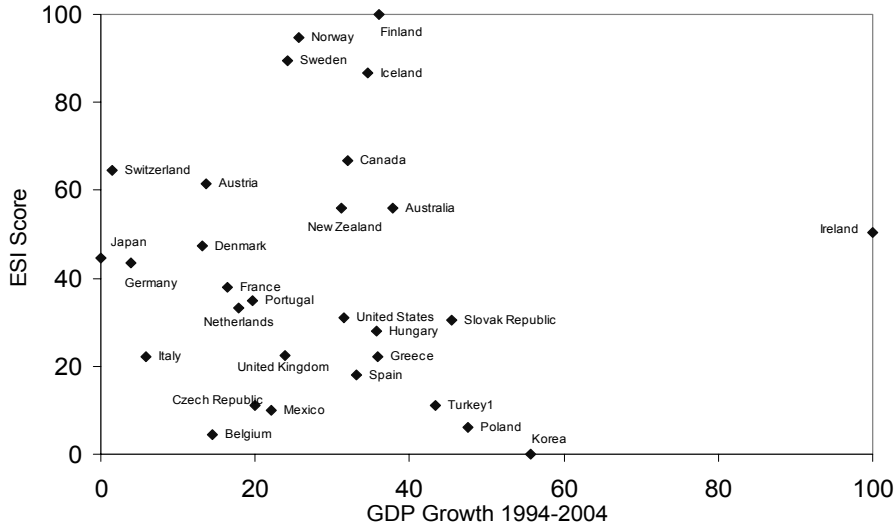
Note: $r^2 = 0.32$ and the correlation is significantly different from zero at the 1% level. The indicators are normalised as explained in the previous section, so the US has the highest KBG and Portugal has the lowest. Finland has fewest pressures on the on environment and Korea has most.

A possible explanation of the high correlation could be a relative large service sector in the countries with high knowledge-based growth. The service sector is perceived to be less polluting than manufacturing. An inclusion of share of value

added in business services and in government and personal services as a percentage of total value added does however show that this is not the case. The share of the service sector is insignificant in a multivariate regression including KBG and the share of service as independent variables and ESI and the dependent variable.

The high correlation between KBG and ESI is surprising because most studies find a negative correlation between growth and indices of environment. A simple correlation plot of GDP growth versus ESI shows for example a negative (not significant) correlation (Figure 9).

Figure 9: Links between ESI and GDP growth



Note: Ireland is an outlier due to a very high growth in this period. Removing Ireland from the data increases R^2 and, therefore, indicates a slightly negative correlation coefficient but does not have any significant impact on the results.

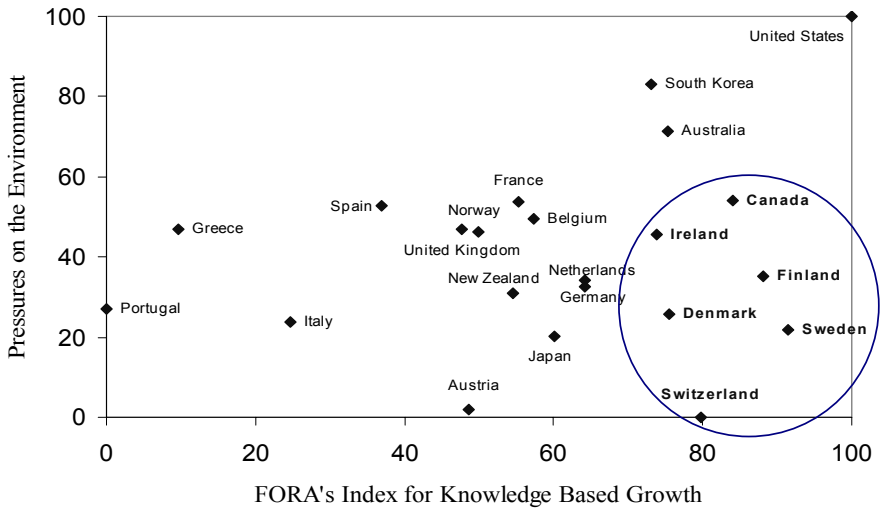
The two figures (8 and 9) taken together suggest that GDP growth might be negatively correlated with sustainability, but that knowledge-based growth (contributing to MFP) might be positively correlated with sustainability. This suggests that countries can become richer and pursue economic growth without harming the environment in the process. It is important to underline that one important assumption of this analysis is that the KBG-indicator measures growth and not income level.

By examining the "pressure" sub-component in the pressure-state-response framework, this analysis can be explored further. The policy challenge lies in reducing pressures created by growth, as the other two components are less directly correlated with growth. The response component in the framework is, for example, an

indication of opportunities for a country to maintain or enhance environmental conditions in the future. The response component is highly correlated with our measure of knowledge-based growth. The social and institutional capacity in the response component, for example, has a correlation of 0.75 with our Knowledge-Based Growth Index. Global stewardship and the state indicators are also highly correlated with KBG. In the following section, the analysis will incorporate our index for environmental pressures (from Figure 7).

The proposed Environment Pressure Index is not directly correlated with KBG, which suggests that the pressure on the economy and growth is not correlated (Figure 10). However, the countries seem to fall into two groups. The first group (Switzerland, Sweden, Finland, Denmark, Ireland and Canada) scores high on knowledge-based growth and low on environmental pressures. These countries have seemingly managed to combine their growth with low pressures on the environment. These countries could be labelled green growers. The second group of countries lies close to a "line" which connects the United States scoring high on knowledge-based growth and environmental pressures to Portugal, which scores low on both. These countries could be labelled trade-offers as higher growth leads to higher pressures.

Figure 10: Knowledge-based growth and environmental pressures



Note: No alternative measures like GDP growth or GDP levels (also squared to test for EKC) are correlated with the indicators of pressures.

The two groups of countries are constructed by spotting countries with similar pressures but very different KBG. Finland, for example, has pressure similar to Germany

but a much higher KBG. Similarly, Canada and France have similar pressures but very different KBG.

All in all, knowledge-based growth might not put pressures on the economy; however, it does not solve the environmental problems by itself. Factor accumulation is still generating growth and externalities still exist for some types of production so environmental policies are consequently still needed. Other studies support that the environment is not merely a function of economic development but will benefit from conscious policy choices (Esty and Porter, 2001, Galeotti and Lanza, 2005, Hettige, Lucas and Wheeler, 1992, and Panayotoa, 1993). The obvious question therefore is whether these needed environmental policies will impede economic growth.

9.6 Growth friendly environmental policy based on regulation, government demand and strategic government investments in R&D

The debate on environment and growth/competitiveness has been viewed from different levels. Besides the mentioned EKC stream focusing at the national level and characterized by being descriptive and only loosely motivated by theory (Haubaugh, Levinson and Wilson, 2002), another stream of literature focusing on the firm-level has discussed whether an inherent and fixed trade-off exists between the environment and the industry's private costs (DeCrane Jr., 1995; Palmer, Wallace and Portney, 1995; Porter and Linde, 1995a, b). This stream is characterized by theory discussion and examples in the form of case studies, and by distinguishing between a static and a dynamic view.

The distinction between static and dynamic is essential to understanding the possible benefits from environmental policies. We see the main static policy conclusion fall into three groups:

First of all, better information gathering and transparency is needed (Esty, 2002, Porter and Linde, 1995ab, and Portney, 2002). Better information is needed for making policy choices and to enforce policy choices. It is important that society employs risk assessment (DeCrane, Jr., 1995) in order to determine priorities based on a realistic assessment of the world's limited economic resources and rank the severity of the risks to human health and eco-systems (Eurostat, 1999) before imposing new regulation. Furthermore, the transparency of information will help consumers make informed choices.

Second, market incentives should be used to a higher extent, based on a cost-benefit assessment (Palmer, Wallace and Portney, 1995, Porter and Linde, 1995ab, Portney, 2002).

Third, co-ordination between regulators at different levels and places, both national and international, are needed (Esty, 2001, Porter and Linde, 1995ab). Co-ordination should take into account that the geographic and temporal spread of environmental issues represents critical policy variables (Esty and Porter, 2001).

These three policy conclusion can be summarised as "getting the prices right". This was also done in the Facilitator's summary of the Expert's recommendations at the Green Road to Growth Meeting (Chapter 3). The impact on competitiveness and growth is, however, unclear in the static setting. The dynamic view is also needed in order to examine possible effects of regulation on innovation.

The main dynamic contribution is often referred to as the Porter hypothesis (Porter and Linde, 1995ab). This hypothesis argues that "correct" environmental regulation can stimulate cost reduction and create first mover advantages. The evidence for the Porter hypothesis counts of several case studies. However, it is not hard to find examples of some firms out of a large amount of firms, which because of strict environmental regulations have come up with innovative solutions improving there competitive position (Palmer, Wallace and Portney, 1995). The Porter theory also builds on the notion of "correct" regulations, which makes it almost impossible to test.

Consequently, the theoretical contribution provides little guidance for policy formulation in a dynamic setting. Practical solutions are needed. FORA has been engaged in some preliminary work for the Danish Ministry of Environment (FORA, 2006 *forthcoming*). The purpose of this work is to identify environmental technologies where Denmark potentially could create new strongholds if strategic and binding collaboration involving companies, knowledge institutions and government authorities is promoted and expanded. The work builds on FORA's knowledge-based growth framework but focus on cluster specific framework conditions. The work provides a guide for policy makers, which is briefly summarised below.

Before a government considers any policies to support clusters in any environmental area the following requirements should be fulfilled:

- There has to be a critical mass of national firms that already have a strong position within the given environmental area.

- There has to be a strong research environment, which already has research excellence within that given area.
- The area has to have a great potential for future growth.
- The development of new environmental technologies presupposes collaboration between companies, knowledge institutions and government authorities.

The basic reason for these requirements is a belief that government can accelerate the growth of existing clusters, but not create new clusters. FORA has done an extensive review of various attempts of creating clusters and does not find the evidence convincing. This conclusion is in line with several other authors, for example, Michael Porter who writes, "*Government should reinforce and build on established and emerging clusters rather than attempt to create entirely new ones*" (Porter, 2000; p. 26)

A country will have one or more areas fulfilling the four requirements mentioned above. Denmark has, for example, water rinsing as one potential area for future government action. After passing the requirements, several analyses have to be performed on the specific area in order to test the relevance and to guide any policy intervention.

Governments have to at least consider:

- What will characterise the co-operation of the triple helix (University-Industry-Government) within that environmental area?
- What characterises the competitive environment (size, knowledge base, organisation of co-operation, resources, role played by government, targeted solutions, and framework conditions)?
- How to support and benefit from competition between different technologies and research environments within an area?
- What role do entrepreneurs and new firms play within the area?

These four questions will provide invaluable input to the strategic policy formulation, but they will need to be supplemented with a detailed analysis of the framework conditions for the given area. The framework conditions and their importance vary from area to area making them hard to define.

In our analysis, the environmental technology companies have been asked to rate the most important framework conditions conducive to the development of environmental solutions, and have also been asked to asses the quality of existing framework conditions falling into 8 categories:

- Government regulation
- The possibilities of testing new technologies
- Collaboration between companies and supervisory authorities
- Collaboration between companies and public research
- The scope and quality of public environment research
- The number and quality of knowledge institutions with a focus on the technology question
- Innovation and creativity among entrepreneurs
- Collaboration with other companies

All the framework conditions are regarded as important while government regulation and the possibilities of testing are considered to be the most important framework conditions. This emphasises a need for binding and strategic collaboration involving companies, knowledge institutions and government authorities.

Overall, this new policy model does require a lot of data and analysis but it will give a much higher payback as this research will assist government in supporting the development of stronger industries that will find solutions to environmental problems and, at the same time, generate jobs and growth in the economy.

9.7 Conclusion and discussion

The knowledge-based economy poses a challenge for countries that have to cope with the increased competition on intangible factors and balancing the possible negative effects of economic growth on the environment. One possible policy response is encouraging innovation and a strong innovative capacity. Innovation depends on the four drivers: *human resources*, *knowledge building and knowledge sharing*, *ICT*, and *entrepreneurship*. It must be kept in mind that the challenges confronting countries are different, therefore different policies are required.

Constructing a strong innovative capacity is an important goal to pursue in order to secure long-term economic growth; However, is this goal in conflict with yet another goal of the Lisbon Strategy: the environment?

Summarizing this paper's findings, knowledge-based growth (through MFP) might be not be correlated with pressures on the environment. The analysis showed that countries fall in two groups when exploring the relation between environmental pressure and knowledge-based growth: the first group scored high on knowledge-based growth and low on environmental pressures. This group could be labelled *green-growers*. The second group of countries falls on a line between those countries that score high on knowledge-based growth and environmental pressure to those countries that score low on both, labelled the *trading-offs*.

The knowledge-based growth may not put pressure on the environment, but it does not remove the pressure from other parts of the economy. Furthermore, some countries like the US have high knowledge-based growth, but are still harming the environment. Environmental policies are consequently still needed. These environmental policies might be aimed at stimulating environmental research in prioritised areas based on a cluster approach and at ensuring that environmental regulations spur innovation. These policies can thereby stimulate firms to produce environmental technologies, competitiveness and ensure a positive relation between improving the environment and generating growth.

These results must be interpreted with care and interest in opportunities for future research. The relation between knowledge-based growth and environmental pressures was explored based on cross-sectional data. Hence, this study only addresses the question as to whether there might be a relation between the two components studies. Because of the cross-sectional nature of this study, it is not possible (assuming that there was a relationship) to address the question regarding causality. While this study only made use of performance indicators related to knowledge-based growth, it might be the case that relations are contingent on certain framework conditions or that other factors excluded from this analysis are significant.

In conclusion, the evidence presented in this analysis states that the new growth patterns might be used to ease the trade-off between economic growth and the environment, but policy choices are still needed to positively reinforce both economic growth and sustainable development.

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10 Opponent note no. 2a: What trade-off between knowledge-based growth and the environment?

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10.1 Opponent note

This 'opponent paper' discusses the paper 'What trade-off between knowledge-based growth and the environment?' by Hoffmann & Gabr (2006). Hoffmann & Gabr raise some important issues about the importance of non-factor accumulation related growth (specifically 'knowledge-based' growth) and its potential direct and indirect environmental effects, and offers some interesting ideas in this area. Since knowledge-based growth is an area which is gaining increasing attention as a potential source of future economic growth, globally as well as in Europe, it is also an extremely relevant area to investigate when trying to answer the question: How can we ensure economic growth, environmental improvement, and employment at the same time?

This opponent paper will discuss some of the conceptual issues raised by Hoffmann & Gabr as well as the empirical evidence of a relationship between knowledge-based growth and the environment presented in their paper. In doing so, this paper will also broaden out the discussion to cover the importance of a general transition from manufacturing to services, and how this is related to the 'knowledge-based' economy.

When discussing trade-offs between economic growth and environmental performance, and how this can translate into policies which minimise the detrimental effects of economic growth on the environment, and on policies which ensure that environmental regulation does not impede economic growth there is often a tendency to focus on *technology*. This is warranted, since technology is one way in which decoupling of environmental harm and economic growth can take place. But there is also a danger that a focus on environmental technology in a traditional 'tangible' sense (manufacturing of industrial products) is too narrow, since it may not always capture environmental effects of other types of production, which may be increasing in importance.

In this context the current transition of OECD economies to being more reliant on services is relevant. This structural change is the case in terms of share of labour force employed in services (now approx. 70 % in OECD countries), share of overall

productivity growth from services, and share of overall GDP derived from services (OECD, 2005). Here, of course, a distinction should be made between low-tech and service sector production, which is also labour intensive (traditional service sector employment), and more high-tech and capital-intensive production.

'Knowledge-based growth' does not necessarily relate specifically to either industry or the services sector. It can take place both within industry (inventions; innovation; new technology) and within the service sector (ideas; the technological base for services). But the increasing importance of not least the high-tech part of the services sector (e.g. tele-communication) in OECD-economies points to the importance of looking at technology not only in terms of improving the economic and/or environmental performance of the industrial sector (decoupling environmental harm from industrial production), but also to the importance of the economic and/or environmental performance of the service sector (making sure growth in production and consumption of services does not lead to increasing environmental harm).

Structural change (e.g. from being predominantly reliant on industry to being more reliant on services) will always mean that some sectors will loose competitiveness. The worry that environmental policies may have detrimental effects on industry competitiveness should be seen in this light. While it is possible that development of environmental technology for industry may increase competitiveness of the involved industry, decreased competitiveness from environmental regulation (to the extent this is based on correction of externalities) should not be a concern from an overall economic perspective, since this will merely be a symptom of a structural process, which may actually be to the benefit of society.

At the conceptual level, there are good reasons to hypothesise that knowledge-based growth in the service sector could lead to improved environmental performance. A possible simple reasoning could be that traditional 'factor-accumulation'-based growth by definition should be less resource-consuming than 'non-factor-accumulation'-based growth, and that 'knowledge-based growth' therefore should lead to less environmental harm.

However, much growth in the service sector is of a high-tech nature, and therefore still requires some industrial production and technology development, so it is not possible to establish a direct link from more intangible production of services to lower overall environmental impacts. For both low-tech and high-tech service sector production fewer physical inputs may be required than in industrial production,

but the sources of these inputs may be more diffuse than inputs to traditional manufacturing of industrial products, and need not have lower environmental impacts (Andrew, 2000). Further, even though production of services often entails close proximity of the supplier and the consumer, globalisation of services may mean more overall transportation (ibid.).

All in all, it is possible to hypothesise links from increased focus on a knowledge-based economy, or from increased reliance on a service economy to environmental performance, but this link should not be automatically assumed. One of the more well-known of these hypothesised links is the Environmental Kuznets Curve (EKC), also referred to briefly in Hoffmann & Gabr (2006). This hypothesises that environmental harm increases until a certain income, above which environmental harm begins to decrease with increasing income. This has very little theoretical backing, and the empirical evidence, both for overall indices of environmental performance and for more specific environmental indicators for cross-country as well as time-series data are scarce, at best (Dinda, 2004).

Taking the hypothesis at face value, the most important question is, whether there is an automatic link from increasing income (or structural changes in the economy following increased income) to environmental performance, or whether any changes in environmental performance are due instead to conscious environmental (or other) policies.

This is exactly one of the limitations of the EKC-approach. The few empirical studies that have established patterns have rarely tested for causality and for the influence of outside factors, e.g. environmental policy (Dinda, 2004).

Unfortunately, this general empirical problem in the literature also constitutes a major limitation of the Hoffmann & Gabr paper. It does a good job at attempting to establish patterns between selected environmental indicators and the indicators chosen for 'knowledge-based growth', but does not, in my opinion, provide convincing evidence of the existence or not of a direct link between knowledge-based growth and the environment.

First, using composite indicators of environmental performance always runs the risk of hiding important information about links between specific policies and specific environmental impacts.

Second, although Hoffmann and Gabr attempt to elicit information from Figures 8, 9 and 10 in their paper, the suggested correlations do not explain the majority of the overall variation. Third, and more important, Hoffmann & Gabr use single-

variable regressions, which do not control for the influence of other variables. Fourth, the causality of any correlation cannot be explained from these regressions.

This has the effect that it is difficult to draw firm policy conclusions presently from this empirical analysis. Thus, the overall question whether an increased focus on knowledge-based growth will lead to more or less environmental pressure is still open. And the question of whether any correlation between the two will be due to a direct causality or whether it would instead be due to the effects of environmental regulation, a general effect of structural changes in the economy, or due to other causes is also still open.

This does not mean that we should not see knowledge-based growth as an area with potentially environmentally beneficial effects. And we should not be discouraged from looking further into possible solutions to growth-environment tradeoffs in this area. It just means that we do not presently have firm empirical evidence to give clear-cut policy advice in this area.

Hoffmann & Gabr (2006) conclude on the basis of their analysis that 'the quality of the environment is still determined by policy choices" (p. 166, 170, 174). I agree, although I do not see this as a natural conclusion from their analysis.

The starting point for environmental policy should be correction of externalities. If correction of these environmental externalities decreases the competitiveness of certain industries and to some extent economic growth as conventionally measured, this is actually desirable from a welfare economic point of view, since it is simply reflecting that this industry previously was given an 'implicit subsidy', which could be seen as a distortion in the economy. Competitiveness problems in industries and how these are related to government regulation should therefore always be seen in connection with the externalities involved, and, as earlier mentioned, the broader structural changes in society. As long as there are environmental externalities in the economy, environmental policy therefore has a role to play. This role may be different in a knowledge-based economy than in an economy based on 'factor-accumulation-growth'. How it is different, and what implications this has for policy advice, is an interesting question, which should the starting point for future analysis of the environmental effects of knowledge-based growth.

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11 Opponent Note no. 2b: The Lisbon strategy, knowledge-based growth and the environment

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11.1 Three Goals

The Lisbon Strategy includes three goals, economic growth, environmental quality and employment. It is important to stress that it is far more difficult to fulfil three goals than one or two. There are lots of examples of contries, which have dropped one of the goals and become highly successful with the two others.

China has for more than ten years succeeded with an extremely high growth and employment, but this success is, however, paid by considerable environmental problems. If one allows considerable pollution and low environmental cost the competitiveness will be strong, and growth and employment is easier feasible.

A number of traditional under-developed societies have for very long periods had high employment and no negative impact on the environment, but in static societies without economic growth.
In a number of European countries we have seen economic development and considerable contributions to a better environment, but with a large part of the labour force being unemployed or on social benefits.

The problem with knowledge-based growth can very easily be that it results in growth and a better environment, but at the same time increases the unemployment problems, which is perhaps the main problem in most European countries. It is a serious problem with Anders Hoffmann and Hesham Morten Gabr's paper in relation to the Lisbon Strategy that they do not discuss the employment effects of knowledge-based growth at all.

11.2 European employment and unemployment

Most of the Western European countries are in different degrees welfare states with high levels of social security and relatively high minimal wages. This means that unskilled workers in this part of Europe have higher wages than in almost all other parts of the world. This means that jobs for unskilled workers are moved to other

parts of the world. Outsourcing to for example Asia is more and more common. Production of traditional industrial products is for many products moved from Europe to Asia.

At the same time the technological development is skill-based. The technological development before World War II was in advance of the unskilled; cars and many other products were earlier produced by skilled metalworkers or other workmen, but the production line where the single worker only has to make one simple part of the production process, made it possible to substitute the skilled workers with unskilled. Today the technological development has the opposite bias – the unskilled workers at the production lines are substituted by computer managed robots. The persistent European unemployment is mostly a problem for the unskilled; this is illustrated with Danish data in table 1. While only 7 per cent of people with long academic educations are permanently unemployed, it is 32 per cent of the unskilled.

Table 1: Employment and education in Denmark 1995-97

Labour market relation				
Education	Less than 5 % unemployment	5-80 % unemployment	More than 80 % unemployment or social benefits	Total
Unskilled workers	35.8	32.3	32.0	100
Skilled workers	55.6	29.0	15.4	100
HNC level	59.7	30.0	10.3	100
Bachelor's level	59.2	31.3	9.5	100
Master's level	61.0	31.8	7.1	100

Source: Danish Economic Council (2000) p. 144

Note: People in education and not receiving either wages or social benefits are not included.

This would not have been a problem if the group of unskilled workers was small and fast declining. But the situation is that a considerable part of the European labour forces still, and as long as it can be forecasted, will be without qualifying education. This is true for the domestic population and to an even higher degree for a number of the immigrants. This is illustrated by figures from the Danish society, see table 2. About 30 per cent of the Danes and up to about the double of the immigrants are unskilled.

Table 2: The Education of people leaving the Danish Primary School 1984-1998 in per cent

	Danes	Descendants	Immigrants	
			Immigrated before age 5	Immigrated after age 5
Stop education after compulsory grade school	11.8	15.4	19.2	31.4
Starts but not finishing an upper secondary school	18.1	30.1	29.5	30.5
Total without qualifying education	29.9	45.5	48.7	61.9
With qualifying education	70.1	54.5	51.3	38.1
Total	100	100	100	100

Source: Think tank on Integration in Denmark (2004a) p. 21

A main problem for the Western European societies is this very big group of unskilled workers. Of course it is very important to give all a sufficient education but even if we - completely unrealistic - succeed with that from now on and all youngsters got a qualifying education the unskilled group from the past will be on the labour market in the next 40 years.

This problem is increased by the fact that the group of immigrants is growing and already a considerable group in most European countries; e.g. 20.9 % in Sweden, 18.4 % in the Netherlands, 7.7 % in Denmark and 6.8 % in Norway (see Think Tank, 2004, p. 32).

11.3 Knowledge-based growth and unemployment

Knowledge-based growth will not contribute to the solution of this problem. On the contrary a change from traditional production easily could escalate the problem. The knowledge-based production needs highly qualified employees and there is little room for unskilled workers. This is indirectly indicated in Hoffmann and Gabr's paper. Among the indicators in FORA's Index for Knowledge-based growth are figures for "share of employees in high-skilled jobs", "private sector researchers per 10,000 labour force", "adult literacy skill", "number of workers using PCs at work" and "percentage of business with ten or more employees that have Internet access", see Hoffmann & Gabr figure 6 page 164.

But if we get a growth stimulated by knowledge-based sectors, can this growth possibly be spread to the traditional sectors and results in higher employment of unskilled workers in these sectors? This might have been the case earlier where the division of labour mainly was a domestic phenomenon, but today the international division of labour is so strong that the derived demand for unskilled workers can be affected in totally other parts of the world.

The unemployment in Western Europe is not mainly a Keynesian type of unemployment caused by low demand, but a classical type of unemployment caused by higher wages than the value of the marginal product of labour. It is then unprofitable for the firms to hire these people. And a higher demand is not in itself sufficient to raise the employment.

This is the reason for the millions of unemployed in Western Europe. Knowledge-based growth will, however, at least create jobs for the highly skilled labour force, someone will argue. But that is not a relevant argument, for it is impossible in an open market economy with flexible exchange rates to have unemployment for all types of labour; at least not in the long run. If European wages for all types of labour are non-competitive compared to the rest of the world, we will not get general unemployment for all types of labour, we will get a change in the exchange rate until our economy on average is competitive. Unemployment in an open market economy with flexible exchange rates will always only be for some groups in the society; and all theoretical and empirical arguments indicate that the main unemployment problem will now and in a foreseeable future be among the unskilled; the only exception will be small specific groups of high educated people with very inflexible wages.

11.4 Empirical investigation of knowledge-based growth

Growth accounting starts always by calculating the so-called Solow residuals; this is to calculate the part of the growth which can not be explained by growth in the amount of labour and capital. The Solow residuals are always considerable, so the factors selected to explain these residuals will normally get a very important effect. But the Solow residuals is as mentioned on p. 152 in Hoffman and Gabr's paper, mainly "a measure of our ignorance" and since the Solow residuals was first calculated around 1960 they have been used to document the great effects of technological progress, of education, of research, of social capital etc.

The analysis by using FORA's "overall performance index" in figure 3 seems either more or less convincing than all the other theories. Only 34 per cent of the variation in the Multi-Factor Productivity is explained and it is remarkable that the exceptional most successful nation measured by the performance index, The United States, only have an average MFP-growth.

A priori it seems reasonable that indicators for knowledge-based growth can explain a part of the economic growth, but how big a part and exactly which of the knowledge-indicators are the most important we got no indication of from the empirical investigations.

11.5 Knowledge-based growth and environmental pressures

The key-figure in the investigation of knowledge-based growth and the environment is figure 10 on p. 169. We are told that the "countries seem to fall into three groups": "Green growers", "Green laggards" and "Trade-offs". But if one looks at the figure without any marking of groups, nobody can see three groups.

There is no correlation between the two variables; six countries are labelled as "green growers", two are labelled "green laggards" and then there is a positive correlation between knowledge-based growth and environmental pressure for the remaining 14 observations. This division into groups seems completely arbitrary and only based on the observations' place in the diagram. The six "green growers" include so different countries as Canada, Ireland, Switzerland and three Scandinavian countries. The reader cannot in the text find any arguments for the division in three groups and this is necessary if one is to accept other conclusions than the simple one that there is no correlation between knowledge-based growth and pressures on the environment.

The conclusion that "the quality of the environment is still determined by policy choices, although the trade-off between growth and the environment might have been reduced by the shift towards knowledge-based growth" (p. 169) seems, however, not controversial, but almost trivial. If there is no correlation in figure 10, we need other explanations for the variation in environmental pressures, and an obvious candidate is of course the environmental policy. But the empirical investigations give no indication of whether this is true or not.

11.6 Conclusion

It seems reasonable to assume the knowledge-based growth will result in less pollution and less jobs for unskilled workers than traditional heavy industry. Knowledge-based growth will then contribute to one of the aims in the Lisbon Strategy ("environmental quality"), but it will make it more difficult to reach another of the aims ("employment"). To evaluate whether knowledge-based growth is a part of the solution or a part of the problem one needs to get the effects quantified and to specified the instruments to stimulate the knowledge-based growth. None of this is, however, done in Hoffmann and Gabr's paper.

11.7 References

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Part V

Case study #3

12 Case study paper no. 3: Environmental Innovations and Economic Success of Firms

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12.1 Abstract

The European Union is already in a leading position regarding environmental technologies. Expectations regarding potential impacts of environmental innovations on competitiveness and employment have, however, often been exaggerated in both directions in the public debate. Empirical studies have found evidence for a significant short-term negative impact of negative environmental events (measured e.g. as toxic releases or hazardous accidents) on stock prices and on the overall economic performance. Only a few studies consider the short-term effects of positive news such as information about companies winning environmental awards. These studies did not find significant impacts of positive environmental events on stock prices. It can be concluded that, from an economic point of view, sustainability performance has still the character of risk management in the short term. While several cross sectored studies have also found a significant positive relationship between environmental and economic performance in the mid term, these results should be treated cautiously since the causality of the effect is not fully clear (does sustainability improve economic performance, or can only successful firms afford investments in social and environmental performance?). It can be summarized that targets for a co-ordinated European environmental and innovation policy should be set at a realistic level. An important economic benefit will be the reduction of environmental (and thus also economic) risks. With regard to competitiveness, a positive but moderate impact can be expected.

The same conclusions can be drawn concerning employment impacts. Unemployment is one of the most pressing political problems in Europe. Thus environmental regulation in general and programmes for environmental innovations in particular have often to be justified by not counteracting goals of labour market policies. In this context, empirical studies found only small quantitative effects of environ-

mental innovations on employment but quite substantial effects on workplace quality and qualification.

In the past years several policy initiatives have been started in the European Union in the context of a European strategy for sustainable development. These initiatives included the implementation of economic incentives for environmental protection, initiatives at the firm level and setting of standards for environmental technologies. These ongoing policy initiatives are a good basis and starting point for further policy initiatives which are linked to the Lisbon agenda and the long-term goals regarding innovation and competitiveness.

12.2 Background: Research questions

The relationship between innovation and sustainable development has received increasing attention over recent years from both policymakers and researchers (Rennings et al., 2004; Brunnermeier and Cohen, 2003; Jaffe et al, 2002). Since the world community committed itself in 1992 in Rio de Janeiro to the principles of sustainable development, it has become increasingly clear that sustainability means long-term and far-reaching changes of technologies. The demand for drastic reductions in environmental burdens, e.g., of greenhouse gases, implies that adaptation within existing technologies is not sufficient. Instead, regulation strategies for "technology forcing" and/or "technological regime shifts" are needed. This type of innovation has been recently introduced into innovation research and has been defined as environmental innovation or eco-innovation (Rennings, 2000), including both technological and organisational changes.

Initiatives for sustainable innovations at the European level have emerged from two different policy approaches: The Lisbon Process (emphasising the goal of competitiveness) including the corresponding Structural Indicators (European Commission, 2002) vs. the Gothenburg Process (emphasising a balance between economic, environmental and social goals) including the corresponding Sustainable Development Indicators (European Commission and Eurostat, 2004).

The call for environmental innovation may be seen as an attempt to exploit synergies between both political challenges by improving environmental quality and at the same time increasing the resource efficiency of products and processes. Important questions to be answered are:

- Can increased funds for R&D and (eco)innovation improve growth, employment and environmental quality?

- Is strict environmental regulation a catalyst for improved economic performace?
- Can government support for for specific sectors (e.g. windmills) increase economic growth and stimulate job creation?
- Can pollution be decoupled from economic growth in OECD countries?
- Is environmental performance primarily achieved by environmental policies (environmental policies versus other policies, e.g. ICT policies)?

Against this background, the paper is structured as follows:

- Monitoring of environmental innovations: The first section shows how the EU performs with regard to environmental innovations, in particular compared to firms in competing countries such as the US and Japan? How are such innovations measured and monitored?
- Determinants of environmental innovations: What are the determinants of environmental innovations in firms? Which role does regulation play compared with factors such as market demand, research and development activities, and other sector- or firm-specific factors?
- Economic impacts of environmental innovations: What are the economic impacts of environmental innovations, i.e. on competitiveness and employment?

Policy implications: How can these insights be used for a good policy design and for a better co-ordination of innovation and environmental policy?

12.3 Monitoring: What do we know about environmental innovation behaviour in firms?

Environmental innovations have emerged in all areas of the economy over the past decades due to ecological pressures and corresponding responses from regulation and markets. Inventing or adapting environmentally desirable processes or products is already part of every day life for a large majority of firms and thus a field of scientific research. It is hard to find even a small or medium sized enterprise that has no experience at all with substituting hazardous substances, designing and using eco-efficient products, saving energy, waste and material, or reducing emissions. Managing environmental innovation is an increasingly important issue for many firms.

Rate and direction of environmentally benign technological and organisational progress however differs depending on the type of innovation. While pollution problems have been countered quite successfully through the use of cleaner processes at the production site, product-integrated environmental innovations still suffer from poor market incentives (Rehfeld et al., 2004). Many changes consisted of "the picking of low-hanging fruits". The invention, market introduction and diffusion of environmental product innovations still suffer from market failure and system failure. The crucial problem still seems to be the lack of a scaling up of environmental innovations from niche markets to mass markets (take-off phase).

Firstly, this section will define key terms with regard to sustainable development and innovation. Secondly, it will investigate current trends in environmental regulation, environmental management and innovation decisions at the firm level. We will use several national and international databases such as EU and OECD surveys, with a focus on data that contribute to assess the competitiveness of the EU 15 and EU 25 compared with other regions such as North America and Japan. For example, we will analyse data from an ongoing OECD survey on environmental regulation, firm-level management and innovation decisions (Frondel et al, 2004).

12.3.1 Key definitions

12.3.1.1 Innovation

In accordance with the OECD Guidelines for Collecting and Interpreting Technological Innovation Data (OECD, 1997), we distinguish between technical and organisational innovations. Technical innovations are divided into product and process innovations:

- Process innovations occur when a given amount of output (goods, services) can be produced with less input.
- Product innovations require improvements to existing goods (or services) or the development of new goods. Product innovations in machinery in one firm are often process innovations in another firm.
- Organisational innovations include new forms of management, e.g. total quality management.

12.3.1.2 Environmental innovation

The following definition of environmental innovation is used in this report (Kemp and Arundel, 1998, Rennings and Zwick, 2002): Environmental innovations consist

of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harms. Environmental innovations may be developed with or without the explicit aim of reducing environmental harm. They also may be motivated by the usual business goals such as profitability or enhancing product quality. Many environmental innovations combine an environmental benefit with a benefit for the company or user.

This distinction is in line with the technical guidelines of the Society of German Engineers (VDI) which set forth industrial environmental protection measures and their respective costs (VDI, 2001). Process-related measures are commonly subdivided into end-of-pipe technologies and integrated technologies (hereinafter: cleaner production technologies). According to the VDI (2001) end-of-pipe technologies do not make up an essential part of the production process, but are add-on measures so as to comply with environmental requirements. Incineration plants (waste disposal), waste water treatment plants (water protection), sound absorbers (noise abatement), and exhaust-gas cleaning equipment (air quality control) are typical examples of end-of-pipe technologies. In contrast, cleaner production technologies are seen as directly reducing environmentally harmful impacts during the production process. The recirculation of materials, the use of environmentally friendly materials (e.g. replacing organic solvents by water), and the modification of the combustion chamber design (process-integrated systems) are examples of cleaner production technologies.

Typically, end-of-pipe technologies, such as filters utilised for desulphurisation, aim at diminishing harmful substances that occur as by-products of production. In contrast, cleaner production measures generally lead to both reductions of by-products and energy and resource inputs. Finally, organisational measures include the re-organisation of processes and responsibilities within the firm with the objective to reduce environmental impacts. Environmental management systems (EMS) are typical examples of organisational measures. Organisational innovations contribute to the firms' technological opportunities and can be supporting factors for technological innovations.

12.3.1.3 Sustainable innovation

Sustainability is not clearly defined in a way, which makes it difficult to define sustainable innovation. Drawing on the 3-pillar concept of sustainable development, sustainable innovations could be defined as new or modified processes, techniques, practices, systems and products with a net positive impact concerning their

environmental, economic and social effects. In the short-term there often is a conflict between the three goals. It is often assumed that sustainability requires wider system changes, captured in the term system innovation.

12.3.2 Trends in environmental innovation at the firm level

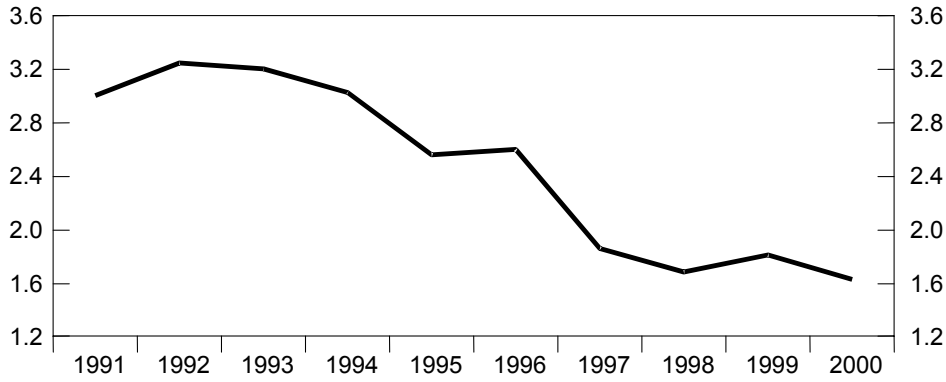
Statistical offices have only counted investments in end-of-pipe technologies. This is due to methodological problems of separating cleaner production measures from investments in non-environmental technologies (Sprenger, 2004). Therefore, data on the use of cleaner production technologies have hardly ever, if at all, been included in official environmental statistics thus far. Although international statistical offices, such as the OECD and Eurostat (1999), agreed to add cleaner production to environmental protection activities, official international statistics on the use of cleaner production technologies are still unavailable. For example, the ECOTEC (2002) report on the EU Eco-industries, their employment and export potential still focuses on end-of-pipe technologies.

Statistical data indicate that investments in end-of-pipe technologies decreased during the 1990s (for Germany, see

Figure 1). The share of investments in environmental technologies decreased from around 4% to 3% of the total investments of the German industry. This observation raises the question as to whether this fact might be explained by the shift of investments to cleaner production technologies.

Figure 1: Investments in end-of-pipe technologies in German industry in the 1990s

In Billion Euros



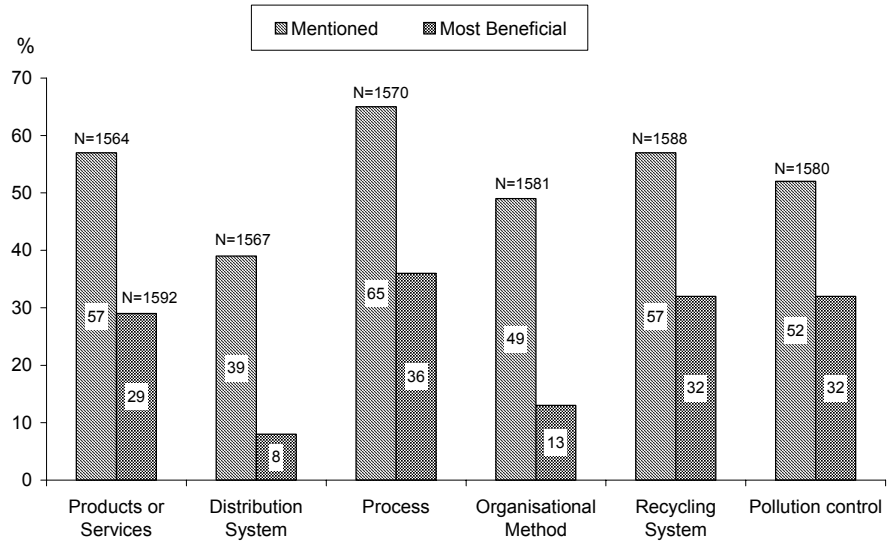
Source: Becker and Grundmann (2002).

A few international empirical surveys have however tried to identify environmental innovations at the firm level. In 2000 a telephone survey with 1,594 environmen-

tally innovative industrial and service firms was carried out in five European countries (Germany, Italy, Switzerland, United Kingdom, and Netherlands) (Bartolomeo et al., 2003). The firms contacted were first asked if they had introduced at least one eco-innovation during the last three years. If this was not the case, the interview was terminated. Therefore, the data base only contains firms that identified themselves as eco-innovators.

Figure 2 shows all environmentally beneficial innovations which have been introduced by the firms in the last three years (column 'Mentioned'; multiple answers were possible). It also shows the innovation which has been cited as the most environmentally beneficial one ("Most beneficial", here also multiple categories were given by some firms). Besides the innovation types process and product integrated environmental innovations, recycling and pollution control (end-of-pipe technologies) also have been frequently introduced. Changes in the distribution system (logistics) and in organisation methods are not widespread.

Figure 2: Environmental innovations



Source: Bartolomeo et al. (2003).

A recent OECD survey on the relationship between environmental performance and regulation was performed in 2003 and covers seven OECD countries: Canada, France, Germany, Hungary, Japan, Norway, and the USA. The whole data set includes 4,186 observations originating from manufacturing facilities with more than 50 employees.

Table 1 indicates that 3,100 of the sample facilities, that is around 74%, took significant technical measures to reduce the environmental impacts associated with their activities.

Table 1: Distribution of abatement technology types in the OECD survey 2003

Cleaner Production Measures	2380	76.8%
End-of-Pipe Technologies	720	23.2%
Total	3100	100%

Source: Frondel et al. (2004).

Out of these facilities with altered production processes, 76.8% changed their production technologies and only a minority of about 23% implemented end-of-pipe technologies. This is a surprising result, since it is a widespread assumption that end-of-pipe technologies still dominate investment decisions in firms.

Regarding the introduction of product or process innovations, the respondents of the sample firms indicated which of these innovation types they use predominantly. Not surprisingly, most facilities report that they took more significant measures in the area of production processes than in product design (see Table 2).

Table 2: Distribution of product and process innovations in the sample facilities

Product Innovations	486	15.6%
Process Innovations	2632	84.4%
Total	3118	100%

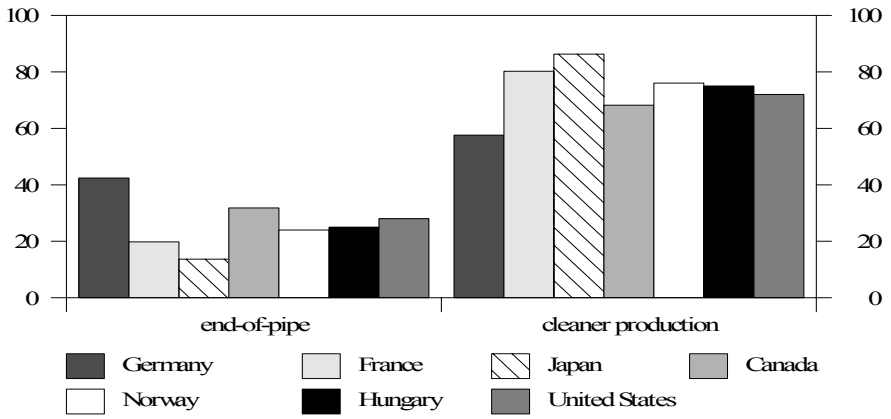
Source: Frondel et al. (2004).

There are, however, significant differences among the interviewed OECD countries. Most notably, Germany displays the lowest percentage of cleaner production technologies among the seven OECD countries (see Figure 3).

The share of cleaner production technologies ranges from 57.5% in Germany to 86.5% in Japan. The reason for this result is that command and control policies heavily supported end-of-pipe technologies in Germany in the past (Hauff and Solbach, 1999).

Figure 3: Choice of environmental technologies in seven OECD countries

In %

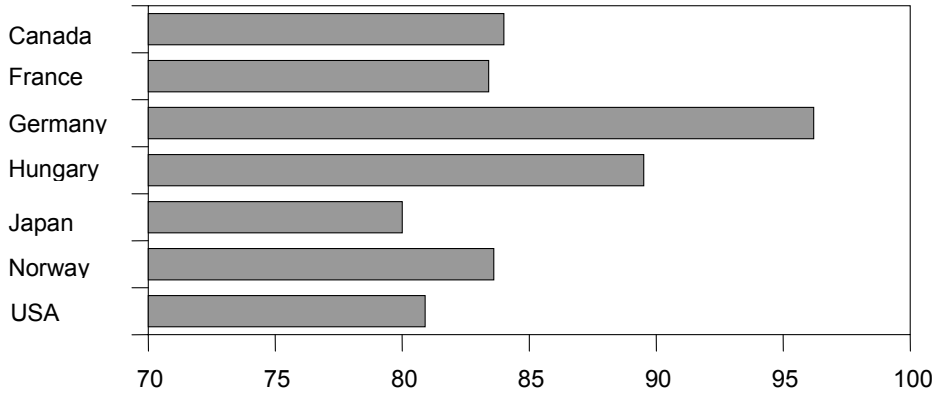


Source: Frondel et al. (2004).

While a large majority of our sample facilities reports that the established measures to reduce environmental impacts tend to aim at production processes and not at products, Germany and Hungary exhibit the lowest proportion of facilities stating that they implemented product measures (see Figure 4). The results are in line with findings of a recent survey in Germany (Rehfeld et al., 2004).

Figure 4: Incidence of measures undertaken (production rather than product)

In %



Source: Frondel et al. (2004).

12.4 What are the determinants of environmental innovations - Theoretical approaches and empirical evidence

The general innovation literature discussed in depth whether technological innovation is triggered by supply-push or demand-pull factors, or by both. Often, these factors are also called technology-push and market-pull factors, respectively, with market-pull factors emphasizing the role of demand by consumers, firms and the government as determinants of environmental innovation (Hemmelskamp, 1997). Empirical evidence indicates that both market-pull and technology-push factors are relevant for spurring technological progress and innovation (Pavitt, 1984).

One peculiarity of environmental innovations is that they produce positive spillovers in both the innovation and diffusion phases (Rennings, 2000). It is not unusual for innovations to produce positive spillovers as a result of their invention and launch on the market. While it can be argued that innovation incentives may lead companies to underinvest in R&D and innovation, this tends to be compensated for by the effects of first-mover advantages and patents. Environmental innovations are unusual, however, in that – owing to the lower external costs incurred in comparison with competing goods and services on the market - they create positive spillovers during the diffusion phase as well as during the invention and market introduction phases.

In other words, the innovator creates or adopts a new process, product or organisational measure which improves the quality of the environment. While society as a whole benefits from the innovation, the costs are borne by the innovator alone. Even if the innovation can be successfully marketed, it is difficult for the innovator to appropriate the profits arising from the innovation if the corresponding knowledge is easily accessible to imitators and if the environmental benefits have a public good character.

This unusual feature of environmental innovations is referred to below as the double externality problem. The double externality problem reduces incentives for firms to invest in environmental innovations. Thus the need for policy measures to stimulate these kinds of innovations (regulatory push and pull) can be explained by market failure from an economic perspective.

An increasing number of empirical studies have investigated the determinants of environmental innovations up to now, with the following results:

12.4.1 Regulatory push/pull

The introduction of environmental innovations depends on regulation due to the double externality problem as described above. In the survey of Bartolomeo et al. (2003) the three most cited reasons for introducing an environmental innovation were to improve the firm's image, to comply with environmental regulation and to reduce costs (see Figure 5).

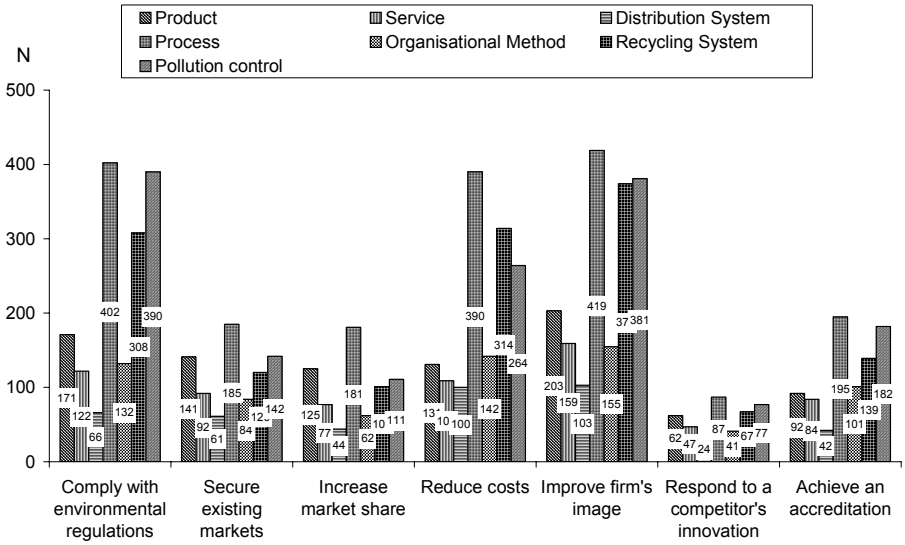
This is particularly noticeable for process integrated innovations, recycling innovations and when end-of-pipe (pollution control) technologies were introduced. Increasing market share plays only a minor role for introducing eco-innovations but is particularly important for integrated technologies (product, service and process integrated).

Popp (2005) analysed patent data from the United States, Japan, and Germany. He examined the effect of environmental regulation on both innovation and diffusion of air pollution equipment. Whereas the United States was an early adopter of stringent sulphur dioxide ($S0_2$) standards, both Japan and Germany introduced stringent nitrogen (NO_x) standards much earlier than the US. He found that in both cases the innovation decisions of firms were mainly driven by the national regulation, not by regulation abroad.

Del Rio Gonzalez (2005) analysed the drivers of adopting cleaner technology in the Spanish pulp and paper industry. He found out that most of the environmental technologies introduced were of the EOP type (i.e. waste water treatment plants) or incremental clean technologies (small changes to close water circuits, mostly the type of so-called "picking up low hanging fruits). Regulation pressure and corporate image were the main drivers for adopting green technologies. Costs are often seen as an obstacle rather than a driver for adoption of cleaner technologies, especially from firms that do not develop innovations themselves but have to buy them from suppliers. This barrier can be specified especially by agreements to statements as:

- Technology does not lead to an increase in sales in sales or exports,
- High initial investments,
- Long pay-back periods, and
- Higher costs not to be recovered with an increase in sales.

Figure 5: Determinants of environmental innovations



Source: Bartolomeo et al. (2003).

An illustrative case for strong regulatory push and pull factors is the construction industry. In a literature survey Bossink (2004) states that "one of the main innovation-stimulating policy instruments was considered to be the definition of innovative wishes, demands and specifications by governmental bodies who were in the position of client in construction projects". Typically such public demands are linked with support programmes and subsidies, i.e. a governmental guarantee for markets for innovative firms.

The regulatory push/pull effect has also been confirmed by several case studies and surveys, the latter including Cleff and Rennings (1999) and Brunnermeier and Cohen (2003). Frondel et al. (2004) find that generally policy stringency is more important than the choice of single policy instruments.

12.4.2 Technological capabilities

It is argued in the literature that solutions often precede problems, i.e. that advanced technologies shape the demands of costumers. Such supply factors are discussed as technological capabilities. Factors influencing the technological capabilities for environmental innovations can be seen in specific efforts in respect of environmental R&D (e.g. at the national level when a country develops regional innovation clusters and centres of excellence, or at the firm level if a company develops cleaner products), or in the implementation of environmental management systems as a supporting factor.

Several studies found empirical evidence that both environmental R&D and management systems have significant impacts. A positive impact of environmental management systems on environmental innovation is confirmed by Rennings et al. (2003a) and Rehfeld et al. (2004). Frondel et al. (2004) also find evidence that the existence of specific budgets for environmental R&D supports environmental innovations. Arimura et al. (2005) find a strong positive effect of environmental accounting systems on the existence of specific budgets for green R&D, and a weak effect of stringent environmental policy on environmental R&D.

Concerning the decision of where to locate R&D units, supply factors such as the access to local scientific and technological resources have gained increasing importance over the past years (Sachwald, 2005; Kleijn, 2005). It is widely agreed that proximity to the best knowledge infrastructure is one of the main drivers of R&D investments abroad (Edler et al., 2003). In many cases, R&D activities of European, Japanese and US firms are located in the same areas (Narula, 2005).

12.4.3 Market demand

Market demand is a crucial factor for driving innovations and investments in R&D, and R&D activities are typically located near to customers and markets (Edler et al, 2003). According to Kuhlmann (2001) “the connection especially to lead markets is seen as a decisive factor for the research and innovation of multinational concerns.”

The price and cost structure of a national market can be encouraging for certain types of innovation. For example, automation technologies develop faster in countries with relatively high labour costs, and energy saving innovations in countries with higher energy prices.

Concerning environmental innovations, these price and cost structures largely depend on regulation (Beise and Rennings, 2005; Edler et al., 2003). The question for environmental policy is whether environmental regulations are capable of creating lead markets enabling domestic firms to export environmental innovations. Lead markets for environmental technologies are located in industrialised countries with high standards of environmental protection (Jacob et al., 2005).

While market demand is a crucial factor for the success of innovations, the conventional view is that environmental products often have strong commercialisation problems. In a broad survey among German environmental product innovators Rehfeld et al. (2004) asked companies whether they agree or disagree with the

following three statements from their own customers: Environmental products are "more expensive", "of lower quality" or "less reliable" than corresponding conventional products. 53.0% of the companies reported that their own customers state that environmental products are more expensive than conventional substitutes. Therefore, price might be one explanation for weak market performance. In contrast, there is almost no confirmation (10.0%) of the statement that environmental products are of lower quality than conventional substitutes. This indicates that environmental product innovators often regard improved environmental performance of products as one component part of comprehensive quality management and strategy. Finally, only 24.7% of the environmental product innovators agreed with the statement that environmental products are less reliable than corresponding conventional products. Thus, economic rather than 'soft' factors appear to be the major obstacles to the commercial exploitation of environmental products and therefore also to environmental product innovations.

12.4.4 Possibility of appropriation, co-operations

The possibility of appropriation is an important factor for innovation and R&D activities in general. Peculiarities of environmental innovations and green R&D with regard to the problem of appropriation have not been observed up to now. Due to the problem of appropriation, firms often regard R&D co-operation as being difficult, especially in the phases nearing market introduction of new products. Co-operation seems to be especially important in the early R&D phase, since other risks (e.g. unsolved technical problems) are dominating in this phase (Hauser, 2005).

Given the specific character of environmental innovations, it is likely that they can be stimulated by co-operative behaviour. The reason is that environmental innovations depend in many cases on co-ordinated work in R&D, production, selling and disposal. Karl et al. (2005) found on the basis of 13 explorative case studies on environmental-oriented innovative co-operations in Germany that:

Intermediaries generally have a favourable effect on co-operations for the development of environmental innovations. The intermediaries vary from research organisations and independent organisations of public law to private companies with or without profit interest.

Durable and independent cooperative co-operations and networks, capable to survive without public support, require to consider the phase after the termination of projects already in the phase of conception.

State institutions have a great influence on building trust between actors that is a prerequisite for successful co-operations. Self-binding agreements between actors and pilot projects initiated by the public authority seem to be suitable to promote environmental oriented co-operations.

12.4.5 Firms size

The role that the size of a firm plays in environmental innovation behaviour may vary from case to case. General economies of scale for innovation activities do not exist (Cleff and Rennings, 1999). While complex innovations (especially process innovations) are easier to develop by large firms, SMEs have advantages concerning less complex innovations (often product innovations) due to greater flexibility.

According to the survey of Del Rio Gonzalez (2005) shortage of financial, human and technical resources is a typical problem of SMEs. Large firms attach little value (as a barrier to adoption of clean technology) to the high initial investments and substantial changes that clean technology involves, compared to smaller firms. Lack of human and financial resources is perceived as an obstacle particularly by SMEs. This is seen as the main reason why the predominant driver for clean technology adoption in SMEs is regulation, while in larger firms the reason for adoption are more diversified (with more weight given to cost savings and market variables).

12.4.6 Market structure

It can be expected that environmentally beneficial products and processes are more frequently developed in competitive, deregulated markets than in monopolistic markets due to a higher pressure to innovate (Beise and Rennings, 2005). However, the counter-argument is that innovations rents are lower in competitive markets and thus monopolistic or oligopolistic structures may favour innovations. Empirically there is no specific contribution to this discussion from the environmental innovation literature, with the exception of a theoretical discussion whether market structure influences the optimal ranking of environmental policy instruments for stimulating investments in environmental abatement technologies (see Carraro, 2000, Montero, 2002 and Fischer et al. 2003).

12.4.7 An illustrative example: Drivers of green innovation in the Dutch construction industry

The case of ecological residential building projects in the Netherlands is used here as an example of green R&D drivers in a sector with a low degree of internationali-

Table 3: Drivers of environmental innovations and managerial reactions in Dutch projects of ecological construction

Innovation drivers	Managerial reactions
Regulatory push/pull effects	
No pull effects from the private market Governmental guarantee for innovative firms Governmental clients with innovative demands Innovation stimulating regulations Subsidies for innovative applications and materials	Professional clients followed market demands The government funded the operations of innovative firms Municipal project managers stimulated innovative architects Organisations followed the rules Clients, architects used subsidised applications
Technological capability	
Product evaluating institutions Programmes promoting access to technology Finance for pilot projects Technology fusion Technology leadership strategy Technology push	Architects used approved applications and materials Consultants introduced innovation checklists The government subsidized demonstration projects Architectural firms co-created innovative design concepts Organisations searched for niches in the market Consultants used checklists to drive the innovations process
Possibility of appropriation, co-operation	
Stimulation of research Creation of knowledge stocks Programmes of promoting collaboration Effective information gathering Training of workers on the site Integration of design and build Involvement of the client Mechanisms for sharing financial risks and benefits Innovations from suppliers Strategic alliances and long term relationships	Consultants developed new applications Knowledge centres functioned as information brokers Architects and contractors joined collaboration programmes Contractors initiated and facilitated training Clients decided which innovative designs to build Clients hired architects and contractors Teams worked in conformance with the demands of the client Alliances developed and delivered sustainable innovation results

Source: based on Bossink, adapted (2004).

sation. Thus it does not offer insights regarding the problems of globalisation, but it offers interesting insights into collaboration between actors, especially between researchers, firms and public authorities.

The case of ecological residential building projects has been analysed by Bossink (2004). Bossink conducted expert interviews in his study and documented ten construction projects. All projects had in common that innovation in the field of sustainability was an important project goal. Table 3 shows the innovation drivers and managerial actions (i.e. the reaction of firms) in the case of ecological construction.

In the case of ecological construction market pull effects are absent as a driving factor of innovation. Clients are mainly interested in quality aspects such as space, location, light and cost-benefit-ratios. Given the lack of market pull effects, most innovations are stimulated by government regulations and programmes, mainly in form of ecological standards and subsidies (e.g. for efficient water systems, solar boilers and collectors). Solar boilers and collectors are also good examples for technological capabilities in the case of ecological construction as they were promoted and made accessible for use on a large scale. The authorities also initiated knowledge exchange by creating knowledge networks for sustainable construction. Interdisciplinary projects were carried out, e.g. when water management systems for a whole area were developed.

12.5 The economic impacts of environmental innovations

12.5.1 The Porter hypothesis

Environmental regulation traditionally was seen as bad for business, as something that impairs companies' competitiveness. The consensus on this was challenged by business professor Michael Porter (1991) saying that: "The conflict between environmental protection and economic competitiveness is a false dichotomy. It stems from a narrow view of the sources of prosperity and a static view of competition. Strict environmental regulations do not inevitably hinder competitiveness advantage against foreign rivals; indeed they often enhance it". Porter does not say that regulations are good per se for business; only certain types of regulation will spark innovative responses. The article sparked a hot debate among economists, business people and government. In policy circles, the thesis of a positive relation between strict environmental regulation, innovation and competitiveness became very popular in the nineties but is still controversial.

The difficulty is in measuring the extent to which the Porter hypothesis on the importance of regulation (properly designed and implemented) is a driver for competitiveness enhancing innovations. It is one of many drivers, including public policy on expenditure on basic research, education and skills, subsidies to R&D, etc.

This raises the question whether regulation can be a stimulus. If regulation was better implemented and enforced and more stringent, could this transform an industry? The problem with testing the link between environmental regulation and innovation is that the empirical evidence is weak, and the theoretical underpinning for the relationship is also controversial.

Empirical studies however widely agree that the effects of environmental regulation on competitiveness (measured commonly as rate of GDP growth or employment growth) are rather small (Rennings et al., 2004). This is because environmental costs tend, on average, to be a small share of total costs. Differential costs are lower because other countries are regulated too, and multinational enterprises do not even bother to exploit lax environmental regulations when locating new plants in such countries. Their environmental performance is more similar to that of their home plant.

This is not to say that there is no trade-off between environmental regulations and economic growth (as conventionally measured by not counting the environmental benefits). Environmental policy does reduce GDP. The importance is in the form of regulation, incentive-based policies keep environmental compliance costs down. The form of regulation is therefore an important policy consideration.

Even in the event that there is a significant depressing effect on GDP or productivity growth as a consequence of environmental regulation, it would be insufficient to conclude that regulatory policies should not exist. The reason is that policy is not only fundamentally concerned about the rate of technical change and corresponding growth rates, but also about its direction. There is a clear link between environmental regulation and improved health or better aesthetic amenities, which often does not show in measured GDP.

Hence, environmental regulation is consistent with economic growth as is quite evident from the current rate of economic growth in developed countries. As regards the trade-off effect, there is a trade-off effect implying that more money spent on environmental R&D investments is less money that will be spent on things that would be GDP producing, for measured GDP. This effect can be interpreted as opportunity cost effect or crowding out effect of environmental innovation (Löschel, 2002). In addition it also depends on the type of trade-offs – i.e. which environmental benefits are being given up in exchange for a faster rate of growth of measured GDP. On the other hand to say that there is no trade-off is to imply that money spent on environmental regulation could be simultaneously spent on other things

which cannot happen. Opportunity cost considerations suggest that innovation offsets may be small.

12.5.2 Environmental performance and economic performance of firms

While the Porter hypothesis itself can hardly be falsified empirically due the difficulty in finding operational measures for a correct policy in the sense of Porter, a rich empirical literature exists regarding the general relationship between sustainability performance (here understood as environmental and/or social performance) and economic performance. Event studies are predominantly applied in the literature. Recently several panel or cross-sectional studies have been carried out (Wagner, 2001).

Event studies investigate the effect of news on the performance of single stocks (see e.g. Muoghalu et al., 1990, Hamilton, 1995, Klassen and McLaughlin, 1996, Konar and Cohen, 1997, Blacconiere and Northcut, 1997, Khanna et al., 1998, Yamashita et al., 1999). These events typically have the character of negative news such as information about hazardous accidents or the emission data according to the Toxic Release Inventory (TRI). These studies find a significant negative impact of negative environmental events on stock prices and on the overall economic performance. Only a few studies consider the effects of positive news such as information about companies winning environmental awards (see e.g. Klassen and McLaughlin, 1996, Yamashita et al. 1999). These studies did not find significant impacts of positive environmental events on stock prices.

Indeed, it can be argued that the sustainability performance of companies cannot be measured by special events. But the main weakness of event studies is their short-term character. Thus, short-term over-reactions of stock markets are possible that may be compensated over time. Consequently, the investigation of the general effect of sustainability performance on economic performance needs long-term consideration.

Panel and cross-sectional studies analyse the characteristics of companies concerning their environmental and social behaviour. These studies investigate the relationships between certain characteristics of companies and their economic performance. This methodology has received increasing attention in recent years due to the restrictions of analyses of event studies on sustainability performance (see Hart and Ahuja, 1996, Butz and Plattner, 1999, Yamashita et al., 1999, Konar and Cohen, 2001, King and Lenox, 2001, Thomas, 2001, Wagner et al. 2002, Rennings et al., 2003b). It should be noted that econometric analyses with longer ob-

servation periods that examine the influence of sustainability performance on the economic performance of corporations differ in the inclusion of the explanatory variables. Due to these differences in the included explanatory variables and in the selected observation periods and regions, the results of the studies cannot be compared. But several of the studies find a significant positive relationship between environmental and economic performance. For example, Hart and Ahuja (1996) analyse in a cross-sectional study the relation between emission reductions and different variables on firm performance. They find a significant positive relationship that is most significant for "high polluters" where there are plenty of low-cost improvements to be made. A second example is the panel study of King and Lenox (2001). They use sector-specific emission indices on the basis of TRI data. They find the most significant positive effect for firms with above-average environmental performance compared to the competitors within the same sector. Firms in cleaner sectors without an above-average environmental performance compared to their competitors do not show a significantly better economic performance.

12.5.3 Employment impacts of environmental innovations

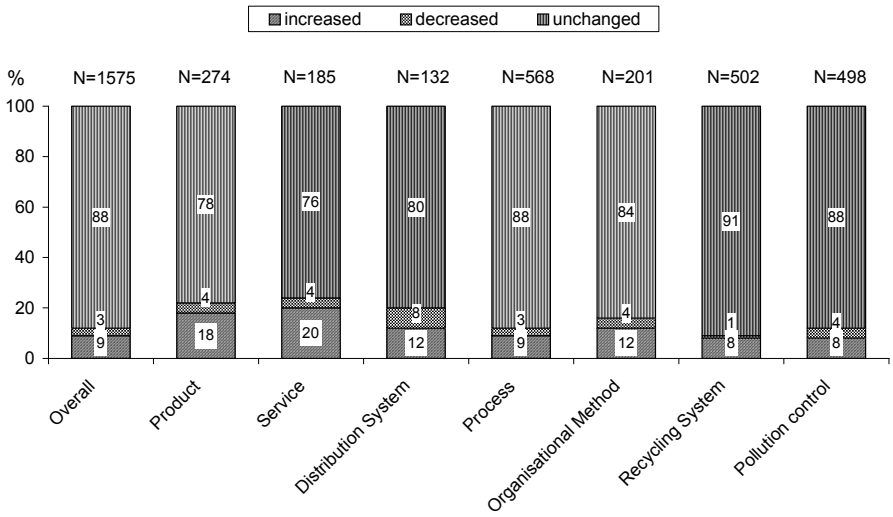
Unemployment is one of the most pressing political problems in Europe. Thus environmental regulation in general and programmes for environmental innovations in particular have often to be justified by not counteracting goals of labour market policies. In this context, empirical studies found only small quantitative effects of environmental innovations on employment but quite substantial effects on workplace quality and qualification (Bartolomeo et al., 2003, 2002; Getzner, 2002).

In the large-scale survey of Bartolomeo et al., overall 88% of the respondents experienced no notable effect on employment due to a specific environmental innovation that had been introduced in the years from 1998 to 2000 (see left column in

Figure 6). In 9% of the cases the number of long-term employees increased due to the innovation, while in 3% of the cases it decreased. Regarding the distribution of employment effects by innovation type, it becomes apparent that product innovations and service innovations have a sizeable above-average positive employment effect (18% and 20% of all firms reported positive effects). Furthermore it is interesting that the employment effect of recycling innovations is positive in almost all cases. Innovations in logistics have the highest shares of negative employment changes. Positive direct effects at company level can however be compensated by indirect crowding out effects as mentioned above. Overall it can be concluded that environmental innovations have small but positive effects at company level.

Substantial impacts of environmental innovations on workplace quality have been observed in another European study, both at companies which were directly affected by the changes in production technologies and as a result of structural changes in the economy and changes in intermediate demand structures (Getzner, 2002). More sustainable methods of production also lead to changes in the organisation of work, in terms of increased labour market flexibility and changes in work processes. Depending on how measures are implemented in practice, this can have positive or negative effects on the quality of employment. Involving employees in the practical implementation of integrated environmental protection can enhance the positive effects on employment quality, meaning that more attention is paid to the needs of the employees.

Figure 6: Employment effects of environmental innovations



Source: Bartolomeo et al. (2003).

In general, the direct and indirect effects of environmental innovations tend to increase the demand for skilled employees and reduce the demand for less skilled workers. The need for unskilled workers to adapt will therefore be intensified. Measures to promote the necessary adjustment through retraining schemes or job creation schemes targeting specific groups can be of assistance here.

12.6 Review of policy options

This section will review policy initiatives (mainly at the the EU level) and develop options for a good policy design and for a better co-ordination of environmental and innovation policy. Relevant policy issues at the European level to be addressed are (Rennings et al., 2004):

- Balancing the processes of Lisbon and Gothenburg,
- Environmental Technology Action Plan (ETAP),
- Economic instruments in environmental policy,
- Integrated Product Policy (IPP),
- Environmental Management Auditing Scheme (EMAS) ,
- The Directive on “Integrated Pollution and Prevention Control” (IPPC),
- Monitoring of lead markets for environmental innovations.

The following section will subdivide these issues in two categories:

- A "narrow" approach including the Lisbon initiatives, including ETAP.
- A "broader" or co-ordinated approach, linking the Lisbon initiatives to similar ongoing activities in the European Commission such as IPP, EMAS and IPPC. It is argued that a co-ordinated approach is required to avoid contradicting policies. Policy co-ordination seems to be necessary to enforce existing initiatives and to exploit synergies.

12.6.1 Lisbon initiatives

12.6.1.1 Environmental innovations as a bridge between the "Gothenburg Process" and the "Lisbon Process"

The need for an integrated, cross cutting approach to minimise possibly deteriorating effects of sectored policies such as energy, industry or agriculture has been acknowledged in the European Community as well as in several OECD countries since the early 1970s. It has been renewed more recently, and gained additional momentum in the late 1980s, as a result of the upcoming debate on sustainable development. Today, the need for more integrative approaches is determined by high-level political strategies such as the Sustainable Development Strategy of the European Union, but also by international obligations such as the Rio Convention.

The commitment undertaken by the European Commission to develop a strategy aimed at integrating sustainable principles in all European policies led to the "European Union Strategy for Sustainable development" (European Commission, 2001b). The definition of the European Union Strategy for Sustainable Development proposed in the Gothenburg Summit is the result of the combination of two strategic objectives: on the one hand, the commitment requested by the Helsinki European Council, and on the other, the purpose of complementing the Lisbon European Council, which sets the objective "to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion". The EU Sustainable Development Strategy pushes forward an integrated approach for policy-making that takes into account the environmental, economic, and social dimensions.

Although the Lisbon strategy focuses on competitiveness and innovation, the Commission has identified environmental technologies as a crucial issue in this process. In the Spring Report 2004 the Commission set out to assess the progress made towards the Lisbon goals (European Commission 2004b). The Commission

urges governments to give the Lisbon strategy fresh impetus by strengthening competitiveness in selected areas, including the area of environmental technologies. Also the report from the High Level Group (Kok Report) addressed the issue of environmental innovations (European Commission, 2004c), with priority for:

- Promoting environmental technologies by the environmental technology action plan (ETAP),
- Removing market distortions that create disincentives for investments in environmental technologies. Instruments are the removal of environmentally harmful subsidies and the increasing use of market-oriented environmental policy instruments such as taxes and emissions trading,
- Promoting green investment funds to improve the access of eco-innovators to finance, e.g. by granting tax reductions to individuals investing in such a fund.

12.6.1.2 The Environmental Technology Action Plan

The environmental technology action plan (ETAP) of the European Commission (2004d) aims at removing financial, economic and institutional barriers to the development of environmentally friendly technologies. The Commission sees it as a bridge between the EU's sustainable development strategy and the Lisbon agenda. The proposed actions have three main objectives:

- To help make the transition from research to markets (by increasing and focusing research, establishing technology platforms and networks for technology testing);
- To improve market conditions (by setting performance targets, leveraging investment, creating incentives and removing economic barriers, promoting environmental technologies via public procurement, building support for environmental technologies in civil society);
- To act globally (by promoting environmental technologies in developing countries, and promoting responsible foreign direct investment).

The Commission plans to monitor the implementation of the plan and will report to the European Council and the Parliament every two years. A European Panel on Environmental Technologies will be set up to exchange information between all stakeholders. With the Member States, the “Open Method of Co-ordination” will be used to exchange ideas on best practices, develop indicators, set guidelines and timetables. The first implementation report on ETAP (European Commission, 2005) recommended to:

- Establish "green investment funds" to mobilise risk funding, especially for small and medium-sized companies;
- Define environmental "performance targets" for key products, processes and services;
- Urge member states to produce "national road maps" for implementation of ETAP, with concrete measures and deadlines, and to draw up national action plans for green public procurement.

It should be noted that ETAP focuses on “soft” environmental policy instruments while the more strict recommendations of the Kok Report (“getting the prices right”) are seen as a necessary complementary initiative (European Commission, 2004d).

12.6.2 Related ongoing activities

12.6.2.1 Market-oriented instruments in environmental policy

After more than 10 years of negotiations, harmonised standards of energy and fuel taxes have now been introduced in the European Union (Umwelt, 2003). Although there are still a lot of exceptions, the minimum standards are an important step to reduce market distortions within the European common market.

While energy taxes have been in the centre of public debate over the nineties, the discussion of the current decade can be expected to be dominated by the introduction of a European emissions trading system. Emissions trading have gained increasing importance in the context of the Kyoto process. In January 2005 the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) commenced operation as the largest multi-country, multi-sector Greenhouse Gas emission trading scheme world-wide (European Parliament and Council, 2003).

However, the superiority of market-based instruments in pulling innovation still needs to be demonstrated in practice. In existing trading systems in the US, especially in the SO_2 trading system, innovation incentives of emission trading were limited to cheap technological or organisational solutions (Burtraw, 2000). Radical regime shifts and system innovations were not supported.

Incentives for further, more long-term oriented innovation efforts are difficult to identify in existing emissions trading schemes. They depend largely on the underlying environmental targets (Rennings et al., 2004). Thus emissions trading are an

attractive addition to other instruments already used in existing policy actions. It should be combined with other (not only environmental) policy instruments; such as innovation policy, especially it should be aligned to long-term policy targets.

An alternative to tough market based instruments is often seen in voluntary approaches or so-called "soft" instruments. The Dutch type of negotiated agreements (covenants) is often cited as a model for such new co-ordination mechanisms in this context. The potential of "soft" regulatory approaches is however mainly limited to the exploitation of win-win-potentials, and additional measures are needed in cases where no win-win-situation exists. Experiences with negotiated agreements are better in small countries than in big countries, and they are better at the national level than at the international level (both probably due to co-ordination problems).

12.6.2.2 Integrated Product Policy

Integrated Product Policy (IPP) became part of the political agenda in the late 90s (Rubik and Scheer, 2005). The European Commission published a Green Paper (2001) and a Communication on IPP (2003). These reports were intended to stimulate discussion by presenting some proposals for IPP. Some of the main characteristics of IPP are described in the Green Paper:

- Integration refers to consideration of the whole life-cycle of a product from the cradle to the grave,
- Co-operation with stakeholders and application of different instruments;
- The term product includes both material products and services;
- The policy is based on a governance philosophy of facilitation rather than direct intervention.

The implementation strategy of the Commission is concerned with strengthening the environmental orientation of both supply and demand. A series of proposals and possible actions are listed referring to both sides, e.g. concerning the price mechanism, greener consumption and business leadership in greener production. The Communication specifies that in "principle, IPP will complement current legislation by triggering, on a voluntary basis, further improvements in those products whose characteristics do not necessarily require legislation" (European Commission, 2003).

The impact of IPP on innovation, and especially on radical innovation processes, is up to now somewhat weak. It seems that firms have a limited ability to strategically deal with green product and service innovation. Life-cycle thinking, among which life cycle analysis is the most famous but not the most widespread assessment tool, has been used for years by few large corporations and, to some extent, by governments (Rubik, 2002). Empirical evidence shows however that these life-cycle approaches, when used, have a more retrospective than prospective role, meaning that the related tools are used to prove the rationale for product changes and, in some cases, to slightly correct existing artefacts and patterns.

The new Communication does not offer instruments or strategies with substantial innovation incentives. While instruments using the price-mechanism can be regarded as potentially powerful and to stimulate innovation, they are rejected in the context of IPP. The new Communication does not see a realistic chance for reduced VAT rates on products with the EU eco-label due to disagreement among Member States. It is also not intended to revise public procurement, instead a better application of existing potentials for greener procurement is suggested (European Commission, 2003).

In general, the philosophy of the Communication can be best described as self-regulation with a strong priority for voluntary instruments (Rubik and Scheer, 2005). Main elements in the Communication are the stimulation of “continuous improvements” of products and pilot projects to identify priorities. The term “continuous improvement” remains somehow vague, it neither includes quantitative targets nor a specification of what is meant by these improvements and how they should be measured. To stimulate product and system innovations, IPP should include quantitative targets or a better specified rule of continuous improvement and should be aligned with market-oriented instruments of environmental policy as described above. Overlaps with ETAP regarding green public procurement should be considered.

12.6.2.3 Environmental management systems

The EU Commission has introduced the Environmental Management Auditing Scheme (EMAS) to promote environmental management systems in firms. A recent large-scale survey of German EMAS firms found that EMAS has a positive influence on environmental process and product innovations as well as on environmental organisational innovations (Rennings et al., 2003).

The degree to which these innovations are stimulated by the management system depends on the maturity of EMAS (age of EMAS, re-validations, previous experience in respect of the organisation of environmental management, ISO 14001 validation). The organisational implementation of EMAS in the facility is another important success factor in encouraging environmental innovations. The R&D department plays a central role in this matter and it should participate in further development of EMAS in order to forge stronger links between product-related and strategic issues.

Moreover, it could be shown that facilities which have reported significant learning processes by EMAS are particularly successful in economic terms. In addition, as Table 4 shows, environmental reports as required by EMAS contribute to the diffusion of environmental innovations.

Table 4: Use of other facilities' environmental reports by EMAS firms

Use for:	Number of facilities	Share of all interviewed facilities
Own environmental report	912	71.4%
Environmental organisational innovations	495	38.7%
Environmental process innovations	442	34.6%
Environmental product-related innovations	259	20.2%
No use	275	21.5%

Source: Rennings et al., 2003a.

A practical policy question is what management standard should be supported and whether EMAS should be privileged in this regard. Concerning the question of environmental innovation effects EMAS can make a difference. Unlike the ISO 14001 standard, EMAS requires external communication via an environmental report. The EMAS survey has shown that the environmental reports of other facilities are being used for gathering ideas for a facility's own environmental innovations. Many firms however plan to quit the systems after "picking off the low-hanging fruits" in the first EMAS years. Firms are often frustrated by missing rewards from private and public markets. This is definitely an advantage in comparison to ISO 14001. It should however be taken into account that many companies participating in ISO 14001 publish a voluntary environmental report. In an empirical study on Swiss companies adhering to ISO 14001 Dyllick and Hamschmidt (2000) found that one third published an environmental report and another 25% were planning to do so.

In the past Germany has linked preferential treatment of EMAS with granting of regulatory relief for registered companies (Wätzold and Bültmann, 2001). Regarding the diffusion of EMS, EMAS is however well behind ISO 14001. Glachant et al. (2002) are quite pessimistic regarding the further diffusion of EMAS due to limited potentials for regulatory relief. These potentials are restricted by national traditions, they differ from country to country and many firms are already disappointed since benefits of EMAS implementation turned out to be lower than expected.

Thus it seems to be important to link preferential treatment not to expectations regarding deregulation. It at all, it should be linked to the communication performance of firms,. It may be useful to link equal treatment of ISO 14001 to the voluntary publication of an environmental report. Other differences between EMAS and ISO 14001 seem to be less important. Most differences were diminished in the revision of the schemes, which took place in 2000 with regard to EMAS and in 2004 in the case of ISO 14001 through the adoption of shared elements.

12.6.2.4 Integrated Pollution and Prevention Control

Before technologies can be improved by innovation, it is necessary to know the existing best available techniques (BAT). In Europe the IPPC Bureau in Seville is responsible for defining BATs for different processes and sectors. IPPC is the abbreviation for Integrated Pollution and Prevention Control.

IPPC has a community legislation which literally tries to bring together the whole environment, from the use of raw materials and the use of natural resources to preventing environmental hazards. In the so-called “Seville Process”, IPPC acts as an information exchange centre. Thirty-two countries (member and non-member states), industries and environmental NGOs constitute the information exchange bureau. The sub committee (Technical Working Groups) is assigned the task of determining the following:

- Review the current performance with respect to key relevant environmental issues,
- Identify techniques used to achieve the “best” current performances,
- Examine economic and technical conditions under which the techniques are applicable and
- Analyse whether it is the right environmental decision and whether it is economically viable for the sector.

BAT serves as a benchmark and is used to judge the performance of an existing installation or a proposal for a new installation, thus assisting in the determination of an appropriate "BAT-based" condition for the installation (Rennings et al., 2004). IPPC permit conditions must be based on the best available techniques and not prescribe the use of a specific technique/technology. IPPC does not prescribe best technology, but identifies the environmental performance, which is consistent with BAT.

Ultimate impacts of BAT will depend on how IPPC is implemented, e.g. legislation must be implemented and enforced by the authorities. A driver for industry to achieve BAT standard at lower cost is to set performance targets rather than technological targets. While BAT cannot be expected to stimulate radical innovations, it should be regarded as an institution providing an information basis for the negotiating of environmental standards. Indeed BAT is no more than a list of available techniques and provides a stimulus to equipment producing companies and engineers to improve their technologies and methods. Indirect innovation impacts can however be expected from the international diffusion of BAT. A major, though understandable, problem area faced by TWGs is reluctance by industry to share cost and performance data on new processes.

12.6.2.5 Monitoring of lead markets for environmental innovations

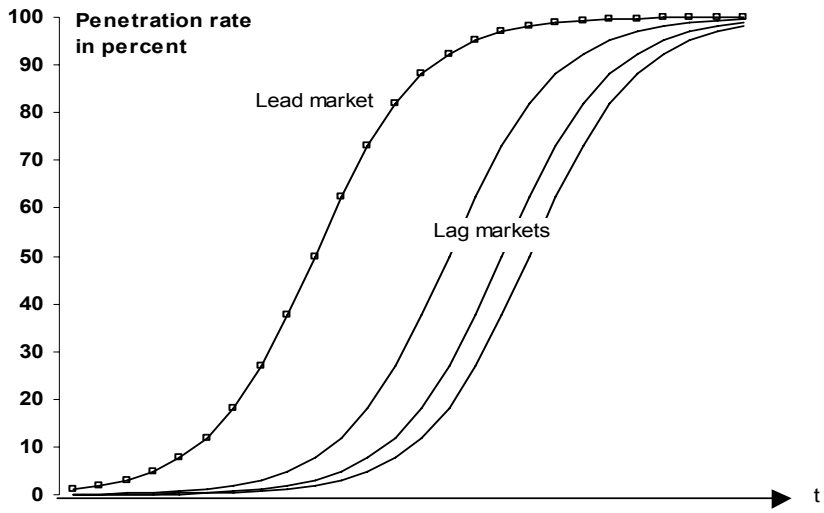
The response of consumers to new products is a crucial factor for their success. And the success of new products, creating new markets, is of paramount importance for innovation. It is expected that the market's impact on innovation will grow in the future, and the majority of managers expect that markets will become more receptive to the introduction of new products (ITT, 2003). In this context, innovation policy needs a deeper understanding of why innovations are adopted by pioneer countries and diffuse from country to country. These processes are the result of the "lead markets" concepts. It explains competition between different innovation designs, early adoption in lead markets and the following global diffusion.

Countries that are first in adopting an internationally successful innovation are referred to as "lead markets" and countries which follow the lead as "lag markets" (Beise, 2001). As far as the diffusion of globally successful innovations is concerned, it is apparent that many innovation designs have only become internationally successful after initially being preferred and adopted in one particular country. For example, the facsimile machine was adopted in Japan before becoming the globally preferred design for text-based telecommunication; cellular phones were

first widely adopted in the Nordic countries. Penetration rates tend to be higher in the leading country for a considerable period of time, and this supplies firms with long-term user feedback and market knowledge which enables them to constantly improve innovation and retain their lead. Figure 7 exhibits the typical international diffusion pattern of a specific innovation design.

Differences between lead and lag markets are not adequately explained simply by referring to a lesser degree of "innovativeness" in the lagging countries (Beise, 2001). While the export success of firms based in a particular country has tended to be explained in the past in terms of leads in technological knowledge, other vital factors determining international competitiveness include demand and market conditions that lead to early adoption of innovations: Some studies found that the international competitiveness of a country originates from a demand gap and that this demand gap is the cause of the technology gap observed after the product becomes established worldwide. The technological gap is based mainly on experience in production (learning-by-doing) and usage (learning-by-using). In contrast, discoveries and inventions often occur in countries other than the country where the innovation is first widely adopted. In these cases, local firms usually use technical knowledge from abroad to meet local demand.

Figure 7: The international diffusion pattern of an innovation design



Source: Beise (2001).

The lead markets approach has also been applied to environmental innovations (Beise and Rennings, 2005), emphasising the important role of regulation for innovation and the international diffusion of environmental technologies. While envi-

ronmental innovations are still largely driven by regulation, they will only be accepted in the long run if market conditions are improved and if there is sufficiently demand from customers.

National markets vary in their receptiveness for a given innovation. Lead markets are not necessarily the countries that developed a new technology. Others may adopt it first due to specific conditions. The price and cost structure of a national market can be encouraging for certain types of innovation. For example, automation technologies develop faster in countries with relatively high labour costs, and energy saving innovations in countries with higher energy prices. Concerning environmental innovations, these price and cost structures largely depend on regulation.

Main factors for national markets to become lead markets are the following:

- They are in advance of a global trend (in income structure, demographic trend, regulations, liability rules, standards, etc).
- They demonstrate a high degree of competition and therefore are likely to experiment and to react to market needs.
- They have gained a high reputation concerning problem-solving innovations in the past and are therefore intensively watched by other countries.

Regarding the integration of the Lisbon and Gothenburg strategy, the lead markets approach can be regarded as an appealing concept for policy makers since it promises a double dividend or what is described as innovation offset in the discussion of the Porter hypothesis. While explanations for technology diffusion are elaborated and already operational for empirical validation, a corresponding approach for the diffusion of regulation (being crucial for lead markets of environmental innovations) is not yet well developed. It would be beneficial to explain “lead policy markets” by a more socio-technical approach. A further question is whether lead markets are beneficial in all cases for the pioneering country, or if the followers have advantages in terms of costs and benefits since they save investments in R&D, market introduction etc.

The Innovation Directorate of the European Commission has “proposed to further investigate the parameters involved in the formation of lead markets, including examination, together with industrial representatives, of the potential for specific industrial sectors to benefit from European lead markets as a step towards a stron-

ger presence on the international market" (ITT, 2003). This proposal can also be supported for lead markets of environmental innovations.

For environmental and innovation policy it would be generally important to recognise the role of non-technological factors for the diffusion of environmental innovations: regulation, market demand, prices and the flow of communication. To date these aspects have been neglected in governmental innovation reports on national technological performance. The German governmental report on technological performance (BMBF, 2000), for example, uses patents and RCA (revealed comparative advantage) values as indicators for the performance of the German environmental goods and services industry. It is true of course that patents and RCA values are useful measures of the actual and potential export position of a country. However, unless a careful analysis of regulation and market trends is performed there is a danger that national innovation policies may support idiosyncratic technologies which - if they are marketed successfully at all – may not get any further than small regional or national market niches. Thus regular monitoring of environmental lead markets and the consideration of monitoring results in innovation reports can be recommended.

12.7 Conclusions for policy co-ordination

Before we draw final policy conclusions, it is reasonable to remind the research questions from the beginning:

- Can increased funds for R&D and (eco)innovation improve growth, employment and environmental quality?
- Is strict environmental regulation a catalyst for improved economic performace?
- Can government support for for specific sectors (e.g. windmills) increase economic growth and stimulate job creation?
- Can pollution be decoupled from economic growth in OECD countries?
- Is environmental performance primarily achieved by environmental policies (environmental policies versus other policies, e.g. ICT policies).

Regarding the first question, it has been stated in the discussion of determinants of environmental innovations that there is a weak evidence for the fact increased funds for environmental R&D can stimulate environmental innovations. The ques-

tion is if these environmental innovations can also increase economic growth and employment.

The European Union is already in a leading position regarding environmental technologies. Expectations regarding pontential impacts of environmental innovations on competitivenss and employment have however often been exaggerated in both directions in the public debate. Empirical studies have found evidence for a significant short-term negative impact of negative environmental events (measured e.g. as toxic releases or hazardous accidents) on stock prices and on the overall economic performance. Only a few studies consider the short term effects of positive news such as information about companies winning environmental awards. These studies did not find significant impacts of positive environmental events on stock prices. It can be concluded that, from an economic point of view, sustainability performance has still the character of risk management in the short term. While several cross sectoral studies have also found a significant positive relationship between environmental and economic performance in the mid term, these results should be treated cautiously since the causality of the effect is not fully clear (does sustainability improve economic performance, or can only successfull firms afford investments in social and environmental performance?). It can be summarized that targets for a co-ordinated European environmental and innovation policy should be set at a realistic level. An important economic benefit will be the reduction of environmental (and thus also economic) risks. With regard to competitiveness, a positive but moderate impact can be expected.

The same conclusions can be drawn concerning employment impacts. Unemployment is one of the most pressing political problems in Europe. Thus environmental regulation in general and programmes for environmental innovations in particular have often to be justified by not counteracting goals of labour market policies. In this context, empirical studies found only small quantitative effects of environmental innovations on employment but quite substantial effects on workplace quality and qualification.

In the past years several policy initiatives have been started in the European Union in the context of a European strategy for sustainable development. These initiatives included the implementation of economic incentives for environmental protection, inititatives at the firm level and setting of standards for environmental technologies. These ongoing policy intitiatives are a good basis and starting point for further policy initiatives which are linked to the Lisbon agenda and the long-term goals regarding innovation and competitiveness.

In the context of the Lisbon Agenda, the Commission has identified environmental technologies as a crucial issue in this process in the Spring Report 2004. Also the report from the High Level Group (Kok Report) addressed the issue of environmental innovations (European Commission, 2004c), suggesting the promotion of environmental technologies by the environmental technology action plan (ETAP). Several overlaps and synergies of ETAP exist with other initiatives at the European level as mentioned above, especially:

- The emissions trading system for greenhouse gases,
- Integrated Product Policy (IPP),
- The Environmental Management Auditing Scheme (EMAS) and
- The Directive on "Integrated Pollution and Prevention Control" (IPPC).

Policy initiatives for stimulating environmental innovations are to a large extent an exercise of policy co-ordination. Thus a "broader" or co-ordinated policy approach can be recommended for the Commission, linking the Lisbon initiatives to these ongoing activities. Policy co-ordination seems to be necessary to enforce existing initiatives, exploit synergies and to avoid contradictory sectored policies.

Monitoring of international regulation trends would be an important supplementary activity (e.g. in the context of the 7th Framework Programme of the European Commission) to avoid the development of idiosyncratic technologies that do not follow or anticipate such trends. This is due to the fact that the introduction of environmental innovations depends strongly on government regulation. Lead markets for environmental technologies are located in industrialised countries with high standards of environmental protection. While market demand is a crucial factor for the success of innovations, environmental products often have commercialisation problems. Higher prices rather than 'soft' factors appear to be the major obstacles to the commercial exploitation of environmental products and therefore also to environmental product innovations. "Getting prices right" is still a crucial issue for a co-ordinated environmental and innovation policy.

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13 Opponent Note no. 3a: Eco-innovation – environmental benefits, economic growth and job creation

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13.1 Overview

The paper by Rennings & Ziegler presents a review of a range of literature on environmental innovation, economic performance and policy measures with a generally positive view on the role of regulation in the fostering of environmental innovation. This response to their paper does not seek to challenge the interpretation of the empirical studies selected nor the overall suggestions for a more coordinated policy framework. However it suggests that some specific domains of European eco-innovation with positive economic potential deserve more attention than they are given. These are:

1. The pursuit of radical, discontinuous eco-innovation by business enterprises leading to global economic competitive advantage
2. The promotion of eco-innovation by business and social actors through socio-technical transitions spanning production and consumption

The neglect of these is considered to arise from the following features of the analysis:

1. A definition of eco-innovation that does not differentiate sufficiently between innovations in terms of contributions to sustainability
2. Data on eco-innovation that is not disaggregated enough to reveal and contrast the performance of radical innovators from others.
3. Little attention to the role of different strategic innovative capabilities at the organization level and how these may be influenced by policy initiatives

It is suggested that the analysis of eco-innovation could be beneficially assisted by:

1. Defining eco-innovation more explicitly in terms of its contribution to the 'de-coupling' of economic impact from environmental detriment
2. Drawing upon case study analysis from business and social studies

3. Giving more attention to relational capabilities and strategic choice and the role of innovation and entrepreneurship policy measures

13.2 Defining eco-innovation

Much of the recent discussion on eco-innovation steers an uncomfortable path between narrowness and breadth. Sometimes it focuses on the environmental industry sector while at other times on environmental innovation in all sectors. Often a restrictive focus on technology may be contrasted with a wider inclusion of social and organizational change. Rennings & Ziegler rightly opt for the broader options which recognize that eco-innovation should be viewed as pervasive throughout the economy and society and should encompass social as well as technological change.

They also adopt a broad and inclusive definition of its 'eco' characteristic as that of offering any type of relative environmental advantage. They outline two definitions as their starting point:

Environmental innovations are considered to 'consist of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harms' while it is suggested that *sustainable innovations* could be defined as 'new or modified processes, techniques, practices, systems and products with a net positive impact concerning their environmental, economic and social effects'.

Both of these definitions adopt an environmental criterion that is essentially relative in nature ie that if innovation offers any improvement in environmental impact, however modest, it falls within the category. Although this is fine as a starting point there is a need to further discriminate between innovations that offer significant and important environmental benefits as compared with those that offer minor and routine improvements. This distinction between radical and incremental innovation is important for assessing the economic as well as the environmental impacts.

Although some further categorizations are offered by the authors - process innovations are differentiated according to whether they are 'end of pipe' or 'cleaner production'; system innovation is contrasted to firm innovation - these do not directly address the environmental significance of innovation. On the other hand much of the discussion which spans the Gothenburg and Lisbon agendas of sustainability and competitiveness uses the concept of 'decoupling' as a fundamental orientation point for addressing this issue.

The 2005 Review of the EU Sustainable Development Strategy restates as a basic overarching societal goal:

'To decouple economic growth from environmental degradation' (CEC 2005a p6).

The initiation of the Environmental Technologies Action Programme oriented this much more explicitly to the development of new technologies:

'New and innovative environmental technologies…help to decouple environmental pollution and resource use from economic growth' (CEC 2002 p2)

While Wim Kok's review of the Lisbon agenda linked 'decoupling' to innovation more broadly:

'Innovations — that lead to less pollution, less resource-intensive products and more efficiently managed resources — support both growth and employment while at the same time offering opportunities to decouple economic growth from resource use and pollution' (Kok 2004 p36).

It would therefore appear to be of fundamental importance for the pursuit of this policy agenda to endeavour to connect the promotion of eco-innovation with its contribution to the overarching goal of 'decoupling' economic growth from environmental detriment.

Research on the concept of 'decoupling' (Azar et al 2002, OECD 2002) demonstrates that there are a number of critical factors which need to be considered when assessing the contribution of an eco-innovation to decoupling.

Relative versus absolute decoupling - this distinguishes between a 'relative' slowing down of environmental impact yet which continues to grow compared with 'absolute' decoupling where environmental impact stabilizes or declines. *Narrow versus broad* decoupling - decoupling may be considered in a narrow sense in relation to a singular innovation or in a 'broad' sense in relation to the wider system of which it is a part. *General versus specific* – decoupling may be assessed in a general aggregated fashion or disaggregated in specific areas.

Overall we can distinguish between 'weak' and 'strong' versions of decoupling. The inclusion of some assessment of the 'decoupling' contribution of a specific ecoinnovation is an important supplement to other approaches to the definition of innovation for two major reasons. It enables a more effective judgment to be made about the significance of a particular eco-innovation and it suggests where targeted effort is needed in eco-innovation.

13.3 The business enterprise

There is an argument to be made that innovations that offer a significant decoupling are of particular interest in terms of both sustainability and economic competitiveness. The exploration of this rests much more strongly on the business strategy case study evidence base rather than on the results of broad industry wide surveys. This is because they are infrequent, but their significance can be very important

The Environmental Technologies Action Plan argued that European business had made encouraging progress towards decoupling industrial output from certain polluting emissions. These examples are often of absolute but narrow decoupling.

There are a number of prominent examples of European companies who have pioneered eco-innovations with strong decoupling which have been accompanied by global economic success.

13.3.1 These include

Rothamsted Experimental (UK) - introduced synthetic pyrethroid insecticides in the early 1970s, a biodegradable alternative to the persistent organochlorines such as DDT; Achieved 20% of global insecticide market through licensing arrangements through companies including Zeneca (UK). Innovation arose from commitment to research over several decades with public funds. Market created through ban on DDT.

Vestas (Denmark) Pioneer of wind turbine technology from the early 1980s achieved 36% of total global market by 2004; Built on domestic industrial base.

ICI (UK) – introduced successful innovation of water based paint for automotive applications in the late 1980s; Drew on in house microgel technology, located research in Canada with strong green regulations. Licensed technology to major automotive suppliers such as DuPont, and with assistance of regulations controlling volatile organic solvent emissions went on to achieve major share of global market.

DKK Scharfenstein (Germany) – introduced non CFC refrigerant Greenfreeze; Drew on traditional technologies, triggered through collaboration with Greenpeace marketed through major manufacturers such as Bosch to become leading global technology (Steward, MBA case studies).

13.3.2 Market

While these cases often exploited a new market opportunity arising through regulatory change, what is also striking is that the innovation was initiated long before the regulatory or market context was a favourable one. These innovation projects arose through an early anticipatory commitment by the businesses concerned. One needs to be careful not to imply that regulation induces ecoinnovation in a simple way. Although proximity to a regulated market can be advantageous it is evident that in a number of cases, European companies were effective in anticipating new market conditions in other countries outside Europe.

13.3.3 Knowledge

Another important feature of such cases is that they draw on a very diverse knowledge base ranging from reinvention of traditional technologies through to new developments in biological and molecular sciences. They draw on new technological opportunities but are not driven by science in any straightforward way. They cannot therefore be seen to arise simply from R&D investment.

13.3.4 Managerial coupling

What these successful cases of innovation illustrate along with studies of innovation in general (eg Freeman 1983) is that neither favourable market conditions nor suitable knowledge opportunities are sufficient in themselves for successful innovation. It requires managerial action to couple these together and it is the presence of this capability that enables some firms to out innovate others

13.3.5 Business strategy of differentiation

These economically successful eco-innovations also express a particular type of business strategy. In strategic terms (Porter 1985) they represent ‘differentiation’ rather than cost leadership. Therefore although they offer economic and commercial benefits this is not of a simple cost saving nature.

13.3.6 Disruptive innovation

Another characteristic of successful innovations like this is that although they may be ‘win-win’ for the firms introducing them, they may also be ‘lose-lose’ for incumbent businesses whose market share they challenge. This is increasingly recognized as the ‘disruptive’ nature of significant innovation (Christensen 1997).

In sum, when one is considering significant 'decoupling' eco-innovations, it should be recognized that the role of firm specific capabilities will play a critical role in which businesses succeed in making the innovation a success and securing the rewards of early entry. A study conducted for the European Commission (Steward & Conway 1998) explored the role of these 'relational capabilities' in ecoinnovation through mapping the social networks involved and the communicative interactions of the actors involved in the innovation process. The business enterprise should not be viewed as a 'black box' responding to external signals. Neither can such significant innovation be explained simply in terms either of top management leadership or of implementation of environmental management systems. Instead it depends on individual managers, the links that they are involved in and the effectiveness of the strategic arguments that they deploy.

The challenge for policy is whether it can promote such relational capabilities and strategic choice in European firms. There is often a view that such innovation capacities, since it is infrequent and dispersed, that it is therefore not amenable to policy intervention, the risk being of a heavy handed, counter productive picking winner's style. In fact there has been an accumulation of understanding about innovation and entrepreneurship at the European level which acknowledges its human and idiosyncratic qualities while at the same time recognizes that there are explanatory patterns, which are open to softer instruments of encouragement. The communications on Innovation Policy (COM 2003 112) and the Green paper on Entrepreneurship in Europe (COM2003 27) both recognize the importance of the human managerial dimension and offer a framework of policy which include measures for skill and capacity building.

Nevertheless there remains a difference between the promotion of innovation capabilities in general and the encouragement of ecoinnovation in particular. Studies of ecoinnovation show that actors and arguments need to embrace sustainability as an important pursuit within the context of competitiveness. There are often competing options in the early stages of innovation with different agendas. There is therefore a critical domain of policy which facilitates innovation and entrepreneurship while encouraging a higher priority for sustainability as a goal. This needs to be pursued through models of network building and learning which promote new communities of practice (Hildreth & Kimble 2004) with shared commitments to ecoinnovation. Although these are 'soft' measures they need to be developed with sophistication and resources. They are quite different to low cost exercises based on existing business associations and professional bodies. They need to actively

build on individuals and enterprises with specific ecoinnovation capabilities and enroll others in this mission.

Another approach which has potential in this regard is the technology specific innovation systems approach of Jacobssen and his colleagues which focuses on the system characteristics needed to promote innovation in certain technological domains (Jacobsson & Lauber 2006). One of the implications of the decoupling orientation discussed earlier is that it can also facilitate targetting on areas which appear more intractable, which require more focused effort, and may also offer the greatest rewards to early successful ecoinnovators.

13.4 The sociotechnical system

An orientation toward the 'decoupling' potential of eco-innovation also leads directly into the need to explore innovation at a system as well as an enterprise level. This is because of the problematic relationship of singular innovations which offer relative environmental benefit with their sometimes limited impact on decoupling at a wider system level. More fuel efficient vehicles may be accompanied by continued growth in carbon emissions in the transport sector. Energy saving devices in the home may still accompanied by growing domestic carbon emissions. The growth of digital technologies offering prospects for dematerialisation of communication has been accompanied by growing consumption of paper. These paradoxical consequences and rebound effects offer a major challenge for the pursuit of ecoinnovation and the achievement of significant decoupling.

Recent research on sociotechnical transitions drawing on historical case studies of radical innovation have led to some important insights. (Geels, 2004, Kemp 2003)

Radical innovation involves a wider process of change than is expressed through the introduction of an individual product or a new business practice. It requires a transformation in a domain of societal activity which embraces both production and consumption and a host of individuals and organisations. It shows a complex pattern of change and interaction between a diversity of societal actors. The promotion of radical innovation for sustainability can be facilitated by the stimulation of new thinking and new stakeholder relationships through a purposive focus on key domains of social practice such as bathing/showering, cooking a meal, reading books & magazines, travelling to work etc. The contribution of technology is an important part, but only a part, of these wider changes in social practice.

Radical innovation, although conventionally contrasted as abrupt compared with slow incremental change, has actually been shown to often require a period of several decades to move from margin to mainstream. The process is a continuous one over a long time period that has been shown by retrospective studies to move through different phases with variations of tempo. The challenge for the promotion of radical innovation for sustainability is to actively connect the long term with the short term. The solution is not a misguided attempt to pick the technological winner decades in advance but instead to ensure that a variety of sustainable options are facilitated and nurtured in a long term process characterised by competition and argument.

These findings suggest the need for a major reorientation of ecoinnovation policy to include a sociotechnical system perspective. An innovation policy framework around social practices such as housing, food & travel (Spaargaren 2003) offers a way forward and represents a different perspective to the technology and industrial sector approach of much policy. It is very much in tune with the new orientation towards sustainable consumption and production, because central to sociotechnical systems and social practices is the involvement of social actors from both production and consumption.

A reorientation to sociotechnical transitions implies that ecoinnovation with strong decoupling potential will often comprise a hetereogeneous mixture of technological, organisational and social innovations. The economic and employment implications of such ecoinnovation are complicated to assess but it appears that the creation of new services and infrastructural activities which accompanies technological and product innovation offers positive scope for job growth. Community based waste management schemes and renewable energy initiatives are examples of this. The promotion of innovative approaches in sociotechnical systems and social practices in Europe offers the prospects both of direct positive gains for employment and economic activity. It also offers indirect benefits, globally from the pioneering of leading models of systemic innovation. The systemic/network character of these innovations means that successful implementation draws strongly on situated knowledge and practice capabilities. Their wider diffusion rests heavily on the transfer of this knowhow which puts the early innovators in a strong competitive position.

As with the earlier discussion on the business enterprise – the recognition of the need for building focussed ecoinnovation capabilities for sociotechnical systems implies a softer network building type of policy agenda, not as an alternative to

research/technology policies and regulation/market interventions but as a supplement to them. Again this type of agenda is not an easy and cheap option if it is to fulfil its purposes effectively. Instead it requires a serious commitment to policy innovation with the purpose of enabling new configurations of businesses and social actors to be facilitated and encouraged. This needs initiatives which: 1) have a more specific sustainability focus than general measures for facilitating knowledge flows between sectors and 2) give a key role to sustainability entrepreneurs seeking to promote new innovative paths of production and consumption. Contestation and diversity need to be valued as inherent in such approaches. There are elements of such an approach emerging in European member states ranging from transition management to market transformation programmes. However the European level framework and commitment need fuller development.

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14 Opponent note no. 3b: Environmental innovations and economic success of firms – a rejoinder

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14.1 Introduction

This paper is a rejoinder to the paper of Rennings and Ziegler "Environmental Innovations and Economic Success of Firms" for the *Green Roads to Growth* workshop in Copenhagen on March 1-2 in Copenhagen. In their paper Rennings and Ziegler offer an authoritative discussion of what we know. My paper supplements things discussed in the Rennings and Ziegler paper. In my paper I offer a further discussion of the concept of environmental innovation (where I deal more extensively with the important category of unintentional environmental innovations and green system innovations). I go more deeply into the issue of costs and benefits from environmental innovation, showing that eco-efficiency should be encouraged by policy because it brings both economic and environmental benefits. I offer some statistics about environmental jobs, which indicate that they exceed jobs in software development & consultancy jobs. And finally I discuss two policy issues not so well covered in the Rennings and Ziegler paper: policy styles and environmental policy integration (Cardiff process). My paper also contains a practical proposal for policy in the form of eco-efficiency targets.

14.2 Typology of environmental innovation

Innovation is commonly defined as the commercialisation of a new product, process, or organizational system but it may also be more broadly defined simply as doing things differently in the realm of economic life (Schumpeter, 1934). According to the influential Oslo Manual (OECD 1997), innovation does not necessary require in-house investment in creative activities such as R&D. Firms can innovate by adopting technology developed by other firms or organizations.

Environmental innovation consists of new and modified processes, equipment, products, techniques and management systems that avoid or reduce harmful environmental impacts (Kemp and Arundel, 1998, Rennings and Zwick, 2003). A substantial fraction of environmental innovation is based on the simple adoption of new technology, although firms may need to adapt the technology to their own

production processes. A smaller fraction of environmental innovation is probably based on the firm's own creative activity (Arundel et al., 2005).

In some cases, reducing environmental impacts may be the sole purpose of an environmental innovation. In other cases, the environmental benefit may be a fortuitous by-product of other innovation activities. Intentional environmental innovation is the product of an expressed goal to eliminate or reduce adverse environmental impacts. The use of flue-stack scrubbers to remove sulphur dioxide, for example, is relatively simple to identify as an environmental innovation. Unintentional environmental innovations are more difficult to identify, but could be of even greater importance. An example is the photovoltaic energy cell for calculators. These permitted thinner calculators that never ran out of power, but they also had the environmental benefit of reducing the use of batteries (Arundel et al., 2005).

LED lamps (Figure 1) are a mixed case. They have been developed for reasons of better light quality, longer lifetime and energy-efficiency.

Figure 1. LED lamps may be used for stop signs and more

Many innovative consumer products are environmentally superior to older versions or alternatives. A special category of these are eco-products: goods that are expressly developed and marketed as ecologically sound. These constitute a small class of environmentally advantageous products.

The environmental gains of normal innovations have never been the object of systematic study. It has been estimated however that 60 % of the innovations of the Dynamo Database in the Netherlands offer environmental benefits compared to existing technologies. It also was found that 55 % of the innovations supported by a general innovation scheme for research cooperation (IS) offered notable sustainability benefits. These two figures coming from the Netherlands suggest that the majority of technological innovations offer environmental benefits.

Eco-innovations may be also achieved through "system innovation": fundamental changes in the way in which services are provided through functional systems. Examples are renewable energy systems, chain mobility, or the development of energy crops instead of food products. Green system innovations are currently the focal point of attention of Dutch transition policies in the areas of energy, transport and agriculture.

An overview of environmental innovation comprises is given in table 1.

Table 1. The time scale and targets of eco-innovations

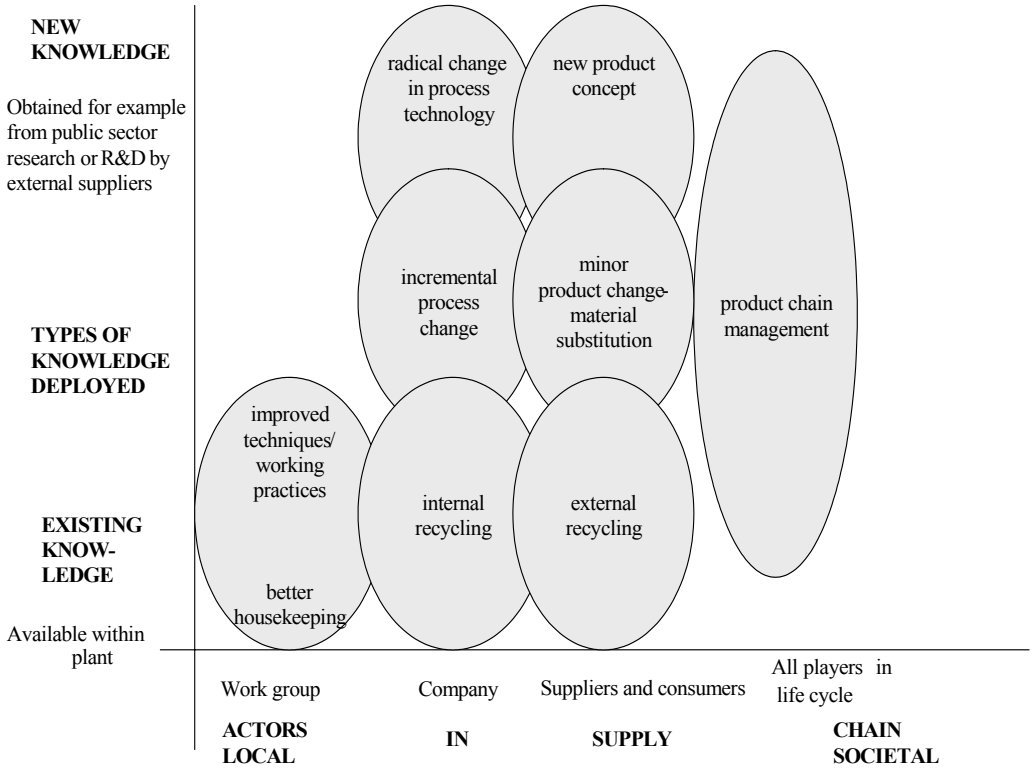
	Targeted decisions	Time Scales
Pollution prevention	Plant operations and maintenance, small changes in the existing production lines, input substitution	Short to medium-term One time or continuous[41]
Pollution control	Treatment of pollution before release into environmental media through special devices (usually end-of-pipe).	Short-term One time
Cleaning technology	Treatment of pollution within the environment (receiving water, soil, or air). An example is remediation of polluted soils	Short-term to medium term One time
Cleaner technology	New technology investment	Long-term New investment cycle (one time)
Environmentally improved products	Product features of material use, energy use, durability and reusability thanks to design for the environment and re-use	Long term Continuous
Loop closing	Sourcing, product design, siting of new facilities	Medium to long-term
Environmental management systems	Decision-making for reducing environmental impacts of products and processes	Short-term to medium-term Continuous
Waste management	Collection, transport, processing, recycling, reuse and disposal of waste materials	Short-term to medium-term Continuous
Environmental optimisation of production chain	Production chains: resource extraction, processing, manufacturing, final product and end-of-life use or care through design for recycling etc.	Medium to long-term Continuous
System innovation	New product-service systems (for example, customized mobility or decentralized systems of energy)	Long-term (one or two generations) Continuous

Source: based on Hertwich (2000)

[41] The term "continuous" refers to a *continuing* process in which there may be some discontinuities.

Product chain changes and new products are wide ranging changing involving multiple actors within production chain -- as visualised in figure 2.

Figure 2. Knowledge and chain aspects of eco-innovation types



Source: Clayton, Anthony, Graham Spinardi and Robin Williams (1999), Policies for Cleaner Technology . A New Agenda for Government and Industry . Earthscan Publications Ltd ., London, p.273

In the past the focus of attention of policy and business was on end-of-pipe solutions. This is changing as shown by Rennings and Ziegler whose paper offers important information about the choice of environmental technologies in seven OECD countries, showing that the shares of cleaner production are higher than those of end-of-pipe. The figures are in line with Arundel et al. (2003) who found that 71 per cent of Dutch firms in five sectors had introduced a production process change, compared to 52 per cent that had introduced an end-of-pipe solution and more or less in line with those of Huber (2003) reports that 85 per cent of technological environmental innovations in Germany were integrated solutions while only 15 per cent were add-on solutions. The figures differ however from those in the European Commission (2002) white paper ... which estimates that integrated solutions account for one-third of environmental investments, with end-of-pipe and clean-up accounting for two-thirds of such investments. Perhaps in investment terms end-of-pipe is more important than cleaner production measures that can be fairly minor

in terms of investment. But in terms of achieving environmental benefits cleaner production is important. The IMPRESS study found that the most important environmental innovation in terms of environmental benefit is cleaner production (Rennings and Zwick, 2003).

Attention of business has shifted to eco-efficiency options: win-win solutions that combine environmental with economic benefits, leading to factor 2 improvements. Examples are: energy-efficient processes, recycling systems, and low-solvent paints.

Eco-efficiency is a broad concept that is usually measured at the product or service level. Eco-efficiency means *less environmental impact per unit of product or service value* (WBCSD, 2000):

Eco-efficiency = Product or service value / Environmental impact

The environmental impact is measured on the basis of both resource use (the source side) as well as emissions to air, soil and water (the sink side) per produced unit/activity. Toxicity is of resources is taken into account. In so doing it differs from material intensity per service (MIPS). In actual practice eco-efficiency is not so easy to measure but the WBCSD has identified seven strategies to improve eco-efficiency[42]:

- Reduce material intensity
- Reduce energy intensity
- Reduce dispersion of toxic substances
- Enhance recyclability
- Maximize use of renewables
- Extend product durability
- Increase service intensity

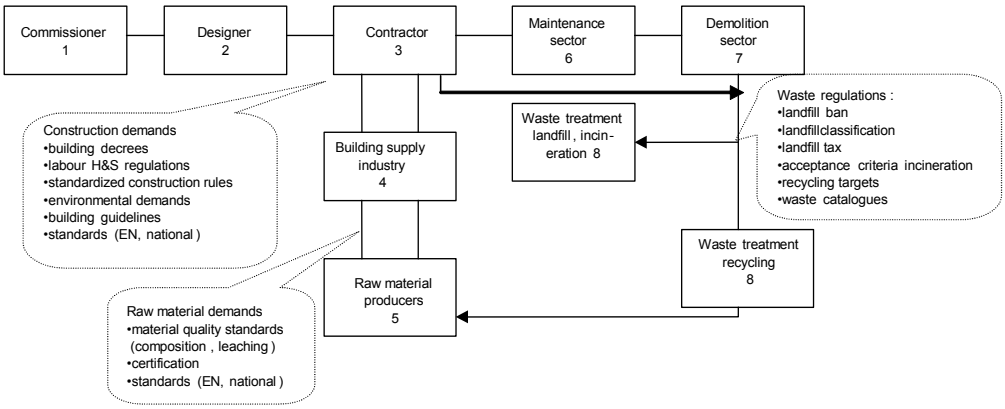
14.3 Drivers for environmental innovation

Rennings and Ziegler offer a discussion of determinants of environmental innovation under the following headings: regulatory push/pull, technological capabilities, market demand, appropriation conditions, firm size and market structure. By regulatory push/pull they mean regulatory pressure. This indeed has been consistently found to be an important driver. Here a distinction between indirect and direct

[42] World Business Council for Sustainable Development (2000): Eco-efficiency – creating more value with less impact.

pressures appears useful. As figure 3 shows, many regulations are affecting the building chain.

Figure 3. The building chain and the regulatory framework that governs it



SOURCE: VERHEUL AND TUKKER (1999)

The paper of Rennings and Ziegler says little about policy styles. This is something of an omission because historically countries have developed different styles of environmental policy. The UK for instance has an environmental quality-based approach to legislation whereas the other countries have a uniform emissions standards-based type of legislation with less attention being giving to local environmental circumstances. Other relevant dimensions are: The role of science in policy, the involvement of business in policy discussions, the implementation and enforcement of regulations, the reliance on self-regulation and monitoring, and extent to which solutions are prescribed. The issue of policy style is important because there is a relation between policy styles and the type of solutions that are adopted by companies. It is commonly believed that more cooperative policy styles lead companies to search for and adopt more preventive solutions: 'The corollary of an additive environmental bureaucracy is an additive, end-of-pipe abatement technology' (Jänicke, 1992: 84). According to Hertin and Berkhout (2002) co-operative relationships will produce positive-sum solutions.

Little quantitative research has been undertaken in analysing the impact of specific styles of environmental policies on types of environmental innovations. According to Wallace (1985) two important dimensions of policy regimes are: quality of dialogue and independence of government. Denmark, Japan, and the Netherlands rank high on both dimensions. Wallace argues that the relative success by these countries in promoting efficient and innovative responses to environmental protection is

directly related to their high ranking in quality of dialogue and independence of government. Jänicke et al. (2000) add that policies based on dialogue and consensus also tend to be innovation-friendly.

Blajeczak et al. (1999) advanced a number of hypotheses about innovation-friendly policy styles, which are very much in line with those of Porter (1991).[43]

Box 1. Innovation-friendly policy styles are

- based on dialogue and consensus
- calculable, reliable and have continuity
- decisive, proactive and ambitious
- open and flexible with respect to individual cases
- management and knowledge oriented
- based on trust and cooperation
- using a mix of policies tailored to specific circumstances
- are based on strategic planning and fomulation of goals
- support innovation and take account of the different phases of innovation
- use economic incentives
- rely on the coordination between different policy areas (vertical and horizontal policy integration)

Based on Blajeczak et al. (1999)

14.4 Does environmental policy hamper competitiveness or does it promote it?

A still controversial issue is whether environmental policy hampers competitiveness or promotes it. Porter is commonly viewed as saying that environmental policy promotes competitiveness by prodding companies to be innovative. He indeed offered a suggestion to that effect but never said that greater competitiveness will be the outcome of regulation.

The article sparked a hot debate about the real effects of regulation and environmental measures. Looking at the evidence we observe that total pollution abatement costs plus expenditures on waste management expenditures amount to 1-2 % of GDP. In the Netherlands it is 2 % (in 1998), in Belgium 1.4 % and in Germany 1.8% (figures for 1998 from OECD, 2003). In the US it is 1.6 % (in 1994). Most of it however is expenditure by the public sector and focuses on wastewater treatment and waste management. Pollution abatement and waste management (PAC) ex-

[43] In the table the term policy style is used in a broader sense than is done by Blajeczak et al.

penditures by business is between 0.3-1.2 % of GDP. It is 0.5 % of GDP for companies in the Netherlands, 0.3% for Germany and 0.2% for the US in 1998. In Poland it is 1.2% (see the table reproduced below).

Table 1b: **PAC expenditure by the business sector as a % of GDP[a,b]**

BUSINESS SECTOR		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
(not including private specialised producers of EP services)												
Canada	♦	..	..	..	..	0.5	0.5	0.6	0.5	0.5	..	0.5
Mexico		..	..	..	..	..	..	..	..	..	..	..
United States	♦	0.8	0.8	0.9	0.9	0.9	..	..	..	..	0.2	..
Japan	♦	..	0.8	0.9	1.0	0.9	0.8	0.9	0.8	0.8	0.8	..
Korea		..	..	0.7	0.7	0.7	0.8	0.8	0.8	0.6	0.7	0.7
Australia		..	0.2	0.3	0.3	0.3	0.3	0.3	..	..	..	..
New Zealand		..	..	..	..	..	..	..	..	..	..	..
Austria		*0.9*	*1.0*	..	..	0.8	0.6	0.6	0.6	0.5	0.5	..
Belgium		..	..	..	..	..	..	0.4	0.4	0.4	0.3	0.3
Czech Republic	♦	..	..	..	1.4	1.6	1.5	1.5	1.6	1.2	0.9	0.5
Denmark		..	..	..	..	..	..	..	..	..	..	..
Finland	♦	..	..	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.3	..
France		0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Germany	♦	..	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.3
Greece		..	..	..	..	..	..	..	..	..	..	..
Hungary		0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	..	..
Iceland		..	..	..	..	..	..	..	..	..	..	..
Ireland		..	..	..	..	..	..	..	..	0.2	..	..
Italy	♦	..	..	..	..	..	..	..	0.1	..	..	..
Luxembourg		..	..	..	..	..	..	..	..	..	..	..
Netherlands		0.7	0.7	0.7	..	..	0.5	..	0.6	0.5	..	..
Norway		..	..	..	..	..	..	..	..	..	..	..
Poland	♦	0.5	0.8	0.6	0.6	0.6	0.7	2.0	1.9	1.9	1.6	1.2
Portugal		..	..	..	..	0.1	0.2	0.2	0.2	0.2	0.2	0.3
Slovak Republic		..	..	..	..	..	..	..	..	2.6	1.6	0.7
Spain		..	..	..	..	..	..	..	..	..	..	..
Sweden	♦	..	0.3	..	..	..	..	..	..	..	0.2	0.1
Switzerland		..	..	..	0.6	..	..	..	..	..	..	..
Turkey		..	..	..	..	..	..	..	0.2	..	..	..
United Kingdom	♦	0.3	..	..	..	0.3	..	..	0.3	..	0.3	0.3

Notes:

a) All significant changes in PAC expenditure must be reviewed with care, as PAC expenditure may also increase because of improved sectoral coverage and data availability. Inter-country comparisons should be limited to orders of magnitude.

b) Based on the abater principle (Expenditure 1). This includes for some countries receipts from by-products, but does not include financial transfers.

N.B.: Figures in italics were derived from earlier surveys, and may not be fully comparable to more recent data.

♦ Country notes:

CAN) Excludes construction, agriculture, aquaculture, fishing and trapping, education services, health and social services; includes expenditure on pollution abatement and control and pollution prevention, environmental monitoring, environmental assessment and audits, reclamation and decommissioning, purchased waste management and sewerage service and other; from 1995 onwards: includes Secretariat estimates for other manufacturing industries.

USA) Break in time series. data for 1990-1994 and for 1999 stem from surveys that differ in scope and methodology.

JPN) Data include a Secretariat estimate for current expenditure (cf. OECD Environmental Performance Review of Japan, 2002)

CZE) Data refer to investment expenditure only.

FIN) Data include payments for bought services.

DEU) Data do not include investments in integrated technologies.

HUN) Data refer to investment expenditure only.

ITA) Data refer to enterprises with 20 employees or more and do not include investments in integrated technologies.

POL) 1990-1995 data refer to investment expenditure only.

SWE) Data refer to enterprises with 20 employees or more within ISIC/NACE 10-41 only. 2000 data refer to investments only.

UKD) Data refer to enterprises within ISIC/NACE 10-41 only.

Although small in relative terms, the total cost is substantial in absolute terms and for some industries substantial also in relative terms. In the US, pollution abatement capital expenditures and operating expenditures amounted to 5.8 bn $ and 11.8 billion $ respectively. The industries with highest operating expenditures were chemicals with 2.8 billion $ and petroleum and coal product manufacturing with 1.7 billion $ (US Census Bureau, 2002).

These absolute figures are frequently quoted to argue that the costs of environmental protection are high, creating competitive disadvantages for some industries and countries. An example is the US National Association of Manufacturers (NAM)

that is saying that as a percentage of GDP American manufacturers spend considerably more on pollution abatement than do their competitors in Germany, Japan, France, the U.K., Canada, Mexico, China, South Korea, and Taiwan. It says that in the late 1990s, the United States spent about 1.6 percent of its gross domestic product on pollution abatement costs, compared to 1.1 percent spent by Canada, 1.4 percent by Japan, 1.5 percent by Germany, and 1.4 percent by France, with detrimental effects on U.S. cost competitiveness which is said to be reduced by at least 3.5 percentage points, with the burden of those costs falling mostly on manufacturers. See http://www.sepp.org/weekwas/2004/Jan%2017.htm. The figure suggests that business is paying these costs, which they are clearly not. In the US business pollution abatement costs expenditure (PACE) as a percentage of GDP is 0.2%.

Two additional important comments should be made here. First, these figures do not say anything about benefits in the form of reduced expenditure on resources which may well exceed this expenditure. And second there is a cost for society when business or the public sector is not dealing with pollution and waste; if you do not deal with pollution and waste *in the company* you must deal with it somewhere else. Costs must be incurred either way: to deal with waste and pollution or to avoid it. The Netherlands has 600,000 polluted sites which must be cleaned in some sort of way. Costs will thus emerge either way.

As to the cost savings from environmentally motivated measures, the US Department of Commerce has also collected data on cost offsets due to savings from investment in pollution abatement equipment. For example, investment in a pollution control system to capture heavy metals, such as cadmium, that were previously discharged into the environment can partly be recouped by selling or reusing the heavy metals. The ratio of the offset to the investment in pollution abatement could form a strong incentive to develop environmental innovations. This ratio has also been subject to strenuous debate, with Palmer et al. (1995) using the Department of Commerce data to show that the offset benefits amount to less than 2 per cent of US expenditures on pollution abatement. The main problem is that the cost offsets from environmental innovations that are not covered by PACE could be much larger, not to mention the financial advantages of unintentional environmental innovation (Arundel et al., 2005).

There is growing evidence that environmental innovations can save costs and bring economic benefits. Hart and Ahuja (1996), using a sample of *Standard and Poor*'s 500 firms in the United States, report a positive correlation between financial and environmental performance.

Possible benefits from environmental innovations consist of two kinds: direct benefits and indirect benefits.

The *direct benefits* for the innovator consist of

1. Operational advantages thanks to greater resource efficiency resulting in lower resource costs.
2. Commercialisation of the innovation.
3. Reduced environmental costs of pollution control and waste management

The *indirect benefits* for the innovating company consist of

- Better image
- Better relations with suppliers, customers and authorities
- Greater attention to environmental issues from employees and management
- A changed view within the organisation: environment is not simply a cost factor
- Better knowledge about environmental issues
- An enhanced capability to deal with environmental issues
- An enhanced innovation capability overall thanks to contacts with knowledge holders
- Health and safety benefits
- Greater worker satisfaction

The nature and size of the benefits have been investigated by a study by Hulshof (2002) under 41 Dutch companies in the food, drink and tobacco, machinery, equipment, furniture and recycling, and metals and metal products, which established that the majority of firms expected that the value of the indirect benefits would exceed the direct cost in 3 years time (only 20 % of the respondents believed that the value of the indirect benefits would still be below the costs). Together, the total value of the benefits exceeded the total cost for the great majority. This study was limited to companies with more than 50 employees in sectors that were *not* environmentally sensitive. The results may not hold true for sectors subject to a great deal of environmental regulations such as the Pulp and Paper industry.

Positive benefits for the innovating company were also found in a broader study under Dutch companies in the manufacturing and services sectors employing more than 100 employees. In the longer term the benefits were believed to outweighed costs from adopting technological environmental innovations for 95% of the com-

panies in the Netherlands. In the short term, the environmental measures constituted a net cost for 15 out of 54 companies[44] (Rutten, 2001).

Table 1. Economic benefits from environmental measures in the short and long term

Long term results					
		Economic cost	Don't know	Economic gain	Total
Short term results	Economic cost	2	1	12	15
	Don't know		5	5	10
	Economic gain			29	29
Total		1	6	46	54

Source: Rutten (2001)

A detailed analysis of economic effects of environmental innovations adopted is the 4-country study by Hitchens et al. (2003). The study is for companies with less than 500 employees in the Furniture, Textile Finishing, and Fruit and Vegetable Processing industries – sectors which are not environmentally intensive. The countries studied are UK, Republic of Ireland, Germany and Italy. The study found that there was great variety of positive and negative economic impacts from adopting environmental initiatives across countries, across sectors and within sectors. For the majority of the (small and medium-sized) companies in the three (non-environmentally sensitive) industries the economic impacts were positive (Hitchens et al., 2003).

The tables below from Hitchens et al. (2003) give an overview of the economic effects for the Fruit and Vegetable Processing industry.

[44] Figures are for Dutch Manufacturing companies with over 100 employees in non-service sectors plus transport, post and telecommunication. The sectors included in the study are: primary sector (agriculture, mining etc.); food, beverages, tobacco; textiles, wearing apparel, leather; wood, cork, paper; publishing, printing; chemicals, rubber, plastics, non-metallic products; metals & metal products; machinery, equipment, furniture, recycling; gas, water, electricity; construction; transport; post & telecommunications;

Table 2. Economic impact, Fruit and Vegetable Processing industry, UK/ROI

Initiative	Labour		Cost		Price		Sales		Position		Compe-titiveness		Profit		Image		Total
	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	
Waste reduc-tion	2		2	5	1		2		2		5	1	8	3	8		39
Packaging	2	2	3	9	1	1	5		5		10		9	1	4		52
Water use and protection			1	8	3						4	1	8	1	2	3	31
Energy	1			7	1	1	1		2	2	11		10		2	1	39
Avoiding artificial ingredients			2	1		1	4		7		7		4		7		33
Organic raw materials and regional sourcing	1		9		8		7		5		7		3	1	5		46
Communica-tion			4	2	1		2		3		5		4		3		24
Total	6	2	21	32	15	3	21		24	2	49	2	46	6	31	4	264

Source: Hitchens et al. (2003) based on face-to-face interview

Table 3. Economic impact, Fruit and Vegetable Processing industry, Germany

Initiative	Labour		Cost		Price		Sales		Position		Compe-titiveness		Profit		Image		Total
	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	
Waste reduc-tion	3		3		5	1	1		1		2		5	1	11		33
Packaging	1	1	2	2	3		3	1	3	1	4	1	2	1	5		30
Water use and protection	1	1	6	7	4	2		1	1	1	1	1	7	2	7		42
Energy		1	4	8	3		1		3		2		7		9		38
Avoiding artificial ingredients				2		1			1		1				1		6
Organic raw materials and regional sourcing	5		8		4	2	8		9		7		4		10		57
Environmental management			1	1	2		1		1		3		3		1		13
Communica-tion	5		4		4	1	15		14		11		7		17		78
Total	15	3	28	20	25	7	29	2	33	2	31	2	25	4	61		297

Source: Hitchens et al. (2003) based on face-to-face interviews

Table 4. Economic impact, Fruit and Vegetable Processing industry, Italy

Initiative	Labour		Cost		Price		Sales		Position		Compe-titiveness		Profit		Image		Total
	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	↑+	↓-	
Waste reduc-tion	3	2		2		2		2		2	2	4		3	2	7	31
Packaging																	0
Water use and protection	2		5	1	4												12
Energy																	0
Avoiding artificial ingredients	9		3		3		3		6		4				7		35
Organic raw materials and regional sourcing	6		6		5		2		7		4		1		7		38
Environmental management	10		6		7		9		13		10				13		68
Communica-tion			1		1		1		1						2		6
Total	30	2	21	3	20	2	15	2	27	2	20	4	1	3	31	7	190

Source: Hitchens et al. (2003) based on face-to-face interviews

Tables 2-4 show that the effects vary among companies. Overall there appear to be employment increases and improvements in competitiveness across countries. Most of the measures are probably voluntary measures for which would be expected positive results for the company.

The performance of Dow Jones Sustainability Group Indexes (DJSGI) against DJGI provides further support to the view that perhaps the conflict between economy and environment is false. Overall, the financial performance of companies listed at the Dow Jones Sustainability Group Indices has been better than the performance of Dow Jones companies. Over a 5-year period from July 1996 to July 2001 the annualised return in % of the DJSGI was 18.35 compared to 14.81 for DJGI companies. The risk measured in price volatility was only slightly higher in the case of sustainability-driven investments (Bell, 2002). The better performance may be due to better management rather than to commitment to eco-efficiency – in general the two things go hand in hand which makes it hard to isolate a single influence.

One should be careful in drawing conclusions from this. Technology companies are overrepresented in the DJSGI. There is also a capitalization difference: the average

market capitalisation value of companies listed in the DJSGI was 2.5 times the corresponding value for those listed in the DJGI (Cerin and Dobers, 2001).

This type of knowledge (about favourable economic effects *for the company*) is not well-known. The above figures are *not* collected by companies on their own or by statistical agencies. Again we should add that for environmental intensive sectors there may be a net cost.

But even for environmental intensive sectors the competitive disadvantages from environmental policy do not appear not to be very large. In carefully reviewing the evidence Jaffe et al (1995) write:

"Overall there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness, however that elusive term is defined. Although the long-run social costs of environmental regulation is significant, including adverse effects on productivity, studies attempting to the effects of environmental regulation on net export, overall tradeflows, and plant-location decisions have produced estimates that are either small, statistically insignificant, or not robust to test of model specification.[45]

Reasons for this are that:

1. For all but most heavily regulated industries the cost of complying with federal environmental regulation is a relatively small faction of total costs of production.
2. There are not great differences in the strictness of environmental regulation between advanced countries and industrializing countries are introducing environmental laws
3. MNC do not exploit differences in regulatory strictness; they typically use state of the art technology from an environmental point of view in countries with lax environmental laws.

[45] Gray and Shadbegian (1995) analysed the connection between productivity, pollution abatement expenditures, and other measures of environmental regulation for plants in three industries (paper, oil, and steel). They found that plants with higher abatement cost levels have significantly lower productivity levels. However, other measures of environmental regulation faced by the plants (compliance status, enforcement activity, and emissions) are not significantly related to productivity, leaving the issue unresolved.

14.5 Growth trends and potentials related to eco-innovation

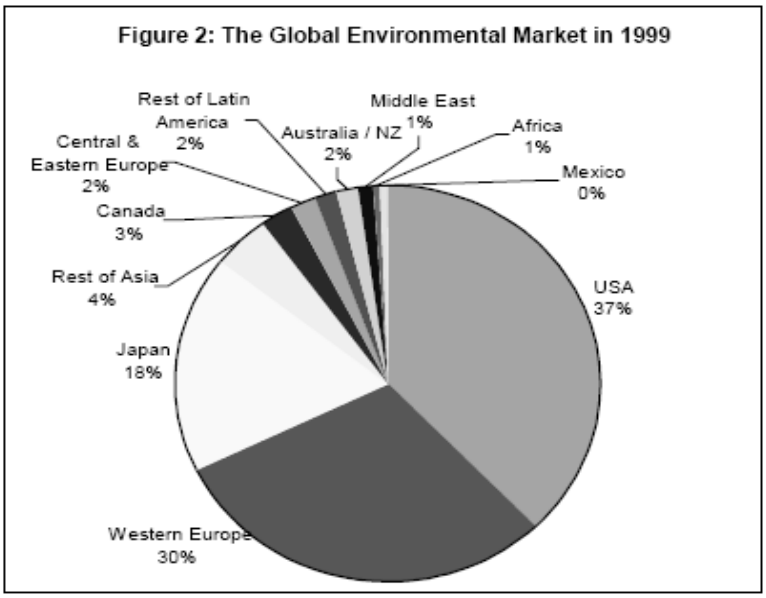
It is difficult exactly to define the "eco-industry", and therefore also its growth and export potential. A recent EU study has estimated the situation in the EU-15 and the Candidate Countries[46]. The eco-industry is broadly defined as "activities which produce goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and ecosystems. This includes cleaner technologies, products and services that reduce environmental risk and minimise pollution and resource use".[47] This means that pollution management, resources management, clean technologies and renewable energies are included, while areas such as nature protection and organic farming are not included.

The report says that EU eco-industry is a strong and diverse export sector, and is major global player alongside the USA and Japan.

- The global eco-industry market is estimated at around 550 Bn euro in 1999. This means the EU has approximately one third of the overall market (183 Bn euros), equal to the USA. The Japanese market is estimated to be worth about 84 Bn euros. The Canadian market is the next most significant at 36 Bn euro.

[46] ECOTEC (2002) "Analysis of the EU Eco-industries, their Employment and Export Potential". The approach used in this study is to focus on the final expenditure incurred by consumers when using environmental protection services. This is used as a proxy in determining the size (turnover) of the eco-industries. Data are from 1999.

[47] The eco-industries are defined according to the definition contained in "The Environmental Goods and Services Industry – Manual for Data Collection and Analysis" (OECD/Eurostat, 1999).



Source: COM(2002) 122Final

- North America remains the EU's biggest export market and has shown significant growth, while the Candidate Countries are becoming increasingly important export markets, in particular for EU Member States with close historical trading relationships to that region. The favoured method of EU company penetration into this market is through setting up a joint venture with domestic companies.

- EU companies are amongst the world leaders in developing new renewable energy technologies, both for domestic markets and worldwide. The strong and expanding domestic markets provide the basis for many EU companies to be active in worldwide markets. For example, the EU is the largest market for wind energy developments, with 75% of the total world installed capacity of 18.5 GW.

- The EU operates a trade surplus in environmental products with the rest of the world of around 5 Bn euros in 1999 which is less high than the surplus in 1997 and 1998 as a result of increased imports and a levelling out in exports. . The balance of trade with respect to environmental services is unknown.

- The total EU eco-industries supply some 183 Bn euros of goods and service a year, of which 54 Bn euros are investment goods and 129 Bn euros are services, including 'in-house' non-market services.

- Total Pollution Management and Cleaner Technologies eco-industry supplies are around 127 Bn euros of goods and services a year.

- Total Resources Management eco-industries (excluding renewable energy plant) supply around 56 Bn euro of goods and services a year.

- The current size of the renewable energy plant market in the EU is around 5 Bn euros a year.

- In real terms, total pollution management expenditure has risen by 5% per annum since 1994. The proportion of expenditure spent on operating costs has increased in real terms by 8% per annum to a level of 69% in 1999.

- There has been an increase in waste management activities during the period (of 11% per annum) and waste water (by 3% per annum) while air pollution control expenditure has fallen by 5% per annum. This is likely to be a result of substantial investments having already been made during the past 10 years. Contaminated land remediation and noise and vibration control expenditure have both risen.

- The private sector is increasingly important in driving pollution management expenditure rising from 45% of total expenditure in 1994 to 59% by 1999. Household expenditure remains around 5% of total expenditure.

- From 1994, the number of direct investment related jobs in the EU in 1999 has increased by around 75% to 550,000 jobs.

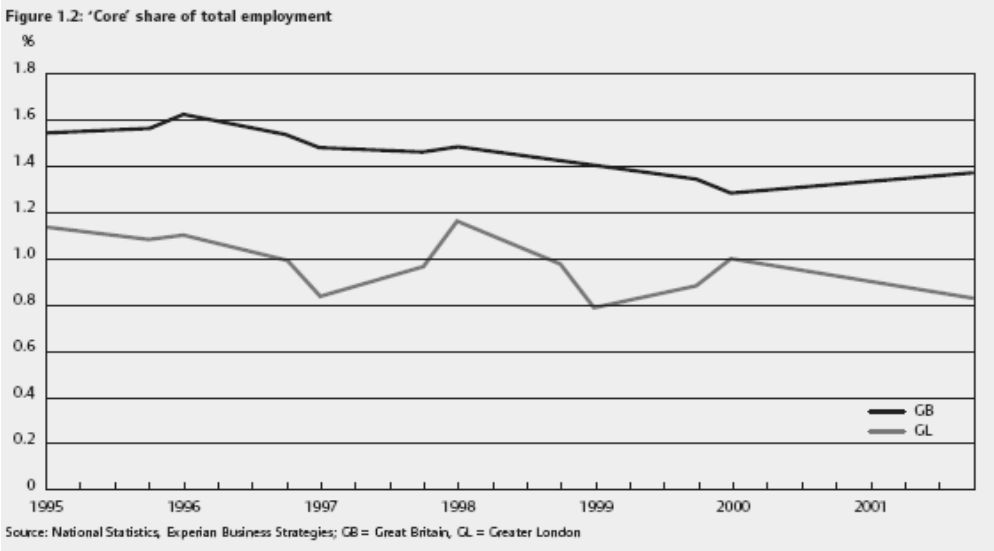
- The estimated value added provided by eco-industries, based on direct labour costs, and in 1999 is 98 Bn euros, which have gone up from 35 Bn in 1994.

Direct employment in the EU in eco-industries amounts to over 2 million (FTE) jobs in 1999. Employment levels for the wider environmental industry sector are significantly larger than the core eco-industry (i.e. pollution management) definitions used in the past. A high-end estimate of environmental employment is around 4 million jobs, using various procedures to give more realistic coverage and including the use of 'multipliers', which try to build in the indirect effects of environmental expenditure (ECOTEC, 2002)

Environmental sector employment accounts for on average 1.3% of total paid employment in the EU-15, although it is higher in some countries (e.g. Austria, Denmark, and France). For every 1 Bn euro of investment in environmental goods and services there is another 1.6 Bn euro generated in operating expenditure and the generation of 30,000 direct jobs (ECOTEC, 2002).

A detailed estimate of environmental jobs is offered in a study for London, making a distinction between core environmental jobs and non-core ones. The non-core environmental jobs are the environmental goods and services activities in the non-environment sectors. They consist of environmental accounting, book-keeping, green finance provision, environment sector organizations (NGOs), environmental lawyers, researchers and the like. Employment in the core is estimated at 35,000 in 2001 (1% of London employment) whereas total employment in environmental activities is estimated at 140,000 in 2001 (3.4% of total employment in London), considerably higher than software development and consultancy (68,000). This suggests that environmental employment broadly defined is important.

Figure 4. Environmental jobs in greater London



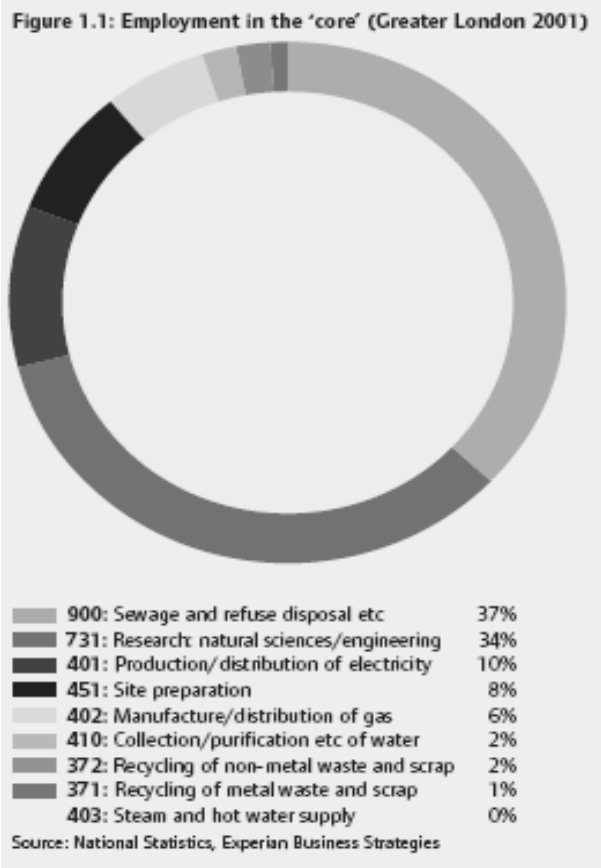


Table 1.3: Environment sector employment in London – estimates for 2001

Core commercial	15,400
Construction & civil engineering	34,000
Architecture & related engineering	17,300
Other commercial	40,100
Financial	4,800
Voluntary sector	1,700
Central Government	6,500
Local government	20,000
Education	>800
TOTAL	140,600

Source: London Development Agency (2003)

According to a study by the Swiss Federal Statistical Office, Switzerland employed approximately 50,000 people in the eco-industrial sector in 1998, equivalent to approximately 1.3 % of all employees that year. This figure comprises 15,000 employees in fully eco-industrial activities and 35,000 employees in partially eco-industrial activities. The organic agriculture, which uses few environmentally harmful processes and is therefore on the edge of the eco-industrial sector, had 12.500

employees in 1998. In the fully eco-industrial sector, 77 % of the employees were active in sewage purification, waste disposal and other disposal and 20 % and 3 % respectively in the areas of recovery and preparation for recycling and wholesale of scrap and waste material. Of the employees in the fully eco-industrial sectors, 6 % were women and 94 % men, of which only 53 % of the women and 92 % of the men were employed on a full-time basis.

Rennings and Ziegler offered estimates about employment effects of environmental innovations in the adopting company, which are found to be small. Overall 88 % of the eco-innovating firms said that the adoption of the most important eco-innovation had no notable effect on employment. In 9 % of the cases the number of long-term employees increased due to the innovation, in 3 % of the cases it decreased. This shows that there is a weak but positive relation between the introduction of eco-innovations and employment *at the company level*, with product innovations and service innovations having an above-average positive employment effect (18 % and 20 %).

No account is being taken of rebound effects: employment changes due to changed consumer expenditure. These can be important. A 1992 input-output study conducted by the American Council for an Energy Efficient Economy, comparing high efficiency and business-as-usual scenarios found that cost-effective efficiency improvements could lead to an additional 471,000 jobs in the United States by the year 2000, and 1.1 million jobs by 2010. The direct and indirect jobs generated by efficiency investments would account for only 10 percent of the job gain. Savings from lower energy bills being spent in ways that create more jobs would account for about 90 percent of this gain. Of course, these are anything more than model estimates. Further study into the cost effects of eco-innovations is needed to calculate the overall rebound effect of changed consumer expenditures. The evidence reported earlier on suggests that many environmental measures help to save costs, which suggests that the costs saving could be large. It is unclear however how the total of cost savings from environmental beneficial investments for all companies together compares to the total costs of pollution abatement and waste managment

which amount to between 0.3-1.2% of GDP. It is likely to exceed this but further research is needed for providing an answer.[48]

14.6 Policies for eco-innovation

Rennings and Ziegler single out four policies which are important for environmental innovation: emissions trading, integrated production policy, EMAS and the IPPC directive. They call for the coordination of policy, to benefit from synergistic effects. Environmental policies indeed have an important role to play but there is also a role for innovation policy (Kemp, 1997, 2000, Foxon and Kemp, 2005, Jaffe et al. 2005) especially for radical innovation and system innovation.

Suggestions for an innovation-oriented policy are given in the BLUEPRINT report (Rennings et al, 2004) and the policy note about strategies for eco-efficiency (Kemp et al., 2005). The first report focuses very much on identifiable environmental technologies and green system innovations whereas the second report focuses more on eco-efficiency as a policy target, to be achieved through 6 strategies:

1. Making companies proactive
2. Improving sustainability assessment by companies and customers
3. Improving the system of innovation for eco-innovation
4. Targeted policies for eco-innovations
5. The use of market-based instruments
6. Policy integration

There is no single best policy instrument; in general, policies have to be combined with each other (Kemp, 1997, Foxon and Kemp, 2005, Jaffe et al. 2005). A focal point for policy could be the creation of niches for promising technologies. Historical analysis of the innovation process across a large number of industries shows that new technologies typically commercialize initially through small niche markets, in which experience is gained and cost reductions through learning can be

[48] Gray and Shadbegian (1995) analysed the connection between productivity, pollution abatement expenditures, and other measures of environmental regulation for plants in three industries (paper, oil, and steel). They found that plants with higher abatement cost levels have significantly lower productivity levels. However, other measures of environmental regulation faced by the plants (compliance status, enforcement activity, and emissions) are not significantly related to productivity, leaving the issue unresolved.

made (see Kemp et al., 1998; Beise, 2001, Rennings and Beise, 2003, Foxon, 2003). Market development is driven not just by price signals and expectation of profits, but also by the development of appropriate knowledge and skills bases, and the formation of institutional structures which support the emerging new technologies (see Norberg-Bohm 1999a, 1999b; Hoogma et al., 2002, Jacobsson and Johnson 2000 and Jacobsson and Bergek, 2004). These issues have been recognized in recent work by the International Energy Agency (IEA, 2003) which argues that policy initiatives designed to facilitate the adoption of cleaner energy technologies should combine three basic priorities:

1. Invest in niche markets and learning, in order to improve technology cost and performance;
2. Remove or reduce barriers to market development that are based on instances of market failure; and
3. Use market transformation techniques that address stakeholders' concerns in adopting new technologies and help to overcome market inertia that can inhibit the take-up of new technologies.

Greater attention should be given to green system innovation. In general environmental policy has merely stimulated pollution control and pollution prevention through process changes, product changes and waste minimization; it has not stimulated system innovation. In our view it is important to have programs for system innovation. The rationale for this is that system innovation may provide factor 10 improvements in environmental impact compared to the factor 2 improvements associated with incremental changes or factor 5 improvements connected with partial system design (Factor 10 Club, 1994). System innovation is not about single environmental innovations but about system changes offering environmental benefits alongside other types of benefits—economic ones and social ones, although there may be tradeoffs, especially in the early phase.
Butter argues that a policy approach to system innovations should have three layers:

- Layer 1 – System innovations: the development, dissemination and adoption of singular innovations in individual organisations.
- Layer 2 – Singular innovations: the stimulation and alignment of singular (individual) innovations that will contribute to the system innovation.
- Layer 3 – Innovation climate: the creation of a supportive generic climate for sustainable innovations.

The basic assumption behind the three-layered approach is that, because of specific problems of uncertainty, complexity and specialized interests (resistance from incumbents, need for institutional change and change over costs), system innovation will need a different approach than singular innovations System innovations, which are by their nature disruptive, are unlikely to be supported by regime actors who favour system improvement options *within* technological regimes. Policy for system innovation should focus on outsiders (Ashford 2002).

The general innovation climate for sustainable innovations may be promoted through internalising external costs, aligning innovation policy with environmental policy and promoting entrepreneurship.

Practical details of this scheme for policy need to be further worked out; however the underlying message is that incentives for innovation, especially sustainable system innovation, require a multi-pronged, conceptualized strategy (Foxon and Kemp and the references therein).

The paper of Rennings and Ziegler does not say anything about the Cardiff process on environmental policy integration, perhaps because developments thusfar have been discouraging. Attempts at environmental policy integration have been studied in the COMPUS study and the OECD study "Governance for sustainable development" for selected countries. The COMPUS study found that most progress has been achieved with vertical environmental policy integration (VEPI) – which is PI *within* the governmental sector – and far less progress with horizontal environmental policy integration – which is integration *across* policy sectors. The rather negative conclusion of the COMPUS study is that

"*The process of intra-ministerial integration has been more formal than substantive. (...) Even where the intra-ministerial integrative ideal has been more thoroughly pursued – as in Norway or Canada – the quality of the departmental engagement with environmental concerns or the broader sustainability development agenda is typically weak*".

About the EU it says that "the environment has remained essentially marginal to key spending programmes such as the Common Agricultural Policy and the Structural Funds" (Lafferty and Meadowcroft, 2000, quoted in Lafferty, 2002, p. 21).

Experiences with the Cardiff process are described in Box 2.

Box 2. Experiences with policy integration for the environment in the EU

Cardiff let to a considerable *agenda setting* effect in almost all sectors, in relation to environmental issues, and has initiated a multitude of mostly internal meetings, discussion papers, studies, and policy statements. It resulted in political mandates for further activities in the sectors. The Industry Council, for example, had not had a substantial discussion of environmental issues since 1992, and environmental projects initiated by the DG had therefore lacked a strong political mandate. On the other hand, few of the Cardiff strategy documents systematically mapped the interrelations between the sector and the environment. In some sectors, e.g. EcoFin, Internal Market and Industry it is remarkable how little the process contributed to providing a coherent framework that clarifies problems, opportunities, and responsibilities at the interface between sustainable development and sectoral policy. As a result, the agenda-setting process which undeniably took place, remained diffuse in these sectors.

Capacity building could be observed in some sectors, but it remained weak and patchy. Those policy areas that have been confronted with environmental issues for a longer time, for example Energy, Transport and Agriculture, were able to deliver more comprehensive strategies. In the General Affairs, Internal Market and Fisheries sectors, in contrast, the Cardiff process has exposed unfamiliarity with wider environmental issues. The Fisheries Council, for example, openly acknowledges that fishing practices 'threaten marine bio-diversity'. Failing to provide a strategy to the Gothenburg Council, it 'invites the Commission to explore further the operative implications of the integration of environmental objectives and principles' into the Common Fisheries Policy (Fisheries Council, 2001). The General Affairs Council recognises that 'further work' is needed to 'formulate a comprehensive strategy' (GAC, 2001). Some new capacity might have built up in these sectors, but it was not sufficient to respond adequately to the mandate of Council formations. In some cases, sectors chose to rely on external expertise (DG Environment, European Environment Agency, and research institutions), thereby reducing the scope for capacity building.

Source: Hertin and Berkhout (2001)

Whilst the EUs own policies show clear flaws in terms of integration, the EU is committed to EPI. There was a clearly expressed will from the start, which was reinforced at various levels throughout the entire process (Kraemer, 2001).

Box 3. A proposal to stimulate eco-efficiency

This is proposal for policy to stimulate competitiveness and environment. The proposal consists of the use of eco-efficiency targets for manufacturing and service sectors, including the public sector.

The proposal is require companies to improve their eco-efficiency with 10% in 4 years time and 25% eco-efficiency target in 8 years time, to be achieved through a compulsory improvement programme defined by the companies themselves, which is discussed with permit writers.

Resource efficiency would include: (non-renewable) energy use, water consumption and raw material use. To increase flexibility and economic efficiency, improvement does not have to be uniform on all three fronts. Companies can opt for 20% or 30% reduction in energy use, a 20 or 30% reduction in water consumption and a 25% or 15% reduction in the use of raw materials; i.e., they can choose any kind of numbers they want as long as it brings the company close to the overall target.

The scheme could be a voluntary with a naming and shaming mechanism of enforcement or a legal system. Given that eco-efficiency also brings benefits for companies perhaps a legal system is not needed. The target could be a target for countries, sectors, individual companies, and individual sites. The target could be differentiated for sectors.

The advantages are: 1) it is a simple model which allows for different choices (which makes is efficient); 2) there is an obligation to do something, 3) it involves a tool for achieving this (the improvement programme designed by the companies themselves on an individual basis); 4) it is suited for all companies, including SMEs; and 5) it is dynamic – allowing for adaptation.

Useful suggestions for environmental policy integration (EPI) are also offered by Lafferty (2002). These consist of the specification of major environmental impacts of policies and activities; the establishment of a system of dialogue and consultation; sectoral strategies for change; actions plans, budgets and monitoring programmes for VEPI (vertical EPI). For *horizontal* EPI he proposes the use of long-term sustainability strategies for sectoral domains; specific governing bodies entrusted with overall coordination and supervision of the integration process; communication programmes; and national action plans with targets and ongoing programmes for assessment, feedback and revision and conflict resolution procedures.

In the Netherlands environmental policy integration is worked at as part of an overall commitment to transition management (see Kemp and Loorbach, 2005). Frameworks of environmental policy integration and transition management are believed to be useful for making instrument choices and making progress towards greater eco-efficiency.

Innovation for the environment stands to benefit from the use of eco-efficiency goals. The Netherlands has good experiences with covenants for energy-saving for industrial sectors. The setting of eco-efficiency goals could promote industries to pay more attention to do more. For promoting eco-efficiency, it may be useful to formulate quantitative targets for sectors. The targets can be part of the Lisbon strategy or part of a separate eco-efficiency strategy.

To me it seems that an eco-efficiency policy is one that can bring multiple benefits to Europe, allowing a reduction in environmental impact in a growing economy. Eco-efficiency can be achieved through “high tech” solutions such as nanotechnology and through mundane changes. Getting prices right by internalizing external costs is important but will not be enough and will take time to come into being. There remains a need for special programmes for innovation for the environment. For this the three-layered model of Butter (2002) appears a useful guide, with the following layers: a) improving the general climate for innovation, b) specific policy support for radical eco-innovations, and c) adaptive programmes for green system innovation. The latter is probably best pursued under a framework of transition management (Rotmans et al, 2000, 2001), making use of lead market policies and strategic niche management (Kemp et al., 1998, Hoogma et al., 2002). In the past policy focused too much on narrowly defined environmental technologies. In the future the focus should be on all innovations for the environment, including general purpose technologies and green system innovations that may bring great benefits in the longer term. The open method of coordination may be used for identifying “policies that work” and for identifying innovation-friendly policy styles. In the short term the greatest gains can be achieved through eco-efficiency policies. It makes more sense for Europe to be focusing on eco-efficiency than on technological missions for nanotechnology and other pet technologies.

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Part VI

Case Study #4

15 Case study paper no. 4: Green taxation

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15.1 Abstract

Thus there are two rationales for green taxation: the first argues for such taxes in terms of the environmental benefits at the 'micro' level and the second justifies them in terms of broader fiscal and employment benefits. While both arguments have strong proponents they also have their critics. First some question the link between the theoretical foundations of green taxes and the actual taxes that have been imposed. Second and related to that, there are economists who argue in favour of other instruments, such as permits, standards, subsidies, etc., as more efficient tools for environmental regulation. Third, green taxation has been criticized for its possible negative impact on competitiveness, employment and growth.

The micro argument for taxes is based on externalities. It shows that that taxes do have a significant role. They can be used in many situations and they provide flexibility of response on the part of polluters and offer continued incentives to develop cleaner production methods. Unfortunately in practice the rates applied are too low, exemptions are common and a great deal of debate is about how to share the revenues rather than about how to make the system more effective. On the positive side most environmental regulations, including taxes have not had a noticeable negative impact on employment or on economic growth.

The second basis on which the case for green taxation is founded is the Double Dividend argument. This paper shows that while the possibilities of such a dividend are there, there are several factors that would lead to a small employment dividend. Most empirical studies support this conclusion but some suggest that there may not be such a dividend.

Green taxation should be seen as a process in which the tax instrument is part of the fiscal and environmental 'toolbox'. We continue to learn when and where to use such taxes. If we keep expectations reasonable we should achieve better results and also not be disappointed.

15.2 Introduction

There is no formal definition of 'Green Taxation', although most people have a similar understanding of what they mean when they use the term. Taxes are considered 'Green' if, in some way, they promote the protection of the environment and the natural resources of the planet. Thus any tax that reduces the use of fossil fuels could be considered green, and in this context the history of taxation of petroleum products goes back a long way (Denmark for example had a petrol tax in 1917). Other green taxes that have been in existence for a long time include taxes on coal, and on the exploitation of natural resources[49]. In Russia in the Tsarist period of the 20th century for example, around 90 percent of local revenues came from taxes on the use of natural resources.

So in this sense green taxes are not new and have been a part of the structure of taxation well before the Green Movement was even thought of. What is new, however, is the targeting of such taxes to meet specific environmental objectives. The earlier taxation of oil and natural resources was seen largely as a means of collecting revenues in a way that was not too painful. Now we see them significantly as a means of reducing environmental burdens. The level of such taxes has, of course, to balance the benefits in terms of environmental gains against the costs of taxation, in terms of reduced consumption and production. Back in the 1930s economists established the framework for calculating the 'optimal' tax as a balance between these two forces and we will present that later. The key concept in this analysis was that of negative 'externalities'. Anthropogenic activities were said to create negative externalities when the actions of one person or group resulted in damages to another group, and when the first group did not take proper account of such damages. The obvious example is a polluter who does not take account of the consequences of his emissions on other when deciding on the level of his own activities.

More recently proponents of green taxation have stressed another potential of such taxation, and that is the possibility of shifting the tax base away from the taxation of labour, capital and goods and services, to the taxation of pollutants. The claim is

[49] To be sure there have also been substantial subsidies on natural resource use as well. For a discussion of subsidies see von Moltke et al. (2004)

that such a shift creates benefits in terms of a more efficient fiscal system (with lower welfare losses from taxation) as well as, possibly, stimulating employment in countries where there is structural unemployment (Pearce, 1991).

Thus there are two strands in the green taxation literature: the first that seeks to determine such taxes in terms of the environmental benefits at the 'micro' level and the second that seeks to justify them in terms of broader fiscal and employment benefits. While the general case for green taxation is made on the grounds cited above, critics point to a number of problems. First some question the link between the theory of internalizing externalities and the implementation of such a system in practice. Even the best practical tax design would not meet the assumptions under which such a tax could be guaranteed to be welfare maximizing[50]. Second and related to that, there are economists who argue in favour of other instruments, such as permits, standards, subsidies, etc., as more efficient tools for environmental regulation. Even these, however, do not in practice meet the conditions for welfare optimality. Both these debates take us into the realm of the 'second best', where we have to compare alternative policies (e.g. using environmental taxes versus the use of direct control) to achieve the desired objectives. Third, green taxation has been criticized for its possible negative impact on competitiveness, employment and growth. Ironically then there are those who suggest that green taxation can increase employment and even enhance growth and those who claim the opposite.

This paper addresses these questions in turn. It begins by setting out the case for Green Taxation on externality grounds and then on macro-fiscal grounds. This is followed by a review of the experience of green taxation in Europe. Finally the paper concludes with a discussion of the open questions and issues for debate.

15.3 The theoretical arguments for and against green taxation as a tool for environmental and economic policy

15.3.1 The pure externality argument

With the onset of industrialization the range of external effects needing some action by the authorities grew considerably. The processes of industrial production involved large-scale use of fossil fuels, which generated harmful pollutants, as well

[50] A tax is said to be welfare maximizing if it results in an allocation of resources such that no person can be made better off without someone else being made worse off.

as the use of chemicals and other inputs that created gaseous, liquid and solid waste. From the early Nineteenth Century we see those responsible for environmental regulation struggling to find the best way of dealing with this problem. Until recently – perhaps the last 30 years or so – the measures taken involved passing a law, or issuing an administrative order, proscribing certain practices and requiring others to be undertaken. In the UK, for example, factories were ordered, by various parliamentary acts passed between 1820 and 1926, to reduce the output of smoke, and more recently the burning of coal was banned in certain urban areas. As transport became a major source of pollution, the use of more polluting fuels, such as lead, was banned and vehicles were required to be fitted with devices that reduced emissions.

All the environmental measures discussed so far are referred to as *command and control* regulations. The authorities tell you what you must or must not do, and there are penalties under civil and/or criminal law if you fail to comply. When economists turned their attention to the environment their instinctive reaction was to look for alternative methods of regulation that did not involve compulsion but that relied on economic incentives to achieve the same goals. The British economist Pigou first noted that if you could tax the activity generating a negative externality (i.e. one causing harm to third parties or to the environment), the party responsible would reduce the intensity of that activity. And by selecting the tax level suitably, the authorities could achieve whatever goal they wished in terms of reducing the negative external effects (Pigou, 1932).

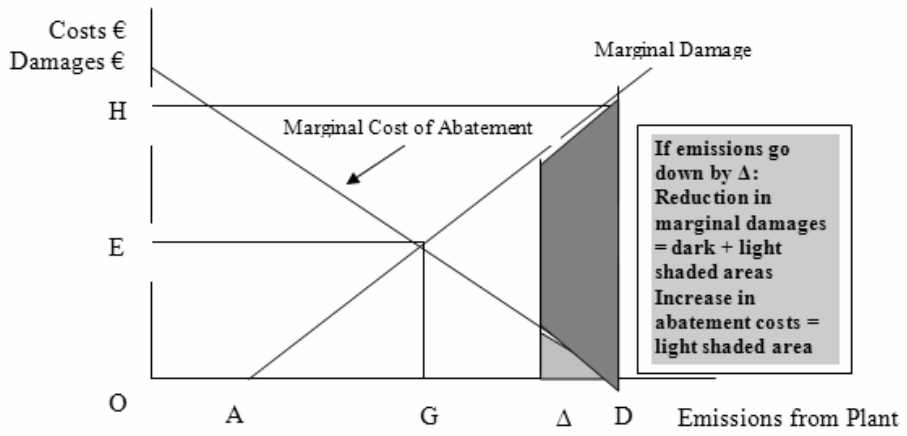
15.3.1.1 Principles behind economic instruments: Controlling emissions to air and water

The objective in theory for the use of a tax or other economic instrument is to regulate the level of an externality generating activity to its optimal point. This point is defined as one where reduction in the additional damage caused by the activity is equal to the cost of abating that additional amount of the activity. Figure 1 shows how this is arrived at[51].

[51] This figure is meant to add our understanding of the issues involved in internalizing an externality. As opponent Smith has noted, it is not a complete description of the problem and should not be seen as such.

In the absence of any regulations the enterprise will generate an output of OD, and will undertake no abatement of emissions because it has no incentive to do so. As it undertakes reductions in emissions (by adopting clean technology, or by using end of pipe clean up or by reducing output, or any combination of these), it incurs costs. These costs are shown by the Marginal Cost of Abatement curve, which gives the additional costs incurred when emissions are reduced by one unit. The curve slopes from right to left because, as more and more reductions are undertaken, the additional, or marginal costs rises (enterprises undertake the lower cost options first). At the same time, the emissions are known to cause damages. At the level of emissions OD, damages are OH as shown in the figure, and as emissions decline, so do the marginal damages. The underlying assumption in the figure is that these damages (to health, property, ecosystems etc.) can be measured in money terms. This is a controversial assumption and, indeed does not hold in all cases. But it is made here for the convenience of showing what, *in principle,* the optimal level of an externality would be.

Figure 1: The optimal level of control of a pollutant



As emissions are reduced there is a reduction in damages and an increase in abatement costs. For a small reduction of Δ, from OD, the addition costs and reduced damages are also shown in Figure 1. Clearly the damages fall by more than costs of abatement increase, (there is a net gain equal to the dark-shaded area) and so the reduction of Δ is justified. This holds for all reductions up to the point at which the marginal cost of abatement and marginal damage are equal – i.e. at the

point where the emissions equal OG and the marginal costs and damages are both OE. *This is the optimal point for the externality.*

There are a number of important points to note about this analysis, which is the fundamental theoretical basis for determining the control and regulation of externalities.

A. The optimal regulation of emissions does not imply a level of zero emissions. Environmentalists would say that an ideal (i.e. optimal) situation would be with no emissions but economists point out that with a requirement of no allowed emissions from the activity the costs of abatement generally exceed the damages and this is not optimal. This is the major difference in approach between economic and ecological solutions.

B. The optimal solution can be obtained in a number of ways. These are:

i. An order to the polluter to produce only OG in the form of emissions, which is a direct or **command and control** solution. This may seem easy and indeed would be so if there were only one plant generating the emissions. In practice the marginal cost of abatement curve is derived from the activities of lots of polluters, and the reductions along it are not undertaken at only one plant. Hence the amount of information needed to implement this command and control solution is very large and, as noted later, does not offer any flexibility in terms of response to the polluters.

ii. A **tax or charge** of OE per unit of emissions. With such a charge the emitters will undertake reductions to the point OG because the costs of abatement are less than the charge.

iii. Instead of a charge, the polluter could be given a **subsidy** for each unit of reduction equal to OE. This acts in the same way as a charge; the polluter finds it pays to make reductions to the point OG because the subsidy it receives exceeds the costs of abatement. Beyond that point the subsidy does not cover the costs of abatement.

iv. Issue **tradable permits** equal to OG and allow polluters to emit as much as they like, as long as they are in possession of a permit. It can be shown that in such a situation a market will develop for permits, with a price equal to OE. Those whose costs of abatement exceed OE will buy permits to cover those costs. The permits can

be given to emitters in proportion to existing emissions or they can be auctioned. In the former case if a polluter was currently emitting 100 units out of a total of 1000 and the authority wanted a overall reduction from 1000 to 800 (i.e. 20 percent), it would allocate the polluter only 80 units, with the right to buy more if he needed them or less any surplus if he deemed it preferable to make a bigger reduction than 20 units.

v. Related to the last case, we could think of a **market for emissions rights**. The laws would have to be passed defining these property rights for emissions, creating a registry of ownership of these rights and allowing them to be traded as desired. A full market solution is perhaps not easily implemented for emissions, but could be implemented for development rights on land. An owner of a parcel of land might have prior development rights on that land when he purchased it. For reasons of conservation these rights may be revoked on that land but, with a market is rights, he could demand the right to similar rights elsewhere.

Thus taxes are only one of the possible solutions to the externality problem and there is a great deal of debate as to which instrument is the most appropriate. There is some agreement, however, on three things. The first is that the subsidy solution is inferior to both the tax – or tradable permit/emissions rights solutions – and the second is that frequently the market based options of taxes or permits result in a more efficient outcome than a command and control option. In Figure 1 it is difficult to see the benefits of the market-based options because all options result in the optimal solution of OG emissions. But this is misleading because in reality we do not have full knowledge of which polluter has which cost curve and we do not know the damage curve with much precision. Hence we cannot identify the optimal solution precisely. Sophisticated studies that take account of imperfect information have shown that in quite a wide set of cases, imposing a charge, which may be approximate yields better results (in terms of total costs of abatement in achieving a given target reduction) than using command and control policies (Tietenberg, 1990).

The preference of taxes over subsidies as a means of getting to the optimal point is a consequence of a number of arguments. First, subsidies, although they act as 'mirror' incentives to taxes in the simple diagram, actually are not complete mirrors because they also increase the profitability of the related activities and therefore

can result in increased emissions on that count[52]. Second, there is always a problem of corruption when handing out subsidies. Third subsidies have to be paid from some source and usually that source is general taxation, which itself has a distortion effect. The latter is measured as the 'marginal cost of public funds', with a euro of taxes having a welfare cost of more than one euro (for the EU this marginal cost is around €1.25-1.3 euros (Snow and Warren, 1996). Fourth there are difficulties in defining who should receive the subsidy. Would a payment be made to an enterprise that closed down? If so, for how long would this payment be made? For all these reasons, economists have a strong preference for taxes over subsidies as the instrument of choice to correct externalities.

The second area where there is broad agreement is the benefits of tax scheme or market permit scheme over command and control on the grounds of the increased flexibility that they offer. The figure does not show this, but, as we elaborate in Section 15.4, there is a real benefit in allowing polluters to have some choice in how they reduce their emissions. The more strictly the actions are prescribed, the more likely it is that the chosen solution will be more costly than necessary.

The choice between taxes and permits partly depends on political issues of who is made to bear the cost of the adjustment, and partly on economic considerations of uncertainty. As Weizmann (1974) showed, if we are not certain of the costs of abatement and impose the wrong (too high) a tax rate, the cost will be borne by industry and we will miss the emissions reduction target. On the other hand if we use permits and are too strict in the number issued, we will over reach the emissions target, but at a possibly higher cost in terms of cuts in output and employment. The actual argument is quite sophisticated and depends on the slopes of the abatement and damage curves. In practice, given that empirical studies in a number of areas suggest that the marginal damage curve is relatively flat, a tax is more likely to get you the right answer than a permit scheme.

On the choice between permits and taxes, there is also the question of to whom the permits are initially allocated to. This issue, which creates both problems and opportunities, is discussed again in Section 3. We should note further at this stage,

[52] More generally, as opponent Smith has noted, the actual value of the MAC curve will depend on the choice of instrument and, with some command and control policies its shape may not even be monotonic.

however, that with small numbers of polluters, a permit scheme is less viable as the permit trading will take place in thin markets.

15.3.2 The fiscal-employment benefits argument[53]

The case for the macroeconomic benefits of green taxation in conjunction with the environmental benefits is also referred to as the 'double dividend'; the argument being that a switch to environmental taxation, combined with a reduction in labour or other taxes in a fiscally neutral way, would lead to a double dividend. The idea behind this suggestion is that environmental taxes not only produce improvements in the environment (the first dividend) but also generate substantial amounts of government revenue. This additional government revenue would allow governments to reduce the rates of other taxes in the economy while maintaining a constant level of total revenue and expenditure: the revenue-recycling effect. As these other taxes are generally regarded as having a distorting effect (interfering with the efficient functioning of markets), the reduction in their rates can be seen as improving efficiency and thus producing a second benefit from the adoption of environmental taxes[54].

15.3.2.1 Gross welfare double dividend vs. employment double dividend

The literature in this area identifies two 'second' dividends: a 'gross welfare' dividend and an employment dividend. The *gross welfare dividend* arises because the tax changes reduce the distortions in consumer choice that result from sales and other taxes. The word "gross" indicates that one is not accounting for the welfare gains from an improved environment. The *employment dividend* arises because one possible distortionary effect of taxation is the reduction of employment. Such a reduction in employment could result from taxes that are obviously related to employment, such as income taxes and social security taxes, but also from taxes that affect the real value of workers' wages, such as value added taxes and excise duties. Thus one aspect of the double dividend could be an increase in employment that follows from a reduction in one or more of these taxes. As discussed later, the

[53] This section draws on considerably on Markandya, 2005

[54] The rate of the tax on the environmentally damaging pollution is not equal to the Pigovian tax as described above, but rather equal to a weighted average of such a Pigovian tax and a revenue raising tax. This point has been made by a number of authors (Bovenberg and van der Ploeg (1994b, 1996), Ligthart and van der Ploeg, 1999).

literature suggests that it is easier to obtain the employment dividend than the gross welfare dividend.

Although a large part of the theoretical double dividend literature deals with the gross welfare dividend, the focus of the policy discussion has been mainly on employment, at least in Europe. The literature on the gross welfare dividend generally does not address issues of employment: it assumes that there is no involuntary unemployment and places no particular value on additional employment creation. The idea is that there is very little gain in individual welfare in moving somebody from voluntary unemployment into employment, in contrast to the very substantial gains in moving somebody from involuntary unemployment into employment. Of course, both types of employment creation can improve tax revenue, and that effect is considered in the theoretical literature even when issues of employment are not addressed.

The pathway by which tax reductions might increase employment depends crucially on whether or not the labour market is in equilibrium, with demand equal to supply. If there is disequilibrium in the labour market, with supply greater than demand and consequent involuntary unemployment, employment creation requires an increase in labour demand. This could be achieved by reducing the cost of employing labour, for example by reducing employers' social security taxes. It is important to note that any increase in employment from this policy does not necessarily imply a reduction of unemployment by the same amount (or at all), because the increased availability of jobs may induce additional people to enter the labour force. The estimates of employment creation that are quoted later in this chapter should be interpreted with this point in mind.

On the other hand, if the labour market is in equilibrium, with demand equal to supply and no involuntary unemployment, an increase in employment requires an increase in labour supply. This could be achieved by increasing the returns to work, by reducing direct taxes on labour income or by reducing sales taxes on goods that workers wish to buy, provided that workers respond positively to such increased incentives. The part of the theoretical double dividend literature that has dealt explicitly with employment has concentrated mainly on the case of involuntary unemployment, not on this case.

15.3.2.2 Weak vs. strong dividends

The primary purpose of environmental taxes is to reduce damage to the environment by increasing the costs of harmful actions, such as the burning of fossil fuels

that produces carbon dioxide. The idea is that consumers and firms will then be forced to take account of the effects of their actions on the environment. For this to work properly, the size of the taxes should equal the monetary value of the environmental damage that the actions cause. Taxes that meet this requirement are referred to as 'Pigouvian' taxes that we discussed in the previous section.

If the revenue from such Pigouvian environmental taxes were sufficiently large to fund all government expenditures, the existing distortionary taxes could be completely removed. Then the economy would be undistorted by either taxation or environmental externalities. The double dividend would be a reality in both welfare and employment terms.

However, most governments have expenditure levels that are more than 40 percent of their GDP, and Pigouvian taxes will not raise that level of revenue. It is therefore necessary to consider the effect of environmental taxes as *reducing* rather than entirely *replacing* other taxes. This means that the interaction between environmental taxes and other taxes—the tax-interaction effect—has to be considered, and it is this interaction that causes the analysis to be so complicated.

In order to understand this interaction, it is helpful to follow Goulder's (1995) distinction between the "weak double dividend" hypothesis and the "strong double dividend" hypothesis. The weak double dividend is simply concerned with what is done with the revenue from environmental taxes, saying that it is better to use this revenue to reduce the rates of distortionary taxes than to provide lump-sum payments to citizens. The strong double dividend says that the replacement of some existing taxes with environmental taxes will reduce the distortionary cost of raising the current level of government revenue, thus allowing real incomes and consumption to rise.

The weak double dividend has been shown to hold in almost all models. The most important exception is when the lump-sum payments are markedly better than tax reductions at raising the incomes of poor households.[55] However, the details of these results are not worth discussing here because the weak double dividend is simply about how to spend the environmental tax revenue. Although it may have

[55] As this sentence illustrates, the theory can also take account of the distributional effects of taxes. However, these have not been paid much attention in the double dividend literature and so will not be emphasized here.

some implications for how environmental taxes are spent and possibly on the choice between taxes and other instruments, it says nothing to enhance the case for using environmental taxes to replace other taxes[56]. It is the strong double dividend that needs to be true in order to claim that environmental taxes can contribute to the efficiency of the economy in other ways than improving the environment. The conditions for the existence of the strong double dividend require more sophisticated analysis, and there is a wider range of disagreement.

Because the strong double dividend is concerned with reducing the distortionary cost of the tax system, the analysis can only be fully understood in the context of the theory of optimal taxation: a theory that deals with the problem of minimizing the distortionary costs of a tax system that generates a given level of government revenue.

The first important fact to be aware of is that the theory of optimal taxation until recently has not concerned itself with environmental issues[57]. It is simply concerned with raising revenue efficiently, and so we can refer to such taxes as "revenue-optimal". Thus a revenue-optimal set of taxes is one that minimizes its effect, as measured by a "distortionary cost", on the actions of market participants, without regard to its environmental effect.[58] If a country has adopted a revenue-optimal set of taxes, there is no possible change to those taxes that will raise the same revenue at a smaller distortionary cost. In particular, the imposition of a higher rate of tax on a good that damages the environment cannot reduce the distortionary cost of the tax system, and can generally be expected to increase it. This implies that *the strong double dividend cannot be true in an economy where the taxes are revenue-optimal*.

Of course, this does not mean that there is never a strong double dividend, because it is unrealistic to suppose that countries currently have revenue-optimal taxes. What it does mean is that a strong double dividend exists when (and only

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[56] Opponent Smith takes the view that the weak dividend is significant in that it shows the benefits of raising taxes to address environmental problems rather than using schemes such as grandfathered permits. Although formally the weak dividend does not state that such tax revenues are better than other instruments, some studies, comparing permits with taxes have found this to be the case.

[57] Sandmo (1975) was an exception. More recently the work of Parry and others has developed on that and begun to look at the environmental dimension more seriously.

[58] This concept of revenue-optimal taxes takes account of all the effects of tax changes, including those that result from the shifting of the tax burden between different groups in society.

when) the imposition of an environmental tax moves the tax structure closer to the revenue-optimum. Thus, those parts of the literature that claim to show the existence of a strong double dividend are based on presumed situations in which the existing taxes are not revenue-optimal and environmental taxes produce a move towards the revenue-optimum[59]. In contrast, the papers that show the absence of a strong double dividend assume either that taxes are already revenue-optimal or that the environmental tax does not move the system towards revenue-optimality. Which of these situations applies to any particular country is, of course, an empirical question, and this is where computer simulation models are useful.

The discussion that follows demonstrates two basic phenomena. First, an employment dividend can arise if the burden of the tax system is shifted away from labour, even if the overall burden of taxation is not reduced. Second, it can also arise if the overall burden of taxation is reduced. The existence of wage rigidities or other sources of involuntary unemployment offers scope for the second phenomenon. We note, however, that the existence of an employment dividend in the above cases is neither necessary nor sufficient to ensure a gross welfare dividend, although in the absence of involuntary employment the employment and gross welfare dividends are likely to go together.

15.3.2.3 The employment double dividend: The case with involuntary unemployment

In economic terms unemployment is caused by the wage being higher than its market clearing value. This leads to a situation where the demand for labour is less than its supply, and the result is involuntary unemployment. In this situation, the only way to create additional employment is to increase the demand for labour. This section analyses how the use of environmental taxes to replace in part existing taxes might achieve such a demand increase.

There are several possible explanations for the “high” wage, including trades unions and various models of asymmetric information, but the analysis is easier if we start by simply taking the real after-tax wage as fixed[60] and only later look at the

[59] Opponent Smith rightly notes that, while true, this is not particularly useful in terms of the design of the environmental tax from the environmental perspective.

[60] This is based on the idea that workers are interested in what they can buy with their (after-tax) earnings, and that they can enforce a particular minimum level of this.

implications of how it is determined. Taking this approach, the important aspect of the unemployed economy is the distortion of the wage, and the standard response from optimal tax theory is to look for ways to reduce that distortion either by direct subsidy or by introducing offsetting taxes elsewhere.

It might be thought that the distortion of the wage could be reduced directly by reducing social security (payroll)[61] taxes, while imposing environmental taxes to replace the lost revenue. However, it must be recognized that the environmental taxes will increase the cost of goods that workers buy, thus tending to reduce the **real** wage. This is the tax-interaction effect. It implies that workers will demand wage increases to restore the previous value of the real wage and this will offset the effects of the reduced payroll taxes. In other words, the move from payroll taxes to environmental taxes has not reduced the taxation of workers; it has simply rearranged it.

In order for a move from payroll taxes to environmental taxes to increase employment, the taxation of workers must be reduced. This can be achieved in two possible ways: (i) the shifting of the tax burden from workers to other groups and (ii) improvement in the efficiency of the tax system. We deal with these two possibilities in turn.

15.3.2.4 Shifting the tax burden

One case in which a shift from payroll taxes to environmental taxes could increase employment is when some consumers are not workers. For example, imagine that some consumers live entirely (or much more than average) on capital income. The imposition of a sales tax on an environmentally damaging good that was used to reduce labour taxes would move some of the tax burden from workers to non-workers, and so reduce the distortion of the labour market, provided that the non-workers did not emigrate as a result. In other words, the revenue raised from the sales taxes would be more than sufficient to generate a subsidy that reduces the cost of labour to employers, and so encourage employment. This would create the employment double dividend, but at a cost to non-working consumers. The employment double dividend has arisen by shifting the tax burden from workers to non-workers.

It is worth noting that the same effect can occur with two other groups of non-workers. The first are people on state benefits, but only provided that the benefit is not increased to compensate for the increased price of the environmentally damaging good. The second are people in other countries, if the good, or products made with the good, are exported and the country has sufficient market power that the other countries are unable to switch their source of supply.

Another form of tax shifting is the taxation of goods whose production uses a particularly large amount of an under-taxed factor of production, with the revenue being used to subsidize (or, at least, reduce the taxation of) employment. If environmentally damaging goods make heavy use of under-taxed factors, then their taxation could produce an employment double dividend. To see this, consider a factor that is inelastically supplied (in the sense that the same quantity would be supplied at a lower price) and currently taxed at less than 100%. The situation is clearly not revenue-optimal, as a higher tax on the factor would raise additional revenue without reducing its supply. A direct solution to this situation would be to increase the tax on the income to that factor. However, an indirect partial solution would be to impose some other tax that would result in a fall in the income to that factor, such as a tax on a good whose production made particularly heavy use of that factor. Thus, if capital were inelastically supplied and taxed at less than 100%, and if the production of energy was particularly capital-intensive, a tax on energy could be seen as partly a tax on capital. In this case the imposition of an energy tax that is used to finance a cut in labour taxes shifts the burden of taxation away from labour and towards capital. This would reduce the distortion of labour demand without distorting the supply of capital (which is inelastic), thus creating a strong double dividend.

In applying this analysis, it is important to be sure that the factor really is inelastically supplied. If capital were elastically supplied, perhaps because of the ease of moving it to countries with lower taxes on capital, then the tax shifting would cause a considerable increase in the distortionary cost of the tax system in the form of capital moving abroad. In this case the benefits of the shift in terms of increased

[61] In principle, cutting income tax would also reduce labour costs by reducing the before-tax wage rates that workers demand.

employment would be smaller[62]. Bovenberg and De Mooij (1998) have addressed this issue. The desirable level of environmental taxation depends crucially on the elasticity of capital supply and the current rates of capital taxation.

This discussion shows that the shifting of the tax burden away from labour can, in certain circumstances, produce an employment double dividend.

15.3.2.5 Improving the efficiency of the tax system[63]

The previous subsection looked at how a shift in the tax burden could impact on employment. In this subsection we look at whether an employment double dividend can be created without shifting the tax burden[64]. The analysis is interesting because such tax shifting could be difficult if non-labour factors of production are elastically supplied and non-working consumers are protected from bearing the tax burden. The aim is to reduce the tax burden on workers so that labour costs can be reduced and labour demand increased.

If we rule out tax shifting by assuming that all inputs into production are elastically supplied at fixed cost (energy and capital because they are internationally mobile, and labour because the wage is fixed), it can be shown that minimization of production costs requires that all factors are equally taxed. What is actually the case in many countries (particularly Western European countries) is that labour is taxed more heavily than other factors. Thus a shift away from the taxation of labour to the taxation of other factors can be expected to reduce production costs. This will reduce the prices that workers face for the goods they wish to consume. In this case, the move from payroll taxes to taxes on other factors will not be offset by an increase in wages, and employment will increase.

This analysis looks as if it will lead to the existence of an employment double dividend for energy taxation, even without shifting the tax burden. However, the situation is not quite that simple, for two reasons. First, the argument in the previous paragraph was concerned with increasing the tax on all non-labour factors. An

[62] In fact the distortionary cost of the tax system could be reduced by an environmental tax that fell on labour and was used to finance a reduction in capital taxation!

[63] For a thorough discussion of the principles of taxation and how to increase tax efficiency see Atkinson and Stiglitz, 1980.

[64] This is not to imply that the effectiveness of the tax system with respect to employment is separate from the shifting of the tax burden. We look at the impacts of shifting and not shifting of the tax burden separaetly for analytical reasons alone.

increase in energy taxation alone may improve the relative costs of labour and energy, but at the cost of possibly worsening the relative costs of capital and energy. Second, as energy is a produced good (although possibly imported) it may well have already been taxed, and so an additional tax on its use could lead to it being over-taxed. Thus, it is not clear that energy taxation will always lead to an employment double dividend. It is more likely to happen if energy is more substitutable with labour than with capital, as that would make the correction of the relative costs of labour and energy more important than the worsening of the relative costs of energy and capital[65].

Before concluding this discussion of employment creation when there is involuntary unemployment, it is important to note that the possible strong double dividend analyzed here does not apply to all sizes of environmental tax. The arguments presented here have applied to small taxes. As environmental taxes are increased, they increase the distortionary costs of revenue raising by changing consumer choices—the tax-interaction effect increases—and this effect can outweigh reductions in the distortion of the labour market.

Finally, let us turn to the question of how the wage is determined and whether or not it would in fact be "fixed". This is important because it is possible that the policies discussed here may affect the real wage. The main influence on wages discussed in the literature is trade unions, and we will concentrate on them here. In most models of trade union behaviour, a reduction in unemployment will lead to a higher wage. This will reduce the size of any possible employment double dividend, because any reduction in unemployment will increase the wage, which will in turn increase unemployment. It is, in fact, possible to produce a model in which unemployment cannot be reduced: the entire subsidy to employment is absorbed by an increase in the wage. However, in most of the literature, trades unions are shown to simply reduce the size of any employment double dividend.

[65] The note by opponent Böhringer refers to a paper by Schöb (2005), which I have not seen, but in which a low enough elasticity of substitution between labour and energy does diminish the positive employment effects substantially. In the same paper the author also shows some conditions under which employment will increase.

15.3.2.6 The employment double dividend: The case without involuntary unemployment

When the labour market is sufficiently flexible to ensure full employment, the emphasis in the double dividend literature moves away from employment creation and towards the general efficient functioning of markets (i.e. the gross welfare dividend). However, the distortion of the labour market is still a major concern, with the idea that employment taxes tend to reduce the level of labour supply below the optimal level. Hence the use of environmental taxes to partially replace other taxes could increase labour supply and increase measured employment. This section considers the scope for such changes.

The cases of tax shifting discussed above continue to be possible sources of a double dividend, but through a different mechanism. Instead of an increase in labour demand that results from reduced taxation that lowers labour costs, we need to look at supply side incentives in the labour market. In this case, a reduction in labour taxation increases the rewards to working and so increases labour supply, which in a flexible labour market leads to greater employment. The impact of the tax-interaction effect on labour supply is muted by the existence of non-workers in the economy who bear part of the burden of the environmental tax.

Even here, however, the presence of internationally mobile capital can make things go the 'wrong' way. As Böhringer reminds us in his note, when capital is able to resist any of the tax burden the reform can in fact result in lower, not higher real wages. In that case labour supply would be decreased, not increased. This possibility has been explored in two papers by Bovenberg and van der Ploeg (1994a, 1994b).

In addition, as when there is involuntary unemployment, it is interesting to look at what possibilities there are without tax shifting. Such possibilities again involve improving the efficiency of the tax system. However, the analysis is now different. The arguments presented previously no longer apply as the wage is not fixed at a level that makes supply exceed demand, and so the emphasis is more on increasing labour supply than increasing labour demand.[66] It is necessary to look at the

[66] Of course, increasing labour demand will increase the wage and so increase labour supply (provided that its supply is not backward bending). However, it turns out that the use of taxes to increase labour demand is an inefficient use of the tax system. Any money is better spent on direct changes to the incentives that workers face.

way in which taxes on workers affect their labour force participation. We now turn to an examination of this.

A simple model that is widely used in optimal tax theory is useful for illuminating this question. It is a model in which the only factor of production is labour. In this framework, the only reason for taxing some goods more heavily others is that their consumption is more closely associated with leisure than other goods (in economic terminology, these goods are said to be particularly complementary to leisure). This means that the heavier tax on these goods would implicitly tax leisure and so encourage people to work more, thus reducing the distortion to labour supply produced by the tax system as a whole. So, if an environmentally damaging good was also a good that is consumed in association with leisure, the imposition of a special tax on this good in an economy with otherwise uniform sales taxes could have a double dividend.

It is worth looking at this case in more detail, as it involves a line of reasoning that is quite helpful in understanding the double dividend. One can think of raising the tax on the environmentally damaging good (let us call it energy) and using the revenue to reduce taxes on labour (such as income tax or payroll taxes[67]), as suggested in the double dividend literature. At first sight, this might appear to automatically reduce the distortion of labour supply, but the analysis is more complex. It is not only taxes directly on labour that reduce labour supply, but also taxes on goods that are bought with the income earned by the labour. Thus, increasing the tax on energy also reduces labour supply by reducing the real wage (the tax-interaction effect). However, if energy were particularly complementary to leisure, this effect would be particularly small because people who were deciding whether or not to work more would expect to spend a relatively small proportion of their extra earnings on energy. This means that the disincentive effect of the tax on energy will be less than the incentive effect of reducing taxes on labour, so labour supply would increase and a strong double dividend result.

Note that if the consumption of energy had been associated more closely with labour (i.e., if it had been particularly substitutable for leisure), the result would have been the opposite: the imposition of an energy tax would have reduced labour

[67] In an economy without involuntary unemployment, payroll taxes also reduce the incentive to work because they reduce the wage that employers are able to pay their workers.

supply, because energy would have been a relatively larger part of the expenditure from the possible extra earnings. In this case, there would not be a strong double dividend. In fact, the environmental tax would have worsened tax distortions in the economy, because of the large negative tax-interaction effect.

A case that has been highlighted in the literature is one that falls between these two possibilities: no goods are particularly associated with either labour or leisure; there is "weak separability" between goods and leisure. In this case, uniform sales taxation is optimal. A very small environmental tax will neither increase nor reduce the distortionary cost of the tax system, but any significant tax will be a move away from the optimum and so increase the distortionary cost. It is this that lies behind the main theoretical result of Bovenberg and Goulder (1996), casting doubt on the existence of a double dividend.

15.3.2.7 Conclusions from the Theoretical Double Dividend Literature

The following conclusions can be drawn from the review conducted above.

The literature on the double dividend distinguishes between a 'weak form' and a 'strong form'. The strong form, which is the one of interest to policy makers, states that a switch to environmental taxes and away from non-environmental taxes will reduce the welfare cost of raising the current level of government revenue even if their environmental effects are neglected. Hence it is a 'gross welfare' dividend in the sense defined earlier. A strong double dividend of this kind cannot occur if the existing tax structure is revenue-optimal. If, as is likely in practice, the existing tax structure is not revenue-optimal, a strong double dividend will occur if the new environmental tax moves the tax structure in the direction of revenue-optimality. Therefore, the prospects for a strong double dividend depend on the existing structure of taxation, as well as on other aspects of the economy.

Next we ask when and under what conditions an 'employment' double dividend might exist. We need to look separately at two cases: whether or not the labour market is in equilibrium. If it is in disequilibrium, with involuntary unemployment, additional employment is created if the use of environmental taxes to partially replace existing taxes results in an increased demand for labour. If it is in equilibrium, without involuntary unemployment, additional employment is created by increasing labour supply.

There are no necessary or sufficient conditions for environmental taxes to increase employment, but the theory has identified factors that make it more likely.

A. The prospects of increased employment *when there is involuntary unemployment* are higher if:

(i) The environmental tax can be passed on to factors that are inelastically supplied and relatively under-taxed.

(ii) Non-working households are large enough in numbers, and are significant as consumers of goods produced with the environmentally intensive inputs that are taxed.

(iii) Through international market power, the environmental tax can raise the price of goods produced with a relatively intensive use of the taxed environmental input. A similar effect would arise if foreign suppliers reduced the price of goods that were subject to environmental taxes when they entered the country.

(iv) Capital is relatively immobile internationally. In this case it can absorb some of the environmental tax and enable the tax to fall less on factors such as labour, enhancing the double dividend effect.

(v) The elasticity of substitution between energy (the environmental input) and labour is greater than the elasticity of substitution between energy and capital.

(vi) The real wage rises little when unemployment falls, so that the reduction in the taxes on labour are not offset by wage rises.

B. *When there is no involuntary unemployment*, conclusions (i) to (iv) still hold but conclusions (v) and (vi) are replaced by:

(vii) The environmental tax is levied on goods that are more complementary to leisure than the goods whose taxes are reduced.

These conclusions raise important implications for policy and for the design of empirical models. The empirical models are discussed in section 4, but there are two policy issues that are worth raising here.

First, the importance of capital mobility in determining the existence of an employment double dividend suggests the need for international co-operation in setting environmental taxes. If one country on its own imposes environmental taxes that reduce the return to capital, it could suffer from substantial capital movement.

If on the other hand a group of countries imposed such taxes at the same time, there would be less scope for capital to move elsewhere.[68] Against this, however, is the fact that the larger is the group of countries that apply the taxes, the smaller is the remaining set of countries that will have to pay the shifted taxes and so the smaller the amount of tax that can be shifted.[69]

Second, the literature does not specifically deal with the practical question of which taxes on labour should be reduced to get the largest employment double dividend. Should it be income taxes or social security taxes? Intuitively, it seems likely that it should be social security taxes because they are more closely linked to employment than income taxes, which can cover non-labour incomes and are progressive (thus bearing less heavily on the incomes of lower-paid workers). This intuition has been tested and results reported in section 3.2.

Third, and related to the above point, we need to consider the wisdom of Green Tax reform when the dividends are generated as a result of shifting the tax burden to non-workers. If most of these are pensioners or unemployed persons, there is a negative distributional impact from the tax reform, which many would consider undesirable. The note by Böhringer rightly reminds us of the importance of this trade-off.

Finally, we can also ask which of the conditions listed above will promote *both* the gross welfare and employment double dividends. From the previous discussion and other literature one can say that factors (i), (iv), (vi) and (vii) are likely to also result in a gross welfare dividend, although this is not guaranteed. In general it is much more difficult to ensure a gross welfare dividend than an employment dividend.

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[68] To some extent, this argument applies also in considering international market power, both in terms of being able to increase the price of exports and in terms of being able to reduce the price of imports. This market power will be greater for a group of countries acting together than for a single country. It is worth mentioning that these concerns go beyond environmental policy. They are general issues related to domestic capital taxation.

[69] International co-operation may also be useful in minimizing the loss of international competitiveness that could result from introducing environmental taxes. International competitiveness is not considered in the theoretical literature, which assumes that exchange rates adjust to maintain equilibrium in the balance of payments. However, it is captured in the empirical models – see Section 4.

15.4 The empirical evidence for externality types green taxes and double dividend type green taxes

15.4.1 Empirical evidence and history of externality type taxes and other market-based instruments

In policy terms the externality rationale for taxes or other market based instruments such as those discussed in Section 2.1 lay dormant for a long time after it was first formalized in the 1930s. It was not until the early 1970s that governments in the industrialized world started to look at *economic* instruments – i.e. ones that rely on economic, fiscal and financial incentives – to address environmental problems[70]. Since then the idea has been catching on, and the number of cases of economic instruments in general and environmental taxes in particular world-wide is large and growing. There is no formal count of the number of such instruments, but it must run into the thousands. In the EU, a survey carried out in its 15 member states in 2001, found 142 examples of environmental taxes or related instruments alone, not including some taxes that have environmental effects but that are imposed for largely non-environmental reasons (e.g. a tax on motor fuels) and not including other market based instruments (ECOTEC, 2001). A summary of that list is provided in Table 1. The full list of EIs would be much greater if one included fuel taxes, as well as charges for services that have an environmental dimension (e.g. water delivery, disposal etc.).

Another area where EIs have been adopted increasingly is in the pricing of natural resources. When water, forests, fisheries were available in abundance relative to the rates at which they were being exploited, the need to use a pricing mechanism to ensure sustainable use was not there. But with economic and population growth the demands have increased and the use is often no longer sustainable and methods of exploitation cause environmental damage in some cases. In these circumstances, one can impose restrictions on users – e.g. physical limits on amounts that can be abstracted – or one charge users a fee for access to the resource. The fee acts to reduce demand, and at the same time it provides financial resources to

[70] We have used the term market based instruments to describe taxes, subsidies, permits etc. and excluding command and control instruments. This group is also referred to as *economic instruments* (EIs). In common usage the terms economic instruments and market based instruments are treated as interchangeable.

protect the resource. The EU is moving strongly in this direction with, for example, The Water Framework Directive, which requires all member states to move to full social cost recovery in the water sector, including the environmental costs of water use.

Why did this change in emphasis in regulation – from purely command and control to a mixed system with economic instrument as well – take place? The main reason was the growing awareness of the costs of command and control or direct regulation. Setting standards and mandating the use of certain technologies to meet these standards was fine when the costs to industry and to society more generally were not high. But as more and more regulations were needed, the costs of direct control became larger and larger and the search for alternatives was accelerated. In addition, these direct methods of control often did not work as well as intended. Sometimes they failed because polluters ignored them, but more often it was because polluters negotiated special terms entitling them to lower standards on the grounds that the regulations would hurt industry and employment and growth. The ability to make a special case would depend, in part, on the political power of the group seeking exemption.

Finally, we should note that command and control instruments offered little *flexibility* in meeting environmental standards. If you were told to reduce emissions by a certain percentage in each factory, or to use a given technology, you could not argue that a bigger reduction in some and a smaller reduction in other factories was less costly, while achieving the same objective; or that an alternative technology could be used, achieving the same effect in environmental terms but costing much less. Furthermore, as an enterprise you would have no incentive to be dynamic – to look for cheaper and better methods of production that were more environmentally friendly and also more economical. As a general rule, command and control methods work best when the regulator has as much relevant information about the problem as the polluters. Since this is often not the case, providing some flexibility to the polluters harnesses their ability to find cheaper solutions and can be a powerful force for more effective and less costly regulation.

In Table 2 the main kinds of economic instruments (abbreviated to EIs) are presented. As notes earlier, this term is used interchangeably with the term market based instruments. To be precise, **economic instruments**, narrowly defined, are ones that act *directly* on the pollution, whereas **fiscal and financial instruments** provide incentives through their effects on the prices paid for the inputs or received for the outputs. Since the whole lot taken together is often referred to as **Economic**

Instruments, we will use the same convention. The table shows that the range of tools available to a regulator is very large. Furthermore, not all the instruments serve the same objectives. How then do we evaluate them, and which one would we recommend in a particular situation? Related to that, how do we judge the success or failure of a particular instrument in practice? Finally, given the title of this chapter, when are taxes the most suitable instruments from an environmental perspective?

The first thing to note is that the proposed economic instruments in Table 1 are not all consistent with the analysis in Figure 1. Only those in bold could be seen as directly able to achieve the optimal level of the externality. Others can 'go in the right direction' but are flawed in one way of another in terms of the implementing the optimal solution. The following are reasons why some of the instruments not in bold may not yield the optimal solution.

i. Input taxes do not allow for the possibility that the enterprise can adopt clear technology or undertake end-of-pipe clean up. For example, a tax on coal as a proxy for a tax on sulfur emissions would not reward those who undertook the capture of emissions through desulfurization equipment.
ii. Product Taxes provide no incentive for cleaner production methods or on intensity of use of the products. A tax on cars, for example, makes no distinction between low and high efficiency vehicles or between those who drive a lot in congested conditions and those who drive a little, on rural roads.
iii. Soft Loans for Clean Technology Investments, encourage technologies that are capital intensive and may act against cheaper, low cost solutions. For example soft loans to water companies for the construction of reservoirs meeting state of the art standards encourages them to spend more on such reservoirs and less on fixing leaks in the pipes, for which there is no subsidy.

These examples are not intended to be comprehensive. They do show, however, why the instruments are flawed when judged in terms of the economic framework that underlies the externality analysis. Of course, this does not mean that, in practice, such instruments are to be avoided in all cases. Inevitably there is a compromise between the theoretically ideal and the practical, and when the former is not feasible for institutional and other reasons, or too costly, the use of these indirect,

'second best' instruments may be justified. It is also possible to amend such instrument so that they are better able to reflect the ideal instrument. So for example, a tax on coal could include a rebate for producer who introduced sulfur-capturing equipment, and a produce tax could be differentiated so as to tax the more polluting products more highly. In the next section we look at how one might evaluate EIs in practice.

15.4.1.1 Evaluating environmental taxes and other EIs in practice

There are number of important features of the actual use of EIs that need to be understood.

A. It is fair to say that very rarely do we know the optimal charge (OE in Figure 1). A guess could be made to estimate it, but the effort in this direction has been relatively weak. Instead, when a charge is imposed, it is either *ad hoc*, or, occasionally, based on achieving a politically agreed environmental quality standard. In general pollution charges are set well below marginal damages and hence are too low.

B. When charges are imposed they are only part of the package of measures used to achieve the environmental goals. The other instruments include command and control measures, such as restrictions on certain activities in certain areas, mandated use of best available technologies and the like. Hence we have to evaluate the package as a whole and see the charge as a component of that package.

C. Charges, as part of the package, are important not only because of the incentives they provide to reduce emissions, but because they generate revenues, which the authorities can use partly for environmental purposes. Indeed one of the most controversial and important debates about charges is how much revenues they generate and what those revenues are used for. Recall that, from the theoretical perspective this was not an important issue (although it is important in the double dividend context, which is considered later). But in practice the distribution of revenues between different stakeholders is often critical.

D. The question around which there is much discussion is whether the revenues should be dedicated to environmental protection, or whether they should go to the general budget. In the former case the revenues are referred to as *earmarked.* The case for earmarking is that it makes it politically easier to get agreement on the charges and ensures that at least

Table 1. Environmental charges and similar instruments in the EU

Instrument	AU	BE	DK	FIN	FR	DE	EL	IRL	IT	L	NL	PO	ES	SW	UK	**Total**
Energy/Carbon Tax			X	X	X	X			X		X			X	X	**8**
NO_x Charge					X				X				X[i]	X		**4**
Sulphur Tax			X	X					X							**3**
Agricultural Inputs																
Pesticides		X	X	X										X		**4**
Fertilizers	X[i]		X[i]	X[i]							X[i]			X		**5**
Eco Taxes on Goods																
Batteries	TBS	X	X			TBS			X					X		**6**
Plastic Carrier Bags			X						X							**2**
Disposable Containers	DRS	X	X			TBS			X					X		**6**
Tyres			X	X										X		**3**
CFCs/Halons			X													**1**
Disposable Cameras		X														**1**
Lubricant Oil			X	X					X				X	X		**5**
Oil Pollution				X	X											**2**
Others	DRS[i]	X[i]	X[i]		X[i]				X[ii]		X[ii]		X[ii]	X[ii]		**8**
Waste																
User Charge	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**15**
Landfill Tax	X	X	X	X	X	X			X		X			X	X	**10**
Hazardous Waste Tax		X	X	X	X	X										**5**
Others			X[ii]	X[ii]	X[ii]						X[ii]					**4**
Water																
User Charge	X	X	X	X	X	X	X	X[iv]	X	X	X	X	X	X	X	**15**
Water Tax/Abstraction Tax			X		X	X[v]			X		X[v]		X[v]		X	**7**
Waste Water Charge		X	X	X	X	X		X	X	X	X		X	X	X	**12**
Others		X	X	X[v]												**3**
Aggregates Tax		X[vi]	X											X	X	**4**
Noise Charge		X	X		X	X		X	X		X	X		X[v]		**9**
Total Number	**8**	**13**	**21**	**14**	**12**	**10**	**2**	**4**	**14**	**3**	**10**	**3**	**7**	**15**	**7**	**142**

Source: ECOTEC et al, 2001Notes:

DRS Deposit Refund Scheme

TBS Take Back Scheme (i.e. supplier is obliged to make arrangements to take back the product after it has been used).

1. Only a regional tax – in Galacia
2. Tax has been abolished
3. Tax on growth promoter fertilizers only
4. Tax has been abolished
5. Tax is a mineral surplus tax
6. Covers lamp bulbs, refrigerators and freezers and packaging
7. Tax on packaging, surplus manure, heavy accidents, and ionizing radiation
8. Tax on chlorinated solvents, disposable tableware, light bulbs, PVC and junk mail. DRS on reusable containers (beer and soft drinks)
9. Packaging tax, paper tax, tax on mines and tax on natural sites
10. Packaging tax and tax on aggregates
11. Surplus manure charge
12. Eco-tax on tourism in Balearics
13. Tax on gravel, limestone, packaging charge, vehicle scrapping charge
14. Tax on electronic and electrical waste
15. Nuclear waste management charge
16. Tax on emissions from incinerators
17. Waste charge on 'disposal of white and brown good decree'
18. Local taxes not related to water consumption
19. Water abstraction charge (regional level)
20. Tax on groundwater only
21. Also water sanitation charge and charge on spills to coastal waters
22. Fish management charge
23. Tax applies at regional level only (Flanders)
24. Air passenger duty

Country Codes: AU-Austria; BE-Belgium; DK-Denmark; FIN-Finland; FR-France, DE-Germany; El-Greece; IRL-Ireland;

It-Italy; L-Luxemburg, NL-Netherlands; PO-Portugal ; ES-Spain ; SW-Sweden; UK-United Kingdom

Table 2. Types of economic and related instruments

Economic	Fiscal	Financial
Charge Systems **Pollution Charges** **User Charges** **Access Fees** **Road Tolls** **Administrative Fees**	Input Taxes/subsidies Product Taxes/subsidies Export Taxes/subsidies Import Tariffs/subsidies **Tax Differentiation** Investment Tax Credits	Soft Loans Grants Environmental Funds
Property Rights **Traditional Management Regimes** **Land Titles** **Water Rights** **Use Rights (licenses/concessions)**	**Royalties** **Resource Taxes** **Land Use taxes**	Location subsidies
Market Creation **Tradable Emissions Permits** **Tradable Land Permits** **Tradable Catch Quotas**		
Liability Systems **Legal Liability** **Natural Resource Damage Liability** Liability Insurance		
Bonds and Deposit Systems **Environmental Performance Bond** **Land Reclamation Bond** **Deposit Refund System**	Accelerated Depreciation	

Note : Only ones in bold face are consistent with the principles of externality regulation outlined in Section 2.

Source: Markandya et al., 2002.

funds are available for this sector, and at the level at which the revenues are collected, when the central government is inclined to allocate very little for environmental protection. The arguments against earmarking are that: it reduces flexibility for the government in its management of the macro economy; it makes expenditures on protection determined by revenues when they should really be determined by the sector's environmental needs; and it promotes inefficiency in public spending with public funds not always going to the areas where the return is highest. Most countries, including those that are industrialized, have conceded that some degree of earmarking of environmental charges is justified, and agreement is

reached with those who pay the charges that some of the revenues will be made available for environmental improvement in the sector from which they were derived.

E. When societies can agree on environmental standards, they can also achieve them by using tradable permits, and the experience with these has been relatively positive, at least as far as air pollution is concerned. Less successful has been the use of permits for fisheries and natural resources, such as water. (Markandya et al., 2002).

F. The term EI has come into common usage for a range of charges and payment that really do not reflect an environmental objective. Take the case of drinking water. Exploitation of the source of this water may have some externalities associated with it, and these need to be addressed through one or more of the instruments cited in Table 1. But the consumers of the water receive a regular service, like many others that they receive (delivery of the mail, cleaning of the streets etc.), and should simply pay the cost of the service, unless the state subsidies some of them on grounds of social protection (they cannot afford to pay for a vital service). Often, however, water charges do not cover the costs of delivery, and the water company operates at a substandard level. The result is deteriorating infrastructure, as well as damage to human health (the water supplied does not meet the required standards) and the environment (the water utility cannot afford to maintain its water source). Hence there is an environmental aspect to low charges but it arises not directly from an externality but from the inadequate financial arrangements made for the provision of a service. A similar case can be made for sewerage and solid waste collection charges, charges to parks etc. where the aim is mainly to recover the costs of the supply of the service, but where an inadequate charge result in environmental damages. A useful way to see these instruments is shown in Figure 2.

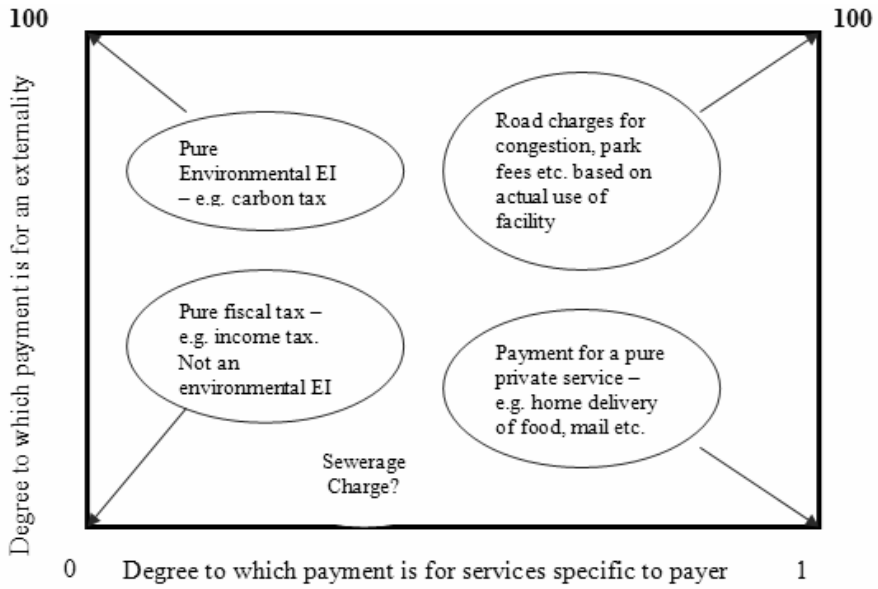
The figure measures, on the horizontal axis, the degree to which the payment if for a specific services that the payer receives. In the case of an income tax there is no service and so such a tax would have a value of zero. The right hand limit of the horizontal axis represents the case of the payment being directly and fully related to the service received, such as the mail. In neither of these cases is there any environmental dimension to the EI. On the vertical axis we measure the degree of this dimension, which

arises when the payment is related to some externality that the polluter is generating. If the payment is purely based on the externality, we have the situation depicted in Figure 1, with payment based on emissions of a pollutant, and the instrument is purely an environmental one. On the other hand the payment may be related to an externality, but one where there is a specific service associated with the externality. Congestion is a good example. The charge for using a road or visiting a site in the rush hour may be purely to pay for the externality generated by your visit but it is also tied to the service provided by the party to whom the payment is made – viz. road services or site services.

Charges for services like sewerage and water, solid waste etc. lie somewhere in the box. They are not purely for the services provided to the user, although that is the principal aim, but they are also for the externality generated by improper disposal of the waste.

Much of the discussion of actual charges deals with EIs that are 'mixed' in the sense shown in this figure. The next section looks at the experience in implementing EIs in a range of countries.

Figure 2: Economic instruments in a wider context



15.4.1.2 Experience with economic instruments in the EU and other OECD countries: Further considerations

A range of pollution charges and some charges on the use of natural resources have been implemented in the EU, as a national response to addressing environmental problems in an effective way[71], strongly supported by various EC declarations. Table 1 summarized the situation as of 2001.

There are a wide range of instruments – 142 have been identified in Table 1 – with the most common applications being in user charges for waste and water (all 15 countries have them). A major increase in the number of instruments took place in the 1990s. Motivations behind the instruments are essentially three: (a) raising revenue for public environment and related activities, (b) providing an incentive to reduce emissions and/or save on the use of natural resources and (c) covering the costs of delivery of environment related services (e.g. waste water collection and treatment). The most notable features of the system of charges are the following:

15.4.1.3 Incentive effects and revenue effects

A. The environmental effect of the taxes is estimated to be positive but small (with some exceptions). This has largely been due to low rates at which they are levied and the myriad exemptions that have been granted, on the basis of hardship, possible employment and competitiveness effects etc.

B. The design of the taxes has given more emphasis to revenue raising than the incentive effects (which would require much higher taxes in most cases). The revenues are often earmarked for specific environmental measures, which helps the government address certain environmental problems.

C. Incentive effects of resource charges are limited because of the way the charge is levied. For example, if a user charge is levied on water, and is paid based on the size of the house, there is little incentive to reduce water consumption, as the amount paid does not depend on the level of consumption. Metering for water is still not widespread in the EU, making water charges a cost recovery instrument rather than an incentive based one. Charges based on amounts of wastewater generated are, however, some-

[71] Excluded from the table are fuel and excise taxes and taxes on sulphur.

what more common, and some countries levy additional wastewater taxes, at rates that vary considerably across countries.

D. For waste the same problem arises regarding incentive effects; rarely are charges related to amounts of waste generated, although variable charging is being introduced by a few municipalities in Austria, the Benelux countries, France, Italy and Switzerland. There are taxes on waste disposal in 10 countries. These may have some incentive effects as the charges paid by the municipalities encourage them to recycle and find other ways to reduce the waste generated. Rates on landfill range from €3-€30 per ton. There is no comprehensive assessment of the impact of these taxes on amounts sent to land fill sites but earlier US studies on the 'pay-by- the-bag' programs found significant reductions in amounts generated. (OECD, 1993, Repetto et al, 1992).

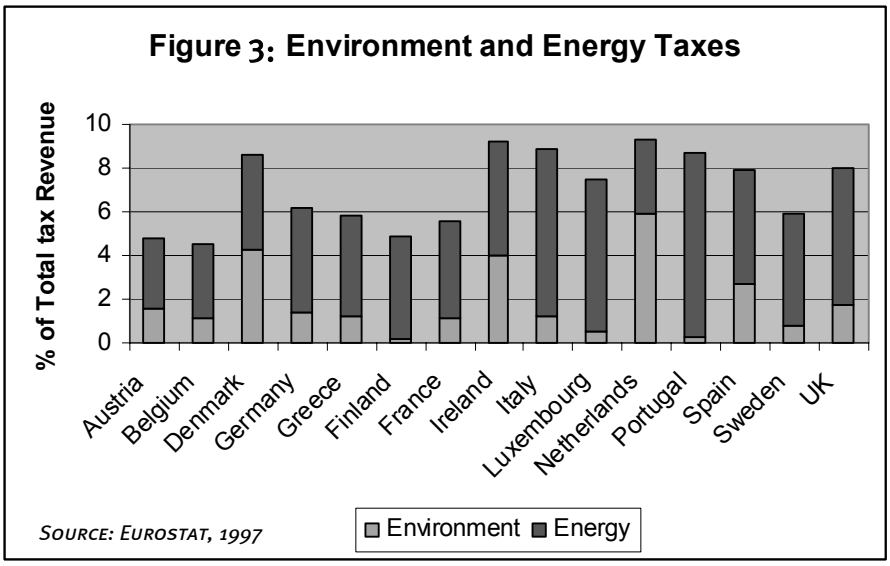
E. A handful of countries impose taxes on agricultural inputs – pesticides and fertilizers. Some however, provide incentives for increased use by, for example, exempting them from VAT. Some countries that have imposed taxes on these inputs have seen some a significant decline in their use (e.g. Netherlands, Denmark).

F. Taxes on products for environmental reasons are growing in popularity (most have been introduced in the last since the later 1990s). The purpose is mainly to defray the costs of disposal of the products, including, in some cases, handling illegal disposal. Incentives to avoid improper disposal and to recycle are provided by 'Take Back Schemes' and 'Deposit Refund Schemes', which are used for batteries, disposable containers, lamp bulbs, refrigerators and some kinds of packaging. In earlier US studies these instruments have been found to reduce the amounts of waste and the costs of waste management significantly. The bottle bills in the US have reduced litter by 10 to 39 percent and solid waste by 1 to 6 percent. In the same country, kerbside collection programmes obtain recycling percentages of around 35 percent for glass containers and 25 to 56 percent for aluminium cans (Repetto et al., 1992). As far producer- based recycling schemes are concerned it is encouraging to note that the German Green Dot scheme has obtained the participation of over 50 percent of households by 1993, and over 80 percent is expected by this year.

G. In terms of revenue generation, environmental taxes are still a minor part of total government taxes. As a percentage of total tax revenue they range from a low of 0.3% (Portugal) to a high of 5.9% (Netherlands). Energy

taxes, on the other hand (which also have environmental impacts) are more significant – ranging from 3.2 to 8.4% of the total. Together the two taxes can add to as much as 10% of total tax revenue (Figure 3).

H. Overall, therefore, environmental taxes have not had strong incentive effects. The case studies carried out showed, however, that even a small tax can have a strong awareness effect, which is hard to measure, but which may, nevertheless be quite real.



15.4.1.4 Employment effects

A. The employment effects of the taxes that have been introduced have been small. Most of the modeling of employment effects of taxes has been with respect to carbon/ energy taxes accompanied by a reduction in social security payments. These are considered in the next section. Environmental taxes, without any accompanying change in social security or other labour taxes, however, do not show any noticeable negative employment effects. This has been supported by other studies carried out by the OECD. (OECD, 1994).

B. In addition to the direct employment effects, there are the indirect ones. The revenues generated from the tax are often used to undertake environmental programs, and this could have a positive employment benefit see. Sectors that could benefit from such spending and from the tax signal more generally, such as recycling, tend to be more labour intensive than the sectors on which the tax falls, so we might expect a positive effect for that reason. There could also be a positive effect of any incentive to adopt

cleaner technologies on employment in those technologies. Although such an effect has been demonstrated for stricter environmental regulations in general, it has not been proven for the use of EIs.

15.4.1.5 Competitiveness issues

C. For most taxes and charge the impact on the total cost base of the supplier of the good or service is relatively small, but difficult to assess. An EC report (Ecotec et al, 2001) concludes that there is little historic evidence of negative effects on competitiveness of the higher environmental standards that have been introduced through environmental policy.

D. One reason why little or no effects are found on competitiveness may be the use of exemptions to those sectors that are likely to be negatively impacted. Others are: the low cost of environmental measures compared to other costs, some savings that result from the adoption of environmental measures and the fact that many taxes affect sectors where there is not much trade (e.g. landfill)[72].

E. It is also interesting to note that, as far as trade and the internal market are concerned, the kind of taxes described above have not emerged as a major problem. Where problems have arisen they have been resolved without too much difficulty. For example, there was a complaint against the Danish law, which provided for the establishment of a DRS scheme for beer and soft drinks and required that the drinks be marketed in returnable containers that had to be approved by a Danish authority. As a result, importers were allowed to market a specific quantity of beverages in non-approved containers. In other cases, national taxes have been abolished when EU directives have been introduced, to avoid double regulation. Cases in point are the Swedish and Finish Packaging Taxes. Finally some taxes have had to be removed when countries joined the EU because they were deemed to hamper competition with other member states. Examples

[72] Böhringer notes that the use of exemptions on a large scale has been criticized by economists who argue there is little justification for these on economic grounds. This discussion has been framed in the context of carbon taxes, where the use of differentiated taxes has been shown to result in much higher costs of reaching a given carbon reduction target (Böhringer and Rutherford, 2000). Opponent Smith also makes the same point and notes that an alternative to exemptions could be border tax adjustments on imports from countries that do not have a carbon tax. The scope for such adjustments, however, is rather limited in practice and may be judged incompatible with WTO rules. The note by Smith discusses the competitiveness issues in further detail.

are the fertilizer taxes in Austria and Finland that were in place before those states joined the EU.

15.4.1.6 Growth and employment

F. Although not directly related to environmental taxes, a considerable amount of work has been done to evaluate the employment and growth impacts of environmental regulations in general. For the US Denisen (1985) concluded that, in the absence of environmental regulations from 1973 to 1982, US GNP growth would have been higher by 0.07 percent. Jorgensen and Wilcoxen (1989, 1992) found an impact of 0.19 percent on US growth between 1973 and 1985 and that the regulations in the early 1990s (particularly the 1990 Clean Air Act) reduced GNP growth by 0.04 percent by 2005 and by 0.05 percent by 2020. For Europe Klaassen and Nentjes (1991) looked at the impacts of an EC Directive to control air pollution pertaining to sulphur dioxide and nitrogen oxides from large combustion plants. The investment necessary to meet the objectives had to be completed by 1993, and during the period of the investments GDP actually *increased* relative to the counterfactual, with increases in growth rates of 0.15 to 0.25 percent per annum. On the other hand there was a small decline after the investment period, with declines in the next four years of 0.05 to 0.25 percent per annum.

G. These studies are careful pieces of work and their results must be taken seriously, but there are a number of reasons why they may be considered as overestimating a negative growth impact of regulations. First and foremost, they do not take account of the environmental **benefits** of the regulations. Hence the measure of GDP they use is flawed and allowing for such benefits would change the picture, although it is not clear by how much. Second, the models do not allow for the “spillover” benefits of the regulations. A cleaner environment results in reduced health care costs and expenditures on capital controls to protect oneself from a damaged environment and allows more to be invested in sectors that cans stimulate growth. Third, there are innovative benefits from the development of cleaner technologies in response to the regulations. A number of studies have found such effects (e.g. Barbera and McConnell, 1990). Fourth, regulations could shock management to adopt more efficient practices resulting in greater efficiency and growth. (Porter, 1991; Porter, 1995). Finally, recent developments in growth theory suggest that, in a sense related to the Porter

Hypothesis, the impetus of new environmental regulations could be to move an economy from one equilibrium to another, where the new equilibrium is more "environmentally friendly". A full presentation of the theory would not be easy for the lay reader, but the essence of it is that economies face production possibilities characterized by some "increasing returns to scale". Facing these production possibilities economies can be in equilibrium with high emissions and low capital per head, or with low emissions and high capital per head. An environmental regulation that provides the incentives to lower emissions can also act as an impetus for a move to the higher levels of capital accumulation and hence to a higher steady state growth rate.

15.4.2 Empirical evidence on the double dividend

This section reports on the results of estimating the employment double dividend for the European Union in relation to the introduction of a carbon tax. Several models have been used in this work and their assumption results are summarized in Table 3 below. For more details see Heady et al. (2000).

15.4.2.1 Key aspects of the empirical models

The discussion of the theoretical literature in section 2.2 suggests that the following features of the economy are important in assessing the likelihood of a double dividend. It is worthwhile to look at the extent to which the models capture each of these features[73]:

Existing tax structure. This is captured in detail by each model.

Complementarity of consumption goods to leisure. This has not been captured in any of the models as they all assume that all goods are equally complementary.

The pattern of factor intensities of production for different goods. This has been captured in detail by each of the models.

The characteristics of non-worker consumers. These are not well captured in any of the models as they all appear to use the representative household approach. The only non-worker consumer is the rest of the world, and all models assume that the

[73] Pautelli et al. (2005) have carried out a similar but wider exercise recently and have concluded that the following factors are critical in determining difference in the results of empirical models: tax type, recycling policy and whether the model is derived from micro foundations or is more of a macro type.

EU countries have some monopoly power in trade. This gives the models some ability to pass on energy tax increases to foreigners and thereby create a larger double dividend in the EU.

International mobility of factors of production. This is really only an issue for capital. None of the models explicitly addresses the issue of the international mobility of capital[74]. If capital is mobile in this way, it will seek the highest return, and investment in any one country must respond to differences between domestic and international rates of return. An increase in energy prices, which can be passed on to capital and thereby reduce the rate of return on capital, should imply a reduction in domestic investment. This reduction in turn will raise domestic rates of return until the international and domestic rates are equalized. Hence capital will not bear part of energy tax, and the tax shift will not result in as big a gain in employment as when capital is immobile. In view of this, we believe that *all* the models could exaggerate the impacts of a shift in taxation from labour to energy in terms of increased employment. If capital is indeed mobile the burden of increased energy taxation could not be passed on to capital and would be borne by energy and labour, reducing the size of the double dividend.

The responsiveness of labour demand or supply to changes in labour taxes. The modelling of the labour market is divided into those models that assume full employment or voluntary unemployment (GEM-E3 and HONKATUKIA) and those that assume involuntary unemployment (HERMES and EUROGEM). The former may generate a 'double dividend' in the sense that employment increases as the incentives to supply labour become stronger. However, as the people who have moved into employment were previously voluntarily unemployed, the benefit to society is very different from the benefit created when involuntary unemployment is reduced. The two sets of employment effects are therefore not really comparable, although they are frequently compared.

The Elasticities of Substitution between Labour, Capital and Energy. We noted that the greater the elasticity between labour and energy, relative to the elasticity between capital and energy, the more likely it is that an employment double dividend

[74] None of the CGE models has examined this but some analytical GE models have. See, for example, Bovenberg and Goulder (1997).

will exist. In general the models have Allen elasticities that reflect this and therefore make the possibility of a double dividend quite strong.[75]

15.4.2.2 Analysis of the impacts of the 1992 EU energy tax proposal

There are now many models that have looked at the impacts of green tax reforms, but is difficult to come across a range that have addressed the same reforms. One exception to this is the 1992 EU energy tax proposal. For this reason we look in some detail at the results of these models[76]. In this, a 50:50% mix of carbon and energy taxes is applied at the level of $3/barrel of oil equivalent (b.o.e.) in the first year and rises to $10/b.o.e. in seven years[77]. This is a revenue-neutral change, with tax revenue being recycled through reduced employers' social security contributions. The models that have been run for this option are E3ME, GEM-E3, LEAN-TCM and EUROGEM. The E3ME is not run for exactly the same scenario, as it increases taxes from $1 per barrel of oil equivalent to $13 in 11 years. The LEAN-TCM also has slightly different tax increases than the others. The E3ME model is only run for the UK.

In spite of these limitations, a comparison of the results is instructive. Table 4 presents the main findings. The following points are worth noting:

A. The models all predict GDP increases, but they differ considerably in terms of the size of the increase, with LEAN-TCM producing the biggest increase in the final year, followed by EUROGEM, GEM-E3 and E3ME. The use of GDP is not, of course, a perfectly reliable indicator of a gross welfare dividend, which is better measured in terms of "overall consumption" or non-environmental welfare (as measured by an equivalent variation).
B. The time profile of the increases also varies. EUROGEM picks up much faster than E3ME. LEAN-TCM does not appear to have increased impacts over time at all. We do not have data on the time profile for GEM-E3.

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[75] If the cost function for the firm is $E = G(X_1, X_2, \ldots X_N, Y)$, where the Xs are inputs and Y is output, the Allen elasticity of substitution between inputs i and j is given by $\sigma_{ij} = \{G \cdot G_{ij} / G_i G_j\}$. The cross price elasticity between inputs i and j is given by $E_{ij} = \sigma_{ij} M_j$, where M_j is the share of input j in total cost.

[76] A similar comparative assessment of the 1997 tax reforms was conducted by Jansen and Klassen (2000)

[77] A tax of $10 per b.o.e. amounts to a tax of around $4 per ton of CO_2. This is based on (a) one b.o.e is equal to 5.5 gigajoules, (b) one gigajoule of petroleum poducts generate 72 kg of CO_2.

Table 3. Main features of empirical models used in the European employment/carbon tax literature

Model	Key Economic Assumptions	Special Points
HERMES	CGE model with unemployment. Uses nested CES production functions. National and EU applications.	Detailed development at national level in EU. Structure is transparent. Real wages determined by productivity growth and unemployment.
EUROGEM	Similar to HERMES. National and EU applications.	EU-wide model. Real wages now also depend on trade union bargaining objectives, which are a function of employment and real income differentials between workers and the unemployed.
GEM-E3	Classical CGE model with full employment. Run at EU12 and EU15 level	Structure has more emphasis on consistency with general equilibrium theory than with detailed estimation of structural equations. Information on model structure is cursory.
E3ME	Econometric model with less basis in economic theory. Assumes unemployment.	No production functions specified; only input demand functions with increasing returns. Cannot derive underlying productions functions from them.
HOKATUKIA	Model for Finland only. Dynamic CGE model with relatively simple structure and full employment.	Firms are imperfectly competitive, which allows some of the tax to be passed on in higher prices. Implications of environmental tax for overall efficiency of economy remain unclear.
LEAN-TCM	Similar structure to HERMES with unemployment.	Real wage depends on tightness of labour market

Notes:

1. The EU12 are Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain and the UK.

2. The EU15 are the EU12 plus Austria, Sweden and Finland.

C. The employment increase is greatest for LEAN-TCM, followed by E3ME. We attribute the high value in LEAN-TCM to the low wage elasticity with respect to unemployment. This means that when taxes are lifted and employment demand increases, the real wage does not increase by much to negate the tax advantage. The E3ME effect is probably due to the increasing returns to scale assumption cited earlier and partly to a greater substitutability of labour for energy. It is noteworthy that, in terms of employment, EUROGEM produces similar results to E3ME for the EU12. GEM-E3 has a much smaller employment impact.

D. The employment/GDP ratios vary a great deal. E3ME has much the highest ratio, followed by EUROGEM and GEM-E3. This suggests that the substitution potential in the three models differs quite a lot, with E3ME having the greatest and GEM-E3 the lowest.

E. E3ME generates a fall in prices, whereas the other two show a small increase in the price level, indicating that a shifting of the tax to the rest of the world is unlikely to be big.

Table 4. Impacts of an energy/carbon tax in EU12: Some comparative results (figures are percentages over baseline)

Year	Model	Countries	GDP increase	Employment increase	Carbon decrease	Energy decrease	Price increase	Employment/ GDP
YR 1	E3M3	UK only	0.02	0.12	0.33	N/A	0.00	0.10
	GEM-E3	UK only	N/A	N/A	N/A	N/A	N/A	N/A
	GEM-E3	EU12	N/A	N/A	N/A	N/A	N/A	N/A
	LEAN/TCM	EU12	0.47-1.4	0.7-2.24	4.1-4.8	N/A	N/A	0.2-0.8
	EUROGEM	EU9	0.00	0.20	5.00	N/A	N/A	N/A
YR 3	E3M3	UK only	0.05	0.47	1.31	N/A	-0.03	0.42
	GEM-E3	UK only	N/A	N/A	N/A	N/A	N/A	N/A
	GEM-E3	EU12	N/A	N/A	N/A	N/A	N/A	N/A
	LEAN/TCM	EU12	N/A	N/A	N/A	N/A	N/A	N/A
	EUROGEM	EU9	0.60	1.08	6.92	N/A	N/A	0.48
YR 10	E3M3	UK only	0.12	2.59	4.51	N/A	-0.22	2.47
	GEM-E3	UK only	0.30	0.53	N/A	-.7.72	2.25	0.23
	GEM-E3	EU12	0.15	0.37	10.34	-5.08	3.89	0.22
	LEAN/TCM	EU12	0.4-2.1	0.8-3.2	6.2-7.6	N/A	N/A	0.4-1.1
	EUROGEM	EU9	0.90	2.20	16.00	N/A	N/A	1.30

Sources: Cambridge Econometrics (1998), Capros et al. (1997), Bayar (1998), Welsch (1996).

Notes:

1. E3M3 analyses a carbon tax starting at $1 per b.o.e, rising to $13 in year 11.

2. For E3ME and EUROGEM the last row is for year 11.

3. GEM-E3 and EUROGEM analyse a carbon tax starting at $3 per b.o.e and rising to $10 in year 7.

4. The year 3 value for EUROGEM is interpolated.

5. GEM-E3 EU figures are estimated from individual country data, using appropriate weights.

6. The EU9 are the EU12 without Germany, Greece and Luxemburg.

To sum up, the empirical analysis has shown that the models differ in a number of ways that the theoretical analysis suggested would influence the likelihood of employment creation. It is therefore interesting to note that *all* the models suggest that the partial replacement of taxes on labour by taxes on energy increases employment and reduces carbon emissions. However, there is considerable variation between the models in the size of these effects.

It is impossible to use theoretical analysis to determine which of the many differences between the models are responsible for the differences in predicted employment creation. Instead, we must turn to a sensitivity analysis, which reports on numerical experiments to investigate which factors are most important in determining the amount of employment created.

15.4.2.3 Sensitivity analysis

Capros *et al.* (1996) provide some idea of the sensitivity of the GEM-E3 model to some parameter variations. A selection of their results is shown in the Table 5. Unfortunately, they do not provide details of the actual parameter values they use. Nonetheless, the table gives some hints as to what might be important. The first line of the table gives the base case results. The second line reports the consequences of making the wage rate strongly dependent on the level of employment, which reverses the GDP change and eliminates the employment gain: because of the wage rise, the energy taxes distort production with no employment gain. The third and fourth lines show the implications of altering the elasticity of substitution between labour and materials, showing that a high elasticity promotes employment growth and reduces energy use. This is what one would expect from labour subsidies.

The fifth line shows the effect of regarding the export market as more competitive, producing a smaller employment gain despite the continued reduction in energy use. It also shows that the GDP growth is substantially reduced. This illustrates the importance of tax shifting, in this case to the rest of the world, in producing a double dividend.

Finally, the last two lines show the effect of altering the substitutability between the capital/electricity aggregate and the labour/materials aggregate. The effects on employment are relatively modest, but interestingly show that a higher elasticity of substitution produces a smaller employment effect. This is presumably because the higher elasticity creates a greater distortionary effect between capital and (non-

electrical) energy, thus reducing efficiency, as witnessed by the much smaller gain in GDP.

Table 5. Sensitivity of GEM-E3 model predictions to key parameters (for France) simulation of European Commission's 1992 carbon/energy tax proposal

	Change in GDP	Change in Energy	Change in Employment
Base case	0.16%	-4.40%	+91,000
Inelastic Labour	-0.14%	-4.25%	0
Low labour-materials substitution	0.07%	-1.21%	+33,000
High labour-materials substitution	0.18%	-6.42%	+116,000
Competitive exports	0.05%	-4.70%	+68,000
Low capital-labour substitution	0.16%	-4.40%	+90,000
High capital-labour substitution	0.05%	-4.70%	+68,000

In addition, Denise Van Regemorter (Department of Economics, University of Leuven) has informed us that GEM-E3 does not produce a double dividend for any country if the assumption of EU monopoly power in international trade is dropped, because of the EU's loss of competitiveness. In other words, in this model, the double dividend only exists if some of the tax can be shifted to overseas consumers. This emphasizes the importance of looking carefully at the modelling of non-worker consumers, something that is frequently overlooked in the literature. However, it should be noted that EU monopoly power is not required to produce a double dividend in all the models. Terry Barker (Cambridge University; private communication) has confirmed that the E3ME double dividend does not depend on being able to pass on costs in export prices.

An additional source of evidence on sensitivity was provided by Ali H. Bayar (Université Libre De Brussels), who kindly carried out some simulations for us with EUROGEM. The results are shown in Table 6. The first row of Table 6 reports the percentage changes to employment and carbon dioxide emissions in the twentieth year after the policy change, based on the standard model assumptions with revenue recycled through reductions in social security taxes. The second and third rows show the changes if the elasticity of substitution between labour and the capital-energy aggregate is changed. As expected from the theory, increasing this elasticity substantially increases the employment benefit, as labour substitutes more easily for energy in response to the tax changes. Halving the elasticity actually eliminates the employment double dividend completely.

The third and fourth rows of Table 6 also illustrate the theoretical results, by showing the importance of the elasticity of substitution between capital and energy. As expected, reducing the elasticity increases the employment double dividend, as the energy tax has a smaller distortionary effect on the quantity of capital used in production. Doubling the elasticity removes the double dividend.

The last row of Table 6 reports on the effect of recycling the revenue through reductions in labour income tax instead of social security taxes. This confirms the intuition of the theoretical section: social security taxes are the best form of revenue recycling for obtaining an employment double dividend.

Table 6. Sensitivity of EUROGEM model predictions to model assumptions. Simulating the imposition of a US $10/tonne carbon energy tax

	Change in Employment after 20 years	Change in Carbon Dioxide after 20 years
Base Case	+ 0.61%	-17.93%
Doubling of top level elasticity: KE vs. L	+3.41%	-18.84%
Halving of top level elasticity: KE vs. L	-0.08%	-17.24%
Doubling of second level elasticity: K vs. E	-1.14%	-26.78%
Halving of second level elasticity: K vs. E	+1.25%	-12.26%
Recycling revenue through labour income tax	-2.12%	-18.55%

Unfortunately, we have been unable to obtain any sensitivity results for the effect of international capital mobility, which the theoretical analysis suggests could be of considerable importance. As reported earlier, the models do not represent international capital mobility directly, although some do make investment depend on the rate of return on capital. However, none of the modelers have reported the sensitivity of their results to changes in the parameters that link investment to the rate of return.

15.4.2.4 An assessment of the Danish carbon tax

The Danish government introduced a carbon tax in 1996, with rates of 5DKK/ton CO_2 for heavy process, 50 DKK for light processes and 100 DKK for space heating. The rates for heavy and light processes were increased by 2000 to 25 DKK and 50

DKK respectively by 2000. Exchange rates have varied over this period, but the 2000 rates amount to a tax range of between $4-14/ton CO_2.[78] There are, however, considerable exemptions to the taxes, with energy intensive industries in heavy processes paying only around 3 DKK/ton CO_2.

The carbon tax was recycled through four channels: employers' contributions to social security (reductions in the payroll tax); employers' contributions to pensions (reductions in the ATP); subsidies for investment in new energy efficient technology; and a special fund for small enterprises.

The Danish government reviewed the experience of the tax. As only a presentation of the work was available to the author, a full comparison with the other studies is not possible. Nevertheless, the results are of interest and complement those from the studies discussed above.

The following are the main findings from the Danish experience:

A. The estimated CO2 reductions from the carbon tax in 2005 were estimated at around 2 percent, which is a relatively small contribution. This is probably the result of significant tax reductions to energy intensive industries (50 percent of emissions are caused by energy intensive industries that pay only 20 percent of energy taxes). At the same time, however, another 1.8 percent reduction in CO2 emissions was attributed to the subsidies mentioned above.
B. The impacts on employment were not reported, but are estimated to be positive and small (Mr. Larsen, private communication).
C. The tax differentiations outlined above were considered necessary to maintain international competitiveness in the energy intensive sectors. (Again the details of the analysis of this are not available).
D. The administrative costs of the tax to companies' amount to 1-2 percent of the revenue, but the costs of applying for the subsidies are much higher: around 3-9 percent of the amount of the subsidies.

[78] Details were provided by Mr. Larsen from the Danish Ministry of Taxation and are available on: http://www.nmr.ee/dokumendid/nordic_forum/larsen.pdf.

15.4.2.5 Conclusions on the empirical evidence on the employment double dividend

Almost without exception these European models find that a switch in taxation from labour to carbon/energy will increase employment and reduce carbon emissions. At the same time they will increase GDP. Hence there is some agreement on this 'good news'. The differences are about the size of the impacts. For the 1992 proposed carbon/energy tax, this rises to $10 per barrel of oil equivalent over about 7 years, the size of the employment impact ranges from 0.4 to 2.6 percent by the end of that period. This is for various groupings of EU countries and should therefore be treated with caution, but it is still instructive about the range of estimates. With around 140 million people employed in the EU12, it translates into a range of from half a million extra jobs to over 3.5 million. The range of impacts on carbon reductions is also huge, from 5 to 16 percent. The GDP increases range from 0.4 to 2.2 percent. It is also interesting that more recent work, such as that carried out by national governments *ex post*, reveal impacts at the lower end of these ranges. The Danish study presented above is an example.

As expected, and as emphasized in the theoretical literature, the degree of substitution between inputs is important in determining the additional employment created. The larger the elasticity of substitution between labour and energy, the larger was the employment increase. Also, the smaller the substitution elasticity between capital and other inputs, the larger was the employment increase. These reflect the efficiency effects of reducing the high tax on labour. The importance of efficiency was also demonstrated in EUROGEM by the fact that the use of energy tax revenue to reduce income taxes, rather than payroll taxes, reversed the employment gain. This reflects the fact that income taxes are not so closely related to employment as are payroll taxes.

The role of shifting the tax burden was also demonstrated in GEM-E3 by two results: employment gains were reduced with increased export competition, and employment gains disappeared completely if none of the tax can be shifted abroad. Unfortunately none of the models captured the possibility of shifting taxes between different groups within society, such as those on pensions. More importantly, none of the models were able to indicate the sensitivity of the results to changes in the ability to shift the tax burden onto capital. The theoretical analysis suggests that

this is very important, and the investigation of this with numerical models should be a high priority for further research[79].

We should also not forget that there is a tension between the employment and environmental benefits on the one hand and the distributional impacts on the other. As we showed, the factors that make the Green Tax more effective in the former areas are also the factors that could have disproportionate negative effects on the groups like pensioners and the unemployed.

For all the reasons given above we would urge caution in assuming that the actual impact of green taxes would have a positive employment effect. We cannot conclude that countries should reduce the employment tax and switch to a carbon tax. The theoretical analysis shows that a simple double dividend view is naïve; the reality is much more complex, and many of the assumptions that have to hold for the employment double dividend to occur are difficult to justify. In the end the employment double dividend turns out to be an empirical issue. The empirical work is indicative of a small double dividend but, painstaking as it is, a number of the key linkages are left out. Hence policy makers would be justified in treading carefully in this area. An initial move to switch taxation may be tried experimentally and, if successful, extended.

Finally we note that the models reviewed above pertain exclusively to Europe. Results from the U.S. and some developing countries are less supportive of an employment double dividend (see e.g. Bovenberg and Goulder, 1997). This suggests that the prospects for a double dividend might be better in Europe than in the U.S. Perhaps this reflects greater inefficiencies in labour markets in Europe, where labour appears to be "overtaxed" relative to capital in the sense that the marginal excess burden per dollar of revenue is higher for an incremental increase in the labour tax than for an incremental increase in the capital tax. In the U.S., the situation is the opposite. This means that shifting the tax burden from labour to capital works in favour of not only the employment dividend but also the gross welfare dividend in Europe, while it works against the gross welfare dividend in the U.S.

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[79] Opponent Smith expresses a more general scepticism about the results from these models. While I agree that they do have several limitations, and have been at pains to point them out, it would be a mistake to reject such simulation based analysis altogether. The models do capture a number of important relationships in the economy and represent the state-of –the-art in this area at the time they were used. There is nothing better available for looking at the introduction of a policy measure before it has been adopted. I do think, however, that, with historic data now beginning to become available, it is time to think of some *ex post* analysis as well.

Conversely, policies that promote the gross welfare double dividend in the U.S.—lower *capital* taxes—work against the employment double dividend.

15.5 Conclusions

Green taxation has taken on the dimensions of a social movement and, for some, one that approaches religious conviction. They dream of the day when we will have only green taxes and no taxation of commodities and labour. At the same time those who want to see the ecological problems addressed effectively without going to the extremes of radical changes in our social and economic institutions place great hope in the potential of green taxes to do the job. There is no doubt green taxation has a strong superficial appeal: it brings together the environmental and the economic, and makes use of economic incentives to address the environmental problems. In practice, however, the situation is more complex. This paper has examined the arguments from both a theoretical and an empirical perspective. The arguments are divided into two: One case based purely on externality grounds and the other based on broader fiscal reforms, in which green taxes replace other more conventional taxes.

The externality arguments are based on sound reasoning, but they do not necessarily point to taxes as the ideal solution. At least one other option has a strong claim to provide an effective solution and that is the use of tradable permits. On theoretical grounds it is difficult to choose between them. There is perhaps a case to be made for taxes when the damage curves are relatively flat, but the force of that reasoning is not strong (the models are relatively simplistic) and the final preference between the two will depend on practical and political considerations. In particular, permits are politically attractive when polluters are awarded the permits on the basis of past emissions (so called grandfathering of rights). Taxes, on the other hand impose a greater initial burden on polluters and so the case for exemptions becomes stronger. Another conclusion is that taxes will rarely be the only instrument; mostly they will be combined with others notably command and control. The golfing analogy is apt: as you cannot play a good round of gold with only one club, so you cannot conduct effective environmental policy with only one instrument.

That said, taxes do have a significant role. They can be used in more situations than permits and their introduction into the regulatory framework has been more pervasive. The practical experience with taxes, however, has not been as positive as one might be led to believe. In many cases the levels imposed have been too low

with the result that the environmental impact has been small. Exemptions are common and a great deal of debate is about how to share the revenues rather than about how to make the system more effective. On the positive side we can say that most environmental regulations, including taxes have not had a noticeable negative impact on employment or on economic growth. Hence much of the concern in that direction is misplaced.

The second basis on which the case for green taxation is founded is the Double Dividend argument. In this paper we have shown that while the possibilities of such a dividend are there, the size of the impact depends on a number of factors, some technical and some social/economic. The technical factors, such as the elasticities of substitution between energy and labour ad energy and capital are matters for empirical testing. In general the actual elasticities do have a structure that supports a double dividend. The social and economic factors are more problematic. The possibility of a double dividend is greater when there is involuntary unemployment, which may be the case in some EU countries but is not so strongly present in all of them. The impacts are also more positive when you can pass the tax on others – either onto foreigners through market power, or onto those who are not in the workforce. While the former may be acceptable (it depends on whom the tax is passed on to), we may have qualms about passing the tax onto pensioners and other non-workers who will pay the higher prices for the energy intensive goods but will not benefit from the increase in real wages. Finally we have to worry about the mobility of capital. The more mobile this is, the less scope there is to obtain the double dividend by passing the tax onto capital. With globalization the mobility of capital has undoubtedly increased, making this a factor that needs more consideration than it has been given.

The empirical evidence on the double dividend in Europe is there, but it is small. The employment benefits do not turn out to be as large as some may have hoped. Of course, the taxes being considered have not been large either, and there is room for experiments with different levels of taxes but these are unlikely to be forthcoming.

In the final analysis, we have to see green taxation as a process in which greater use is made of the tax instrument, along with other economic instruments in the regulation of the environment. As we learn (and we are still learning) we will become more effective in when and where we use such taxes. If we keep our expectations reasonable we will achieve better results and also not be disappointed. The

road ahead is long, but it worth taking, with a compass based on the accumulated experience of the past.

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16 Opponent note no. 4a: Green taxation[80]

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16.1 Summary on Markandya's paper

Markandya (Chapter 15) provides an extensive review of theoretical findings on the effects of green taxation and summarizes some empirical evidence on this issue for the European Union.

The theoretical part begins with a pure externality argument which refers to potential environmental benefits from green taxation (1st dividend). These benefits would occur due to the internalization of the external costs from 'dirty' production and consumption activities: At the optimal – socially desirable – level the green tax absorbs the difference between social and private marginal costs of an economic activity (a Pigouvian tax). In absence of a green tax only the private marginal costs are borne by a polluter thus causing too high production/consumption and pollution levels. From a theoretical perspective the optimal pollution level with fully internalized external effects can also be achieved by alternative environmental policy instruments such as differentiated standards, subsidies, or tradable permits. The ultimate choice of the appropriate environmental instrument or a combination of instruments may then be based on institutional or political economy considerations.

Drawing on the theoretical double dividend debate, non-environmental benefits from green taxation reform are further considered (2nd dividend). Such non-environmental benefits might occur in the context of green tax reforms where revenues from green taxes are used for a revenue-neutral swap of existing distortionary taxes (levied to finance public spending). Theoretical studies identify these additional benefits as a 'gross welfare dividend' and an 'employment dividend', however, emphasizing the fact that they appear simultaneously only under certain con-

[80] I would like to thank my colleagues Viktoria Alexeeva-Talebi and Niels Anger for valuable research assistance.

ditions.[81] Rather, often these non-environmental dividends would differ in sign, in a sense that the welfare might decline while the employment would rise due to green tax reforms. Meanwhile, an elaborate research on the potential employment effects of green taxation has been conducted. The analysis of labor supply and labor demand effects is usually carried out within two different frameworks, i.e. neoclassical full-employment models and models featuring involuntary unemployment. In this context, Markandya (Chapter 15) discusses two main channels through which the labor supply and labor demand may be positively affected by green taxation. These channels are tax burden shifting and improved efficiency of the tax system. Remarkably, the first channel implies increasing employment through redistribution of the overall tax burden away from the production factor labor rather than through reduction of the overall burden. In contrast, the second channel requires the efficiency improvement of the overall tax system in a sense that the green tax reform finances public spending more efficiently with potentially positive effects on labor demand and supply.

Empirical evidence on the double dividend hypothesis is subsequently being discussed for the 1992 EU Energy Tax Proposal within several computable general equilibrium models (HERMES, EUROGEM, GEM-E3, HOKATUKIA and LEAN-TCM) and the econometric model E3ME. According to Markandya (Chapter 15), all referred models report a positive scope for the double dividend: Carbon emissions are reduced and employment is increased due to a partially revenue-neutral replacement of employers' social security contributions by a tax on energy. However, there are considerable differences in the respective model assumptions regarding key determinants of a double dividend as laid out in the theoretical literature. Moreover, the reported size of environmental and non-environmental effects varies substantially. Markandya (Chapter 15) then emphasizes the need for sensitivity analysis regarding critical assumptions for positive employment effects to occur (e.g. elasticity of substitution, capital mobility, revenue recycling method, etc.)

[81] Markandya refers to the 'gross welfare dividend' and the 'employment dividend' as two 2nd dividends. In the literature on green taxation, the 'gross welfare dividend' is occasionally identified as 2nd dividend, whereas the 'employment dividend' is referred to as 3rd dividend.

16.2 Alternative theoretical considerations

An extensive review on the double dividend literature was conducted by Goulder (1995) in the mid-90ies and then updated by Bovenberg (1999) four years later. Whereas Goulder's contribution focuses on efficiency effects ('gross welfare dividend'), the updated reader's guide by Bovenberg in addition deals with employment issues ("employment dividend") of green tax reforms. This section primarily explores arguments on the employment dividend since this issue represents one of the main interests in Markandya's paper.

Markandya (Chapter 15) first identifies fixed production factors (e.g. fixed capital) as being crucial for a positive employment dividend to occur through tax burden shifting. However, if we assume that capital is internationally mobile in a long-run, some further theoretical considerations have to be taken into account. Bovenberg and van der Ploeg (1994a) explore this issue within a competitive labor market model for a small open economy featuring three factors of production (internationally immobile labor, internationally mobile capital and natural resources). The authors demonstrate that the green tax reform will result in a lower consumer wage, since the higher tax burden cannot be shifted to internationally mobile capital and therefore rests on the non-mobile factor labor. Given a positive uncompensated wage elasticity of labor supply, lower consumer wages result in adverse negative effects on labor supply (e.g., the uncompensated wage elasticity is reported to be particularly high for female workers). Labor supply may then decrease substantially as a consequence of the green tax reform. Hence, a tension may emerge between the desire to increase employment and to improve the environmental quality. Similar results are derived by Bovenberg and van der Ploeg (1994b) in a model with one production factor (labor) for a small closed economy with consumption externalities.

Markandya (Chapter 15) then identifies two further types of tax burden recipients which are necessary for a positive employment dividend to occur: households with a transfer income (i.e. unemployed persons or pensioners) and foreigners (i.e. foreign countries or foreign consumers). Tax burden shifting from labor towards these groups might, however, cause severe redistribution effects. Therefore, additional normative considerations have to be addressed while assessing the green tax reform. Bovenberg (1999) demonstrates this issue within a simple competitive labor market model with two heterogeneous households. The first household relies entirely on the labor income, whereas the second one finances its consumption out of

the transfer income. Bovenberg shows that the tax shifting effect, which enables employment (labor supply) to rise, involves redistribution of income between labor and non-labor incomes. Hence, in this case, a green tax reform might yield the double dividend only at expenses of the inactive household. Similar results can be obtained in models with involuntary unemployment where the tax burden is shifted to individuals receiving unemployment benefits (Koskela and Schöb 1990).

As a consequence, positive employment effects based on the tax shifting argument are generally short-run in nature (due to mobility of capital in the mid-/long-run) or might not be desirable from a distributional point of view. An alternative and more optimistic view on the employment dividend perspective is presented by Schöb (2005) who applies the framework of a small open economy with two production factors (labor and energy) and a single monopolistic firm producing an output good. The initial equilibrium is characterized by a so-called labor tax regime with relatively high tax rates on labor and relatively low tax rates on energy. According to Schöb (2005), the revenue-neutral switch to a green tax regime with higher taxes on energy and lower labor taxes will increase the employment. The respective tax rates for labor and green tax regimes are determined analytically under consideration of the following constrains: i) the same output level is produced in both tax systems at the same marginal cost (this condition implies constant total cost if linear-homogenous technologies are assumed), ii) the firm profits do not change, iii) the government collects the same amount of taxes, and iv) the net-of-tax wage is fixed. In the new equilibrium, i.e. within the green tax regime, higher employment and welfare levels as well as a cleaner environment are achieved.

In implementing Schöb's model and performing sensitivity analysis, it turns out that the elasticity of substitution between both production factors (labor and energy) and the magnitude of labor taxes in the initial equilibrium are crucial for the positive employment dividends to occur. To illustrate, a relatively low elasticity of substitution between both inputs in combination with a relatively moderate tax on labor in an initial equilibrium diminishes positive employment effects substantially which may even turn into larger employment losses. Moreover, the problem of *Laffer efficiency* may exist for rather "realistic" parameters values, so that the increase of energy tax would reduce the overall tax revenue if the tax regime switch will be undertaken.

Finally, some remarks are in place regarding the optimal environmental taxation in a second-best world with environmental externalities since this issue is related to

the double dividend hypothesis but has not been addressed by Markandya. Bovenberg and van der Ploeg (1994b, 1996), Ligthart (1998b), and Ligthart and van der Ploeg (1999) stress that optimal environmental taxes in a second-best world would deviate from the Pigouvian tax level. It may be optimal to set the environmental tax as a weighted average of a Pigouvian tax and a Ramsey tax (revenue raising tax). Particularly, if raising of public funds becomes more expensive (as measured by the marginal costs of public funds – MCPF), the government should focus less on the internalization of external effects than on revenue raising.

16.3 Further empirical considerations

In the empirical assessment of green taxation, Markandya (Chapter 15) discusses both the history of externality-type environmental policy instruments and the empirical evidence for a double dividend from macroeconomic model-based studies. Regarding the latter, additional critical assumptions of simulation-based numerical analysis could be added to the presented discussion. One example is the temporal scope of empirical model analyses. Besides the choice between static and dynamic models, the assumed simulation period may be of critical importance for the (absolute and relative) employment effect of environmental taxation. Regarding dynamic simulation models, the incorporation of exogenous versus endogenous technological change may also play a crucial role for the magnitude and even the sign of the employment effects (e.g. if assumed to be factor-saving).

As addressed by Markandya (Chapter 15), sensitivity analysis is one important means to check for robustness of model-based results. In order to conduct a balanced assessment of model-based studies of the double-dividend issue, it is central to identify those model assumptions which are most relevant for the estimated economic outcomes. Credibility of input (modeling) assumptions will then be a prerequisite for the credibility of model-based results. One approach to assess the relevance of model specifications for simulation results in a comprehensive manner is to conduct a (statistical) meta-analysis. Besides controlling for features of studies (such as tax level, regional scope or simulation period), the impact of central assumptions (such as international capital mobility or labor market specification) on the simulated employment effect of green tax reforms can be systematically investigated. Based on a meta-analysis of green-tax-reform studies, Patuelli et al. (2005) concluded that tax type, recycling policy and economic model foundations (e.g. micro- versus macro-foundation) are of critical importance for a double divi-

dend to occur. In a similar vein, Barker et al. (2002) analyze model-based assessments of the costs of greenhouse gas mitigation.

Although the limited number of model-based studies presented by Markandya (Chapter 15) may be due to comparability considerations – here: studies analyzing the same policy, i.e. the 1992 EU Energy Tax Proposal – it should be mentioned that there are many additional empirical studies on the double dividend issue, especially on the employment dividend. Some assess the same environmental policy with alternative model types, e.g.. computable general equilibrium models and macro-econometric models (see Jansen and Klaasen 2000), others combine different models in order to either cover both partial and general equilibrium effects of green taxation (see Capros et al. 1998), or to comprehensively analyze economic distribution effects at the macro and micro level (see Bach et al. 2003).

While the great majority of model-based studies estimate quite weak (but generally positive) employment effects of green taxation, there exist studies which come to different conclusions – although accounting for revenue-recycling towards the labor market. Slightly negative employment effects of environmental tax reforms are simulated e.g. by Welsch and Ehrenheim (2004) using a dynamic CGE model and assuming wages that rise with employment, as well as by Conrad and Löschel (forthcoming) who model the labor market as perfectly competitive but assume "true costs of labor" according to a cost-price approach (including additional input costs for workers as compared to pure salaries). Scholz (2000) uses a dynamic CGE model for Germany and finds a negative employment effect of as high as 0.5% if assuming wages as the outcome of a bargaining process.

In conclusion, I agree with Markandya on the difficulties to obtain broad-based evidence for a double dividend since a consistent comparison of model-based studies appears rather cumbersome, if not impossible. However, for the same reason as well as on rather theoretical grounds, I would warrant more caution regarding the prospects for a double dividend of green taxation.

16.4 Outlook

Theoretical research on green taxation demonstrates that the costs of introducing green taxes may in general be higher than the benefits which are obtained from the revenue-neutral cut of existing distorting taxes (Böhringer et al. 2003). Even if the green tax reform results in some win-win-outcome, i.e. positive environmental and non-environmental dividends, negative distributional effects may occur. Unfortu-

nately, empirical analysis of the incidence of green taxation at the household level is rather scarce; most numerical model simulations rather report on the employment implications than on the wage effects. Some insights have been so far presented by Koschel (2001) and Scholz (2000) who incorporate heterogeneous (low-skilled and high-skilled labor) households. Further empirical research is required to properly assess the distributional effects of the green tax reform.

The theoretical and empirical double-dividend literature in general presumes the imposition of uniform environmental tax rates across polluters. In reality, however, environmental taxation in OECD countries often implies differentiated tax rates between sectors, typically discriminating in favor of energy-intensive industries (OECD 2001). Although there are theoretical arguments to back green tax differentiation quantitative evidence to justify discriminatory taxation is rather scant: Drawing on simulations with a computable general equilibrium model based on empirical data, Böhringer and Rutherford (2002) conclude 'that there is little economic rationale for the common policy practice of discriminating strongly in favor of heavy industries, even when accounting for interacting taxes, leakage, and international market power.'

The inefficient implementation of green tax reforms in terms of larger tax rate spreads may be explained by enforcement of political interests through potentially heavy-burdened 'dirty' industries. In an analysis of Germany's green tax reform, Anger et al. (2006) show that environmental tax differentiation between sectors is consistent with political-economy reasoning: Both economic characteristics of industries (such as exposure to international trade flows) as well as their lobbying power determine the design of the tax scheme.

Besides a lower environmental dividend through tax reductions for energy-intensive industries, also the chances for obtaining a second dividend may decrease as soon as differentiated green taxes are considered. Böhringer and Rutherford (1997), Babiker et al. (2000), and Kallbekken (2004) identify large welfare costs from differentiating climate policy by sector, finding that costs of reaching a certain emission target can easily double compared to an efficient design. Sub-optimal implementation may therefore worsen the efficiency and employment prospects of environmental tax reforms.

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17 Opponent Note no. 4b: Green taxation

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17.1 Introduction

I am in substantial agreement with much of the argument and analysis in the case study on "Green Taxation" by Markandya. The paper is a balanced and well-informed review of the main strands of economic thinking on the case for green taxation. It concentrates on issues of practical substance, and addresses many of the key theoretical and empirical questions relevant to the use of green taxes. Underpinning it is a clear appreciation of the economic literature on optimal environmental taxation, but the paper does not get sidetracked into unnecessary detail about some of the less policy-relevant directions taken by some contributions to the "double dividend" literature. Likewise, the paper is appropriately sceptical about the empirical literature on the double dividend, and identifies clearly some important questions about empirical simulation studies in this area.

In this note, I comment on the paper under three main headings: the environmental policy case for environmental taxes (section 2), the issue of a potential "double dividend" (section 3), and the issue of "competitiveness" (section 4). The concluding section of the note draws together key points and policy implications from the analysis.

17.2 The case for environmental taxes and other market mechanisms

Section 2 of Markandya's paper addresses theoretical economic arguments for and against the use of green taxation. Section 2.1 discusses the role of green taxes in correcting environmental "externalities" - in other words, the case for green taxes, even if there are no potential gains in terms of greater fiscal efficiency or lower unemployment. Section 2.2 is devoted to the issue of the possible double dividend, in terms of greater fiscal efficiency or lower unemployment, if the overall fiscal burden is shifted towards green taxes, and away from other taxes such as payroll taxes on employment.

The relative length of the discussions in section 2.1 and 2.2 reflects the complexity of the underlying literature, and should not be taken as indicating the practical significance of the two groups of arguments. The discussion of the role of green

taxes in correcting environmental externalities is of the greater practical relevance for policy, and in my view deserves substantially greater emphasis. Indeed, since I think the "double dividend" argument is (at the very best) a weak and unreliable justification for using environmental taxes, the case for green taxation, in my view, must be made substantially in terms of its potential to improve *environmental* policy, rather than on the basis of possible fiscal benefits. The arguments in section 2.1 are then central to the case for making greater use of green taxes.

Figure 1 of Markandya's paper sets out the framework underpinning the subsequent discussion in section 2.1 of green taxes and other environmental policy instruments. Figure 1 defines the optimal level of pollution abatement (G) as occurring when the marginal cost of pollution abatement (MAC) equals the marginal damage from pollution (MDC). Assuming that MAC rises with increasing abatement, and MDC falls, each unit of abatement up to this optimal point can be justified on a cost: benefit test, but each further unit of abatement beyond G would cost more than it would yield in benefits. The analysis represented in this diagram is central to economists' thinking about the trade-off between economic costs and environmental benefits. The optimal solution identified in Figure 1 can be implemented using a range of different instruments, including various forms of "conventional" legal regulation ("command and control"), and also economic instruments such as pollution taxes, tradeable permits, and abatement subsidies.

Figure 1 can be used to define how each of these instruments could be used to achieve the optimal regulation of emissions:

- Conventional "command and control" regulation can be used to instruct polluters to restrict their emissions to a maximum of G, or to instruct polluters to install various pollution control technologies that would have this effect.
- An emission tax set at E per unit of emissions would induce polluters to reduce their emissions to G
- An abatement subsidy of E per unit of abatement below the initial level of D would encourage abatement of GD, leading to a residual level of emissions G
- If tradeable pollution permits are to be used, a quantity of permits equal to G is issued (by various possible means), and would then trade at a market price E per unit of emissions.

Figure 1 does not provide a basis for understanding the benefits of market-based environmental policy instruments, because all instruments can achieve the same outcome G. The case for using the market-based approach thus goes beyond the analysis of Figure 1, and merits more extensive discussion than in the paper. Otherwise, there is a risk that Figure 1 is misinterpreted as the intellectual foundation for advocating use of green taxes and other MBIs, which it is not.

The most important issue, initially at least, is one of ***flexibility*** (ie static cost minimisation). MBIs allow us to overcome the severe informational problems which we would encounter in trying to achieve an efficient (least-cost) regulatory outcome using command-and-control regulation, in situations where the abatement costs of polluters differ. They do this by allowing polluters to respond flexibly to the financial incentive that the MBI establishes. The effect of this is that the total abatement is distributed between firms in a way that minimises aggregate abatement cost, without the need for the regulator to obtain abatement cost information from individual firms.

It might be suggested that MBIs face equally-intractable informational obstacles, in that we do not know enough about the abatement costs and pollution damage to construct the schedules shown in Figure 1. But this is to overlook two points.

First, Figure 1 represents the basis for efficient environmental regulation in general, and not just the use of MBIs. To set command and control regulations efficiently we need the <u>same</u> information about aggregate marginal abatement cost and aggregate marginal damage cost curves that we need for using MBIs. Of course we can always set command and control regulations arbitrarily, without this information (and frequently this is done), but regulating industry blindfold is not to be recommended.

Second, while informational limitations are central to the case for MBIs, but the key problem is that we do not know the position of ***individual*** polluters, not that we do not have full knowledge of cost and damage curves. We might, for example, be able to construct the aggregate MAC curve with considerable accuracy but still be better off using emission taxes than command and control regulation. For example, if we know that half of all polluters can use type A abatement technology and half can use type B, and if we know the marginal abatement costs for a typical type A and type B firm, we can calculate the MAC curve. However unless we know which individual firms are type A and which are type B, we <u>cannot</u> implement the efficient abatement outcome using command and control.

17.3 Is there a double dividend?

The theoretical discussion of the double dividend in section 2.2 begins, very usefully, by distinguishing between the "gross welfare dividend" and the "employment dividend". The paper notes that the literature generally suggests that an "employment dividend" is rather more likely than a "gross welfare dividend". It is worth stressing that the employment dividend is a narrower concept than the gross welfare dividend, and that achieving an employment dividend while failing to achieve a gross welfare dividend implies that employment is being increased at the expense of overall social well-being.

Section 2.2 then turns to the distinction between "weak" and "strong" double dividends. It is noted that the weak double dividend has been shown to hold in almost all models, while the strong double dividend can only arise where the existing structure of tax policy is sub-optimal. However, in my view the paper is unduly brief in its discussion of the policy implications of the weak double dividend, arguing that "the weak double dividend is simply about how to spend the environmental tax revenue", and "says nothing to enhance the case for environmental taxation". By contrast, my own view is that consideration of the weak double dividend has some major and direct policy implications bearing on the question of the choice between environmental taxes and alternative policy instruments, while discussion of the strong double dividend rarely has any substantive practical implications for environmental policy.

17.3.1 The "weak" double dividend

Where the "weak double dividend" argument has particular force is in the choice between revenue-raising and non-revenue raising instruments, such as, on the one hand, carbon taxes and auctioned carbon permits, and, on the other hand, permits issued for free. Under conditions of certainty there is a close equivalence between tax and tradeable permit instruments. Tradeable permits distributed by auction would trade at a price per tonne of emissions equal to the emissions tax rate that would have the same impact on emissions, and the tax revenues and auction receipts would be equal. Tradeable permits distributed free to existing firms ('grandfathered' permits) would be equivalent to an emissions tax, the revenues from which were given back to firms as a lump-sum windfall (as with the Swedish NOx tax). This latter equivalence highlights the fiscal wastefulness of grandfathered tradeable permits, in the sense that they forego the opportunity to raise revenues which could be used to cut the rates of existing distortionary taxes in the fiscal

system. There is similar fiscal wastefulness if political opposition to the introduction of emissions taxes is "bought off" by commitments to use the revenues in ways which do not reduce the marginal rates of existing taxes.

Recent work by Parry (2003) indicates the scale of the economic losses that would be involved in wasting the revenue-raising potential of auctioned tradeable permits (or equivalently, a carbon tax), by distributing carbon permits free through a grandfathering allocation process. On his estimates, a revenue-raising instrument such as carbon tax or the equivalent auctioned permits, set at $20 per tonne of carbon, would produce an annual welfare gain of somewhat over $1 billion, while grandfathering rather than auctioning permits would generate an overall welfare loss of some $6 billion annually. Grandfathered permits may perhaps have political attractions, in buying off the opposition of affected firms, but they have the potential to do substantial economic damage by foregoing revenues which could be used to cut other tax rates.

17.3.2 Improving the efficiency of the tax system

Markandya notes the very limited circumstances in which a strong double dividend could exist (achieving both environmental improvement and an improvement in revenue-raising efficiency). If a country has an existing tax structure that is optimal from the point of view of revenue-raising efficiency, then (by definition) no change in the tax structure can improve revenue-raising efficiency. Imposing a higher tax on a good that damages the environment may be good from the perspective of environmental policy, and may therefore be socially-desirable, but it cannot, in these circumstances, reduce the distortionary cost of the tax system. In general, it would be expected to increase the distortionary cost of the tax system.

Clearly, the starting point of this argument, that existing taxes are revenue-optimal, is unlikely always to correspond to the actual situation. However, while a strong double dividend would then arise, if environmental taxes move the economy closer to revenue-raising optimality, this is not a particularly strong foundation for environmental tax reform, for two reasons. First, it requires a particular form of inefficiency to exist, so that environmental taxes bring the economy closer to, rather than further from, the revenue-raising optimum. Second, this argument is generally a stronger argument for tax reform than for environmental taxation.

17.3.3 Simulation models and the (strong) double dividend

The paper has an extensive discussion, in section 3.2, of empirical simulation results on the double dividend. The discussion is clear, balanced and well-argued. It notes a number of respects in which the features of the available empirical models are critical to whether "double dividend" outcomes are found.

My own view on this literature is very sceptical. The literature contains examples of two very different approaches, based on macro models and CGE models. Both approaches have major problems, but for rather different reasons.

Macro models typically include behavioural equations estimated on the basis of real data. But they are much more effective in understanding short-run properties of the economy than in analysing longer-run properties. Indeed, the longer-run properties are often imposed, rather than estimated, and I am unaware of macro models that have freely estimated the set of long-run properties that would be critical to investigating the double dividend (in the "welfare dividend" sense). I do not think much is learned by running simulations with models that have imposed properties that guarantee double dividend effects.

CGE models in principle can be structured in a way that allows them to evaluate more seriously the long-run properties critical to the existence or otherwise of the double dividend, and there are some good studies based on CGE models reflecting the relevant theory. My main concern, however, is that these models typically reflect rather limited estimation or testing against real data. Such testing would of course be very difficult, but its absence does severely limit the extent to which the models add much beyond the theoretical results.

17.4 Environmental taxes and competitiveness

The impact of carbon taxes on the international ‘competitiveness’ of industry has, in practice, been a major source of political opposition to carbon tax proposals. Despite this prominence, the paper devotes little attention to this issue, beyond noting (correctly) that exchange rate adjustment can restore balance of payments equilibrium, and some other, rather brief, remarks.

The processes governing competitiveness, while clear-cut at the level of an individual enterprise, are less straightforward if the term is applied to the impact of national policy measures on an economy as a whole. At the level of an individual business enterprise, competitiveness is primarily a matter of being able to produce

products that are either cheaper or better than those of other firms. Applying the concept of competitiveness to whole economies is more controversial. One key reason is that it is necessary to take account of the macroeconomic adjustment mechanisms (such as exchange rate changes) that would be prompted by a deteriorating trade balance, or rising output prices. The principle of comparative advantage implies that a country will always trade successfully in some commodity, no matter how inefficient its firms are (or how burdened with environmental taxes or regulations), while the same is not true of a business enterprise. What matters, then, is not whether the country continues to trade successfully, but the terms on which such trade takes place. Whether a carbon tax would harm a country's competitiveness might then be gauged by whether it requires a fall in the country's real exchange rate, either through a change in the nominal exchange rate or through adjustment in domestic wage and price levels, to restore macroeconomic balance.

The impact of a carbon tax on competition can thus be seen to be primarily a relative issue, once adjustments through real exchange rate change or other channels are taken into account. The net impact of the carbon tax would be to worsen the relative position of carbon intensive sectors, whilst improving the competitiveness of sectors of industry with low carbon intensity.

In the long run, some contraction of carbon intensive sectors might be one of the desired outcomes from policies to reduce carbon emissions. However, whilst other countries do not impose the tax, these sectors may be liable to contract too much, in the countries which do impose the tax, relative to the final desired equilibrium where all countries impose similar carbon taxes. Part of this contraction may represent ‘carbon leakage’ – international displacement of carbon intensive production when a carbon tax is implemented without full international co-ordination – and this may impose adjustment costs and loss of profits, without any corresponding environmental gain.

One possible way of limiting this would be by exempting particular sectors in the tax structure. This has the drawback that it removes the incentive for emissions reductions in these sectors, and thus reduces the overall effectiveness of the tax. An alternative approach which might reduce the extent of international displacement to countries which do not impose the carbon tax would be to levy compensatory border tax adjustments (BTAs) for the carbon contained in traded goods. As Hoel (1996) demonstrates, there are economic advantages to BTAs compared with sectoral exemptions, but such compensatory tariffs are not an option for an individual EU member state acting alone, and even for the EU as a whole there is the

possible obstacle that they might be judged incompatible with the rules of the World Trade Organisation.

The effects of an economy-wide measure such as the introduction of a carbon tax on the competitive position of individual firms, and on the performance of an economy in aggregate, will arise through a complex set of channels. A key issue that is frequently overlooked is the need to define the consequent changes to public finances, either in terms of scope for reductions in other taxes, increases in public spending, or changes in net borrowing. If the existing stance of fiscal policy is efficient, the net marginal benefit of using additional tax revenue in each of these three directions should be broadly comparable, and we may therefore focus on the case where carbon tax revenues are used to make an equivalent reduction in other taxes.

If the tax reductions take the form of other taxes affecting the selling price of business outputs, such as a reduction in VAT, the implications of a tax shift towards carbon tax are straightforward to analyse.

With a revenue-neutral shift between two different origin-principle taxes levied on firms' outputs or sales, tax burden effects on competitiveness will arise through changes in the tax burden on different firms and sectors. For some the tax burden will rise, and for others the tax burden will fall. With an unchanged real exchange rate, the sectors with a higher tax burden are likely to lose market share in competition with foreign firms not subject to the environmental tax, either as a result of the exit of marginal firms, or as a result of higher prices. The opposite effect will be felt by sectors where the tax burden falls. Although the overall effect is assumed to be revenue-neutral, this does not necessarily imply that the impact on the trade balance will be neutral – this will depend on the relative price sensitivity of demand for the output of the sectors with increased and reduced tax burdens respectively.

In addition to the effects of the redistribution of the tax burden between sectors, there will also be costs of environmental compliance to be taken into account, and these may be unevenly distributed across firms and sectors. This effect will be greater, the greater the heterogeneity of firms in terms of marginal abatement costs.

If the carbon tax revenues are used to reduce the rate of tax on labour, superficially it might seem that there would be economic gains, through better incentives in the labour market – the so-called 'double dividend' of an environmental tax. But it is clear that this claim – at least, in simple versions of the story – rests upon a mis-

apprehension, that incentive effects in the labour market are confined to taxes levied directly on labour incomes. As the theoretical work on the 'double dividend' idea has made clear (Bovenberg and de Mooij, 1992; Parry, 2003), if a carbon tax is passed forward to customers in the price of energy and of goods produced using energy, this will have disincentive effects in the labour market that at least offset the labour market benefits of the reduction in labour income taxes.

17.5 Conclusions

My own selection of the key policy messages that might be drawn from this discussion would emphasise the following points:

- The key advantage of green taxes (and other market mechanisms) as compared with conventional regulatory policies requiring the use of particular technologies or setting quantitative limits on emissions is that it offers ***flexibility*** to polluters, and can hence reduce the cost of achieving a given standard of environmental protection. The tax encourages polluters who are able to abate at low cost to do more than they might be required to do under command-and-control, while allowing those with particularly high marginal abatement costs to do less abatement. Faced with a tax reflecting the marginal damage cost of pollution, these responses are efficient, and their aggregate effect is to improve the trade-off between environmental improvement and economic cost.

- Within the double dividend literature, the "weak double dividend" argument is well-founded, and has particularly strong implications for policy. It implies that there should be a strong preference for revenue-raising market mechanisms, over those with otherwise equivalent effects but which do not raise revenues. Grandfathered tradeable permits may have political attractions, but the revenue foregone is a substantial opportunity cost compared with similar, but revenue-raising, instruments. Likewise, environmental taxes accompanied by measures to return the revenues to the taxpayers as a group in a way that does not reduce marginal tax rates (eg the Swedish NOx tax) are potentially much more costly than taxes which contribute additional public revenues. There may be various reasons why environmental taxes sometimes have to take this form, but the revenue foregone is very costly.

- The strong double dividend argument has very limited practical applicability to policy. One situation in which a strong double dividend would arise is where the existing tax structure is not optimised. However, this is a much stronger argument for tax reform (ie for optimising the non-environmental tax structure) than it is a support for green taxation. The double dividend argument that introducing green taxes would benefit both the environment and the economy may have a lot of political resonance, but its economic foundations are shaky.

- In my view the case for green taxation has to be made on the basis of its potential to improve environmental policy (eg by reducing the aggregate cost of abatement), rather than on the basis of its potential to improve fiscal policy.

- I do not think the simulation model results from short-term macro models are very helpful in informing policy options on green taxation. Such models tend to focus on temporary adjustment effects rather than long-run costs and benefits. By contrast, any decision to use green taxes in environmental policy needs to be assessed as a long-term change in the regulatory environment, aiming at changing the long-run incentives for polluter behaviour. For example, the impact of green taxes on energy will be distributed over many years, as existing energy-using capital equipment comes up for renewal. Ensuring long-run regulatory stability in environmental tax regimes will be a key issue in ensuring that they work well, and one to which too little attention is generally given.

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Part VII

Case Study #5

18 Case study paper no. 5: Support to organic farming and bio-energy as rural development drivers

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18.1 Abstract

The paper conducts an analysis of the potentials of organic farming and bioenergy as *win-win-win* strategies promoting economic *growth*, *employment* and the *environment* at the same time. Empirical evidence does not indicate that conversion to organic farming will enhance economic growth and employment, but there are environmental benefits primarily due to the absence of pesticides. If energy crops are grown on idle land bioenergy has the potential of generating economic activities and employment alongside with CO_2 reductions. *Liquid* biofuel production is a relatively expensive way of reducing CO_2, but there is a potential for technological breakthroughs making it economically viable to use low value feedstock like straw and waste for bioethanol production. It is recommended that the positive environmental effects of organic farming and bioenergy are internalised through green taxes on the negative externalities from conventional farming and fossil energy use.

18.2 Overview

The aim of the meeting "Green Roads to Growth" is to provide input to policy makers on policies that could meet the goals of the Lisbon Agenda in the way of stimulating *economic growth*, *employment* and the *environment* at the same time – also known as a *win-win-win* strategy. This paper presents analyses of the potentials of organic farming and bio-energy to promote *win-win-win* strategies in the sense of the Lisbon Agenda. The growth and employment aspects are seen in relation to rural development in particular.

18.2.1 Organic farming

Based on literature studies it has been investigated if there are systematic differences between the remuneration of factors of production in organic and conven-

tional farming. It is the conclusion that there is no systematic tendency for organic practices to yield either higher or lower economic returns than conventional practices. Analyses of farm account statistics indicate that the relative Net-Factor Income of organic farms, compared to conventional farms, depends on the year, country, and enterprise – rather than the practice as such. In other words, there is no clear empirical evidence that conversion to organic farming has the potential of satisfying the first "w" in the Lisbon Strategy, i.e. stimulating economic growth in terms of increasing rural income.

The second "w" concerns employment. Organic arable farms and mixed farms generally have somewhat higher inputs of labour per ha, while organic dairy farms use the same amount of labour or less than comparable conventional farms. On organic horticulture farms labour requirements are much higher. However, a relatively small share of the farmed area is needed to grow the horticultural products demanded. Off-farm employment would tend to decrease as a result of conversion of agriculture to organic practices. Hence, there is no clear-cut tendency for employment to either increase or decrease as a result of conversion.

The third "w" is about environmental improvements. Organic farming differs from conventional agriculture with respect to the provision of public as well as private goods. The public goods are (reduced) environmental externalities and the private goods (perceived) differences in taste and health attributes of the produced commodities. Generally, the provision of private goods can be left to market forces. Externalities, on the other hand, must be dealt with through some form of public intervention.

The absence of chemical pesticides in organic farming represents an environmental advantage in terms of ground water protection and enhancement of wildlife. Nitrate leaching is lower per ha on organic farms, but similar or slightly higher per unit of production. N_2O and methane emissions exhibit the same pattern. Energy use is found to be lower in organic farming systems, but the difference is small when measured as energy use per unit of output. It is the overall conclusion that there are environmental benefits associated with a conversion of conventional agriculture to organic practices, primarily due to the absence of pesticides. However, the survey indicates that these benefits could be provided at lower social costs through other agro-environmental measures.

The conclusion drawn from these findings has two components: 1) there is a need to internalise the externalities from agricultural production (especially from fertil-

izer and pesticide usage) through environmental taxes or similar measures; 2) provided externalities are internalised to all producers the extent of conversion to organic farming should be determined by consumers' demand/willingness to pay for organically produced food. In addition to securing the internalization of external costs the Government has an important institutional role as a guarantee of the authenticity of products marketed as organically produced.

18.2.2 Bio-energy

When certain conditions are met bioenergy production has the potential of generating economic activities and employment in rural areas alongside with provision of environmental benefits in terms of CO_2 reductions. To constitute a *win-win-win* strategy in the sense of the Lisbon Agenda it is essential that energy crops are grown on land which would otherwise be idle. If energy crops crowd out traditional crops it is unlikely that this will have positive net effects on employment. Therefore, *win-win-win* opportunities in relation to energy crops will have to be found in areas with an "abundance" of abandoned agricultural land – and unemployed labour, i.e. typically in less favoured areas.

Rising oil prices have created considerable optimism regarding the commercial opportunities for bioenergy production, in particular ethanol and biodiesel. A considerable number of studies have investigated the energy efficiency and economic viability of these alternatives. Unfortunately, the results do not provide a unique answer to these questions. However, it seems reasonable to conclude that the production of bio-energy on agricultural land is not generally a commercially competitive land use. Inclusion of external costs and benefits improves the competitiveness of bio-energy from a societal perspective. Still, the competitiveness of bio-energy is sensitive to the value of the avoided green house gas emissions.

When biomass is converted to liquid biofuel the oil price plays a crucial role for the competitiveness of the bioenergy alternative. Other factors creating uncertainty about the long run viability of biofuel are crop prices and land rent. If biofuel becomes a commercially competitive alternative to conventional crop production at the global level an equilibrium will have to be found between land based energy production and food production. This will inevitably lead to higher crop/grain prices and higher land rents, which in turn will reduce the competitiveness of energy crops everything else equal. Trade regimes have a significant influence on price formation. Biofuels – especially ethanol – can be produced at much lower cost in Brazil than in the EU. At present trade barriers protect EU producers from

global competition in biofuels. Accordingly, trade liberalization could drastically change the economic prospects for biofuel production in the EU.

Generally speaking conversion of biomass into liquid biofuels is an expensive way of reducing CO_2 emissions – at least when relatively expensive raw materials such as starch and vegetable oil are used as feedstock. A potentially viable alternative is lingo-cellulose in low value biomass like straw and waste wood. The processing cost component may be significantly reduced in the (near) future due to expected technological breakthroughs in terms of the so called second generation biofuels.

The overall policy recommendation is to implement an adequate price structure for all types of energy. This implies that the externalities from fossil fuel combustion – primarily CO_2 emissions –should be taxed at a level compatible with the long run marginal costs of realizing the specified reduction commitments in the EU/Member States. When fuel is taxed for fiscal purposes biofuels should be exempted from the CO_2 tax element. The right price structure will create adequate incentives for innovators and producers to develop and implement new technologies. However, there are still a number of unanswered questions regarding the economy wide and global interactions between bioenergy production and other economic and social factors. There is a need for thorough investigations of the interrelationships between the economic factors mentioned above. Such analyses should be based on an analytical framework in the form of computable general equilibrium models.

18.3 Introduction

The objective of this study is to analyse the potentials of *Green Roads to Growth* policies, enhancing organic farming and bio-energy production. The focus will be on incentives to convert agricultural production from conventional to organic practices and incentives to increase the production of energy crops and biogas. For these two policy areas the study will assess the impact of support measures on economic growth, employment and the environment. The approach will primarily be a meta-analysis based on the literature in these fields and the results of data analyses already published. A special feature of the study is the spatial-economic perspective. Organic farming and bio-energy production are closely tied to agricultural land, implying that policies promoting these activities can also be regarded as rural development measures.

18.3.1 Rural development policy

Rural development policies focus on a wide range of measures aiming at enhancing economic growth, avoiding depopulation of rural areas, and increasing the supply of rural amenities[82]. In Europe, the EU plays a key role in the definition of rural development policies. The Agenda 2000 reforms of the Common Agricultural Policy introduce the concept of rural development policy as the second pillar of the CAP. The new rural policy is mainly implemented through The Rural Development Regulation (1257/1999). It lists a number of rural development measures which can be implemented by the Member States and which will be co-financed by the EU. The regulation also prescribes that Member States must prepare rural development programmes at the national or regional level.

As already mentioned, support to organic farming and bio-energy production has obvious rural development perspectives. In most EU-countries, subsidy schemes for organic farming are integrated in the rural development programmes (European Commission, 2005), and production of bio-energy can be seen as an option for economic diversification in rural areas (Sims, 2004).

18.3.2 Objectives of the study

It is the hypothesis that support to organic farming and bio-energy has the potential of *simultaneously* enhancing economic growth, employment and environmental qualities. To what extent these assumptions hold is an empirical question. The present survey of bio-energy policies will focus on the production of energy crops. Concerning organic farming, the focus will be on the conversion of agricultural production from conventional to organic practices. The impacts of relevant support schemes will be investigated with the aim to:

1. Identify *win-win-win* policies in terms of

2. The impact on *regional economic growth*, *rural employment* and the *environment*

[82] In Denmark rural areas are statistically defined as the parts of the country that are not urban, where urban is defined as communities of 200 persons and more. Rural areas are also defined as rural municipalities, i.e. municipalities in which the biggest town has less than 3,000 inhabitants.

18.3.3 Approach

The primary focus of the study will be on policies implemented in Denmark, however, results of similar policies in other (EU) countries will also be addressed. The analysis will be based on a review of existing studies reported in the literature. In addition, the study will draw on the comprehensive accountancy data base for agriculture, available at the Food and Resource Economics Institute.

There are only a few published studies on the impact of organic faming on income and employment. This is one of the reasons why this paper, to some extent, is based on an analysis of primary data from The Danish Farm Account Statistics.

18.3.4 Outline

In the second chapter, organic farming is analysed, and the third chapter addresses bioenergy. The chapter on organic farming first introduces organic farming and discusses the analytical framework from a theoretical perspective. Then, analyses of the impact of organic farming on income, employment and environment, reported in the literature, are reviewed, and an empirical analysis of Danish data on organic farms is performed. The third chapter first discusses biomass production in relation to agriculture and rural development. Next, the analyses of farm production of biomass for energy, reported in the literature, are reviewed. Each of the two chapters concludes with a summary of the main findings.

18.4 Organic Farming

What is understood by organic farming has changed over time, and in the early 1980s the definitions of organic farming varied between countries (Wynen 1998). However, in the beginning of the 1990s, the organic production was defined by the European Community and standards for organic production were set.

Organic farming can be considered as a particular agricultural production system in which synthetic fertilizers and pesticides are not used. Organic farming can also be considered as an alternative paradigm for production of food which seeks to integrate humane, environmentally, and economically sustainable agricultural production systems (Dabbert et al. 2004). In this paper organic farming refers to the production systems which comply with national definitions and regulations of organic agriculture in Europe.

In the year 2002 certified and policy-supported organic production accounted for four per cent (over 5 million ha) of the total agricultural land in Europe (Häring et al. 2004). As the recorded area of organic farming was only 100,000 ha in 1985 this represents a remarkable increase in area. The countries with the highest relative organic area were in 2001; Austria, Switzerland Sweden, Finland, and Denmark. In Denmark the growth in the organically farmed area seems to have stopped, and Jacobsen et al. (2005) expect a decrease in the organic farmed area.

The conversion to organic farming has been driven by a combination of high market prices on products and generous subsidies. By 1996, all member states, with the exception of Luxembourg, had introduced policies to support organic farming within the agro-environmental programmes co-financed by the EU (Lampkin et al. 1999). In 1997 the support for conversion to and continuation of organic production amounted to nearly 260 million ECU. In the year 2001, a total of 275 million € was spent on organic farming within the agro-environmental measures of the Council regulations (EC) 2078/92 and 1257/99 covering more than 18,000 holdings, farming nearly 3 million hectares (Häring et al. 2004). The subsidies for organic farming vary between countries, e.g. France and Great Britain only support in the conversion period, whereas other countries have continued supporting organic production (Offerman and Nieberg 2002).

18.4.1 The analytical framework

Arguments often brought forward in favour of organic farming are its contribution to conversion of farm incomes and increase in labour employed in agriculture (Häring et al. 2004). Organic products receive higher prices, and the organic production methods influence the labour intensity, e.g. mechanical or manual weeding and a higher share of labour-intensive crops, such as vegetables, may imply a higher labour input, compared to conventional faming.

However, the impact of organic farming on income and employment is ambiguous because the production is normally lower per hectare at organic farms than at conventional farms due to extensification of the production, e.g. the livestock density is often lower at organic farms (Häring et al. 2003).

Since agricultural land is an essential input factor in the production of (organic) crops, and the supply elasticity for agricultural land is close to zero, any given use of agricultural land is competing with other uses for a share of the fixed total area. Thus, to increase value added and employment in land-based production as a

whole, we must look for alternatives which "yield" more value added and employment per hectare than the displaced activities.

Comparing the performance of organic and conventional farms with respect to value added and employment, it is required that the organic farms are compared to conventional farms which look like the organic farms if they have not been converted (Nieberg and Offermann 2003). The main approach used in the literature is to compare organic farms with a selection of comparable conventional farms. These farms should have a similar production potential, i.e. a similar endowment with production factors as the analysed organic farms. Only "non-system determined" variables, e.g. location factors such as region, soil texture, topography, climate and market distance, can be used for this matching.

Other variables like farm size, farm type, and crop rotation may possibly be affected by the choice of production. However, these variables are also often chosen as variables for selecting comparable farms (e.g. Dubgaard 1990, Dubgaard 1994, Offermann and Nieberg 2000).

Differences in crop rotation between organic and conventional farms illustrate the problem. For example, the share of land for production of vegetables is often higher on organic farms compared to conventional farms (see e.g. Dubgaard 1994) and the income and labour use per hectare is higher for vegetables. Therefore, differences in income and labour use between the organic and the conventional farms may be a result of the differences in the crop mix.

Ideally, an assessment of the impact on income and employment of subsidizing organic farming should be performed in a general equilibrium framework where the feedbacks on relative prices and the interactions with the conventional sector are included. For example, an increased production of organic products may have a negative effect on the prices of organic products and a positive effect on prices of conventional products. Furthermore, changes in the organically farmed area may also influence upstream as well as downstream activities generated by the agricultural production.

The present analysis is primarily based on studies applying a partial approach, i.e. without including feedback mechanisms, because only a few studies are based on a general equilibrium approach. The analysis also includes an analysis of primary and recent data, based on the Danish farm account statistics.

When evaluating organic farming as instrument for rural development, organic farming should be compared with the best available alternative options (Dabbert

2003). It may not be the case that the present policy and production system represent the best alternatives. For example, taxes on pesticides may be a less costly instrument to increase the supply of environmental benefits, e.g. biodiversity, compared to subsidizing organic farming.

However, in this study organic farming is compared with corresponding conventional production systems. This implies that we are not analysing whether organic agriculture is the best use of production factors in general but only compared to similar conventional systems.

18.4.2 Literature review

The literature review is divided into two parts. The first part reviews studies that are based on a partial approach. The second section reviews three studies of organic agriculture in Denmark applying a general equilibrium model.

18.4.2.1 Partial analyses

18.4.2.1.1 Income

Offermann and Nieburg (2000) compare the income from organic farming with the income from conventional farming based on an empirical study of farm account statistics in a number of European countries in the 1990s. They also analyse the underlying factors determining the relative income, i.e. relative yields and prices of the organic products and the cost structure on organic farms.

They find that prices of organic products are higher and yields are lover. The average price premium for organic products varies between products and marketing channels. They find that the relative farm gate price premium for organic products in different European countries varies between a few per cent to 200 hundred per cent, lowest for milk and higher for crops.

In their empirical study they also find that the relative difference between organic and conventional yields depends on the intensity of the production systems compared, the farm types, and the crop types considered. Furthermore, natural conditions, e.g. soil types and climate, have also an impact on the relative yield. The performance in livestock production is less influenced by the choice of farming system when measured per livestock unit, since the main difference between the two production systems is that the livestock density is lover on organic farms compared to conventional farms.

In the empirical analysis they find that fixed costs per hectare are generally higher on organic farms relative to comparable conventional farms, whereas the variable costs are lower on organic farms. The cost structure is different due to restricted use of external inputs, e.g. fertilizers, pesticides, and concentrates which reduce costs, whereas the cost of buying organic seeds and feedstuffs may increase the costs per hectare or per output unit. Often labour input is high at organic farms, as analysed in the next section, due to the substitution of labour input and pesticides in weed control, and more on-farm processing and marketing at organic farms.

They also find that the total costs per ha at organic farms relative to comparable conventional farms vary between European countries and between crop and dairy farms.

Offermann and Nieburg (op. cit.) analyse the income from organic farms in eight European countries. Income is measured as the relative profit of organic farms compared with profit on conventional farms. They define profit as family farm income, i.e. the sum of market revenues from sales of agricultural products, subsidies, other farm income (rents, contract work for others, etc.), net value of change in stock, and the value of farmhouse consumption minus variable costs, overheads, wages, salaries paid to seasonal and non-family workers, interest paid on borrowed capital, and rent paid. In their study they find that organic farms in Europe on average achieve similar levels of income as comparable conventional farms. However, variance within the samples is high. Arable farms have, in general, achieved above average incomes over the years investigated. Organic dairy farms generally have a higher return to family labour but a lower return per ha agricultural land than comparable conventional farms.

The family farm income is, however, not an appropriate measure for comparing the income between conventional and organic farms. First, it does not include the income generated for the paid labour and secondly, the profit includes subsidies which do not represent a production value but an income transfer.[83] Offerman and Nieburg (op. cit.) find that about 20 % of the profit at organic farms is generated by subsidy payments to organic farming.

[83] Alternatively subsidies to organic farming can be seen as remuneration for the provision of public goods in terms of less pollution.

The results of an analysis of 36 Danish organic farms in 1998 (Dubgaard et al. 1990 and Dubgaard 1994) indicate that factors of production received about the same remuneration in conventional and organic agriculture – after a conversion period of some length. The remuneration of labour was somewhat better in the organic sample than in a group of comparable conventional farms. Labour remuneration was measured per hour and was calculated as total returns to labour divided by the recorded labour input. The return to labour was calculated as the residual of total net factor income after remuneration of capital. Conventional farms were found to have a higher return to capital than organic farms given the imputed value of the farm-family labour. This analysis is based on rather few farms and from an early stage in the development of organic farming in Denmark. Therefore, conclusions can not be drawn about future organic performance based this analysis. In section 2.3 more recent (1999-2004) farm accounts from organic and conventional farms are analysed and compared, based on the Danish farm account database (Institute of Food and Resource Economics, FOI, 2005).

18.4.2.1.2 Employment

Generally, it is expected that organic farms are more labour intensive due to more labour-intensive production activities, e.g. mechanical weed control in arable production, higher shares of more labour-incentive crops, more marketing activities and on-farm processing activities, and increased information requirements (Schulze Pals 1994 quoted from Offermann and Nieberg 2000). Häring et al. (2003) also find that there are more non-agricultural commercial activities on organic farms than on conventional farms, e.g. tourism. However, lower yields and stocking rates, i.e. less livestock units per hectare agricultural land may imply a lower labour intensity than at conventional farming.

Since organic farming is a relatively new production system we may expect organic farming to have a higher potential for technical processes. It is only in recent years that the allocation of resources for research and development in organic farming systems has increased. Therefore, it should be possible to reduce the labour input relatively more in organic systems than in conventional systems. Offermann and Nieberg (2000) find empirical evidence of the decreasing difference in the labour input between organic and conventional farms.

Based on a case studies in nine European countries Offermann and Nieberg (op. cit.) conclude that the labour use per ha Utilisable Agricultural Area on average is 10 %-20 % higher on organic farms relative to comparable conventional farms.

However, for some countries, labour requirements are lower on organic farms than on comparable conventional farms (see Table 1). The results are based on data from various years in the different countries.

Table 1. Annual work unit per ha utilisable agricultural land on organic farms as a percentage of comparable conventional farms in different countries (Offermann and Nieberg 2000).

	Austria	Switzer-land	Germany	Denmark	Finland	France	Luxembourg	Italy	The Neder-lands
Year	1993	1993-96	1993-97	1996/97	1995	1997	1997	1992-95	1995
%	91	110-132	102-118	105	89	(125)[1]	(125)[1]	60-90 (214)[2]	197

[1] *Expert estimate*

[2] *Single study (Cerasola and Marino 1995), year of data unknown.*

The results are dependent on the farm type. Organic arable farms or mixed farms generally have higher inputs of labour per ha while organic dairy farms use the same amount of labour or less than comparable conventional farms. On horticulture farms, labour requirements are much higher than on conventional farms.

In their study they also found that organic farm types are, in general, more labour intensive than average conventional farms, i.e. the relative labour input on conventional farms, which are comparable to organic farms, is 10 -20 % higher than the average labour input on conventional farms.

Based on 1.3 % of the agricultural land converted to organic farming in 1996 Europe, Offermann and Nieberg (op. cit.) estimate, that 18.000 more people were employed in agriculture than there would have been in a situation without organic farming. This corresponds to 0.3 % of the total agricultural labour force. They note that it is not possible to extrapolate from these results to estimate the labour use in a situation with a higher share of organic farming.

Since to some extent the increased labour demand is due to on-farm processing and marketing activities, it is unlikely that labour intensity will be unchanged by increased conversion to organic farming. In some areas there will be no demand for regional products and the benefit of on-farm processing, and marketing may also decrease when more farms in a region follow this trend. On-farm processing and marketing may also reduce employment in agro-industrial processing and market-

ing enterprises. Furthermore, organic farming will also result in less employment in the industries supplying pesticides and fertilizers. However, for the rural communities it may be an advantage that labour use is moved to the farms from industries, which are typically located in urban areas.

18.4.2.2 General equilibrium analysis

Frandsen and Jacobsen (1999) and Jacobsen (2001, 2003) analyse the Danish organic farming sector applying the Danish Research Institute of Food Economics' Agricultural Applied General Equilibrium model (AAGE). The advantage of using the AAGE approach is that this modelling framework covers the interdependencies between the individual industries, interaction between industries and consumers, and between domestic and foreign agents. The model thus covers the whole Danish economy, and is characterised by the requirement that there should be equilibrium in all markets. The model therefore calculates long-run results of a given policy scenario (Jacobsen 2003). Another advantage of the model is that it includes the upstream and downstream impacts of organic farming.

Applying the AAGE model, Frandsen and Jacobsen (1999) show that the cost to society of a complete transformation of Danish agriculture into organic production would be around 2-3 % of real GDP, whereas the costs of a complete or partial ban on pesticides would amount to 0.82 % and 0.35 % of real GDP, respectively.

Jacobsen (2003) analyses five scenarios for the development of organic farming in Denmark. Besides a baseline, which includes ongoing policy development and known shocks to the economy, four alternative scenarios are analysed. One alternative scenario assumes that domestic and foreign consumers change their preferences in favour of organic products (preference scenario). Two scenarios introduce subsidies to agricultural land in the organic sector to induce a conversion of land into organic production in order to achieve a positive environmental effect. The first subsidy scenario is designed to achieve the same level of land converted to organic production as in the preference scenario, and the second subsidy scenario is designed to obtain the same environmental effects as in the preference scenario. The environmental impacts are measured as the level of input of environmentally harmful inputs (fertilizers and pesticides). The fourth alternative scenario introduces a tax on fertilizer and pesticide use to achieve the same effect on the use of environmentally harmful input as in the preference scenario.

The analysis shows that the relative organic area and production volume increase in the preference scenario (8.7 % and 10.7 %, respectively). In the subsidy scenarios, the cost of land (net-costs after area-based subsidy) decreases for organic farmers, implying substitution of land for other inputs. This corresponds to an extensification of the production, i.e. the area with organic farming is equal to or higher than in the preference scenario, but the increase in organic production is much smaller. In the fertilizer and pesticide tax scenarios, the increase in organic farming is less than in the preference scenario. This is because the environmental effects are primarily achieved by substitution on conventional farms - rather than conversion of land into organic farming.

A larger share of organic land use is required in the subsidy scenario compared to the preference scenario to achieve the same level of environmental benefits as in the preference scenario. This is due to substitution of land by fertilizers and pesticides at conventional farms because the land prices increase for conventional farms when organic land use is subsidized. In the preference scenario, where organic land use is not subsidized, the production intensity is higher on organic farms and the demand for land is less.

In the preference scenario, the employment in conventional farming decreases by 3,211 full time workers, while employment in the organic sector increases by 3,100 full time workers, i.e. a net decrease of 111. In the subsidy scenarios the net decrease is 600 full time workers. The tax scenario has a small positive effect on employment, due to substitution of fertilizers and pesticides by labour. The negative effect on employment in the subsidy scenario is mainly explained by the transfer of land from conventional production to organic production, but since demand for organic products does not follow the inflow of land, this results in an extensification effect in organic production. In the fertilizer and pesticide tax scenario, the production is lower but the taxed inputs are to some degree substituted by other inputs, especially labour in conventional farming.

The preference scenario and the subsidy scenarios also have a negative impact on the employment in the processing sector. In the preference scenario the employment increases with 819 full time workers in the organic processing industry but decreases with 1281 in the conventional sector. In the subsidy scenarios, total employment in the processing sectors decreases with 469 and 679 full time workers.

A comparison of changes in GNP between the subsidy and the tax scenarios shows that the GNP decreases most in the subsidy scenario. Achieving the same reduction in nitrogen and pesticide use by using subsidies is more than seven times as expensive as the use of fertilizer and pesticide taxes.

It is important to note that the above analysis was conducted at the national level. The environmental effects (the reduction in pesticide and fertilizer inputs) are positive in all scenarios but total production also decreases – and, consequently, agricultural exports decrease. This may imply intensification of agricultural production in other countries and negative environmental effects.

In DØRS (2004) three scenarios for protection of groundwater and biodiversity by regulating Danish agricultural production are analysed. In the first scenario, pesticides are taxed higher than today; in the second scenario pesticide use is banned in buffer zones around fields and drillings for drinking water, and in the third scenario, conversion to organic farming is increased by increasing the subsidy to organic farming. The scenarios are designed to incur the same costs by the three different policy interventions. The objective is then to identify the policy which yields the highest level of environmental benefit. The scenarios are modelled in an integrated model framework involving two economic models, the general equilibrium model, AAGE, and ESMARALDA[84] which is an agricultural sector model, and ALMaSS[85] which is a landscape model for simulation of fauna in the landscape. In the present study, ALMASS was used to model the population of skylarks, which was used as indicator of biodiversity.

The results indicate that establishment of buffer zones have the most positive effect on biodiversity. Organic farming also has a positive effect, but less than buffer zones. Increased pesticide taxes had a small negative effect on biodiversity. One of the reasons for this negative effect is changes in the land use which is less favourable for skylarks, the biodiversity indicator species. In all three scenarios, the risk of contamination of groundwater with pesticides was reduced. The lowest risk reduction was in the organic scenario.

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[84] ESMERALDA (Econometric Sector Model for Evaluating Resource Application and Land use in Danish Agriculture). See Jensen (1996) and Jensen et al. (2001) for documentation.

[85] ALMaSS (Animal, Landscape and Man Simulation System). See also Topping et al. (2003).

It is concluded that increased conversion to organic production is not a cost-effective instrument for improving biodiversity and protection of groundwater.

18.4.2.3 Environment

Stolze et al. (2000) assess the impact of environmental and resource use of organic farming relative to conventional farming systems. The assessment is based on a literature review and a survey of specialists in eighteen European countries using a structured questionnaire. It is concluded that organic farming clearly performs better than conventional farming with respect to floral and faunal diversity, and due to the ban of synthetic pesticides and N-fertilizers, organic farming systems provide potentials that result in positive effects on wildlife conservation and landscape.

Due to mostly higher contents of organic matter and higher biological activity in organically farmed soils than in conventionally managed soils, organic farms tend to conserve soil fertility and system stability better than conventional farming systems. However, the results are highly site-specific.

The above survey showed that nitrate leaching is lower per ha on organic farms but similar or slightly higher per unit of production compared to conventional farms. The ban of synthetic pesticides in organic farming implies that there is no risk of contaminating the ground and surface water with pesticides.

On a hectare scale they find that nitrate leaching is lower per ha on organic farms but similar or slightly higher per unit of production compared to conventional farms. For N_2O and methane the limited amount of available data indicates that emissions from organic farming systems are lowest compared to conventional systems based on a hectare scale but higher on a per-unit output scale.

Energy use in organic farming systems is found to be lower than in conventional systems. Similar results are found in Jørgensen and Dalgaard (2004) where it is concluded that the energy use per unit of organic output of meat and milk is lower than for conventional products, but the difference is small. The same holds for crop production but the energy use per unit of outputs depends on the crop type and the production practice.

Stolze et al. (2000) find new clear differences between organic and conventional farming with respect to animal health and welfare. Finally, based on the reviewed studies they cannot make clear-cut conclusions about the quality of organic food in

general. However, it can be assumed that the risk of contaminating food with pesticides and nitrate is lower for organically produced food.

Wrang et al. (2004) review the differences between organic and conventional production with focus on Danish agriculture and the five specific areas: economy, environment, health, animal welfare and taste.

They find that organic farming has positive effects on biodiversity, soil quality, water environment, and genetic variation. However, organic farming also has negative effects on the environment, including harmful effects of mechanical weeding and increased area requirements for the production of the same amount of food.

The empirical evidences of the effect of organic farming on health are not clear, but theoretical considerations indicate that organic food could be healthier.

In the case of animal welfare it is not documented that there are general differences in level of animal health or mortality between organic and conventional production systems. However, primarily organic farming satisfies consumers' considerations about animals being well-treated and that production methods follow ethical practices.

Based on studies of the sensory properties of organic products it is not possible to conclude that organic products have significantly different sensory characteristics compared to conventional produced food.

Finally, it is concluded that there is a cost-difference between organic and conventional production of 430 million DKK. The additional costs are due to the fact that organic agriculture experiences lower yields and higher production costs. Furthermore, there may be additional costs associated with the processing and distribution of organic products. Valuation of the environmental benefits is not attempted because there are different environmental effects, many of which are difficult to value.

18.4.3 Danish case study

Since no recent studies on the relative performance of organic farms are reported in the literature, an analysis of the generation of income and labour use in organic farming is carried out based on the Danish account statistic for agriculture (FOI 2005). The objective of the analysis is to empirically estimate the income generation and labour input by organic farming compared to conventional farming systems. Income is measured as net factor income per hectare, and labour input as

hours per hectare. Labour input includes both unpaid family labour and paid labour.

18.4.3.1 Data

The empirical analysis is based on the Danish database of farm accounts. These data are collected and analysed by The Institute of Food and Resource Economics. The Danish data input to the European Farm Accountancy Data Network (FADN) is based on the same data.

The database includes a representative sample, including around 1,900 farm accounts (Pedersen (2005). The full population of farms included 49,000 farms in 1999 which decreased to 39.000 farms in 2004. The reduction in the number of farms is a consequence of the development in farm structure, i.e. increasing farm sizes.

The farms are in the statistic defined as holdings, i.e. a farm may include more farm estates owned by the same farmer.

The minimum size of the farms included in the population and the sample are farms of 10 hectares. However, if a farm with less than 10 ha has an aggregate Standard Gross Margin which exceeds 8 European Size Unit, i.e. a standard gross margin of 71.496 DKK, the farm is included in the population.

18.4.3.2 Method

The analysis is performed for dairy cow farms and arable farms separately. The main reason for this distinction is that there are significant differences in the geographical location and size of these two groups of organic farms.

The number of organic dairy cow farms is high in the southern and western part of Jutland, whereas the organic arable farms are more evenly distributed throughout the country (Jacobsen et al. 2005). One determinant of the geographical distribution of dairy cow farms may be the differences in soil quality. With regard to sandy soils, dairy cow farms have a comparative advantage to other farm types. Furthermore, Offermann and Nieburg (2000) suggest that organic farms are expected to be found on poor soils where costs of extensification are lower than on fertile soils. However, whether this holds generally is not empirically documented. Anyway, the highest concentration of organic dairy cow farms is found in the western and southern part of Jutland where sandy soils are dominating.

Organic dairy cow farms are in average larger than other organic farms, e.g. in 2003 dairy farms constitute 26 % of the number of organic farms but they cultivated 46 % of the organic area.

The share of part time farmers, with annual working hours less than 1,665 standard working hours, are higher among arable organic farms than organic arable farmers. For example, in 2003 no dairy cows were found on farms managed by part time farmers even though these cultivate 28 % of the organically farmed area (Jacobsen et al. 2005).

Ignoring these systematic differences in the production structure between organic and conventional farms in the analysis may lead to biased conclusions. Since most of the organic farms are either located on relatively poor soils in Jutland or are small-sized and owned by part time farmers, a comparison between an average organic farm and the national average of conventional farms may disfavour organic farm with respect to income. Since it will be a comparison of income between organic farms primarily located on poor soils with conventional farms primarily located on more fertile soils. Furthermore, the comparison may be biased by a higher number of part time farmers among the organic arable farmers.

It is important to emphasise that the results of the present analysis only apply to the production structure of organic farming which is observed today. It is not possible to extrapolate the result to a situation with a more widespread adaptation to organic farming. With a larger share of organically cultivated land, the organic production structure may change, i.e. we may see more organic production on more fertile soils and more full time farmers will become arable farmers. Furthermore, the distribution between milk, pork, crop and vegetable production may change too.

In the empirical analysis we have used two approaches to estimate the contribution of organic farming to rural income and employment. Firstly, we have compared organic dairy farms and arable farms with conventional farms with a similar production structure. Secondly, we have statistically estimated a model describing income from organic and conventional farming as a function of some underlying structural variables, like farm size, livestock, and soil types.

In the comparison of the organic diary farms with conventional dairy farms, the group of comparable conventional farms is based on the group of farms selected in Sotelo (2005). The conventional farms are randomly selected from the sample of farm account statistic and given the restrictions that the sample of conventional

farms should correspond to the organic sample with respect to the age of the farmer and the size and composition of the production. These variables are selected because based on experience these variables have an impact on the economic results Sotelo (op. cit.). For example, the conventional farmers are generally older than the organic farmers and the labour productivity is higher for young farmers.

The production structure of the sample of organic dairy and arable farms is shown in Tables 2 and 3, respectively. The tables also include the production structure of the conventional farms selected for comparison with the organic farms. For most production structure indicators, the organic and conventional groups are rather similar. However, the area of the organic farms is around 10 % larger for the dairy cow farms (Table 2).

The Net-Factor Income is defined as the total revenue from agricultural production, excluding subsidies, and minus costs, except taxes, labour costs, and capital costs. Employment is measured as working hours, including working hours of the farmer, the farmer's family, and paid labour.

In the comparison of arable farms the same approach has been followed as in the comparison of the dairy farms. In the selection of conventional arable farms for comparison, relatively more small farms have been selected to match the generally smaller organic arable farms.

Table 2. Farm and production structure on organic farms and group of comparable conventional farms.

	Units		1999	2000	2001	2002	2003	2004
Sample size	Farms	Conventional	162	126	225	205	253	244
	Farms	Organic	81	122	150	138	134	115
Agricultural area	ha	Conventional	81	85	82	88	94	95
	ha	Organic	98	109	104	106	112	112
Dairy cows		Conventional	80	88	82	86	94	95
		Organic	80	88	83	87	94	91
Farmer's age	years	Conventional	43	43	43	46	45	44
	years	Organic	43	43	44	45	45	44
Labour, Farmer and family								
		Conventional	3010	3264	3184	3191	3080	3032
	hours	Organic	2887	2940	3024	2989	2927	2882
Labour, Paid	hours	Conventional	1223	1152	1043	1076	1302	1200
	hours	Organic	1475	1504	1333	1354	1541	1458
Labour, Total								
	hours	Conventional	4233	4416	4227	4267	4382	4231
	hours	Organic	4362	4445	4356	4343	4468	4340

Table 3. Farm and production structure on organic arable farms and group of comparable conventional farms.

	Units		1999	2000	2001	2002	2003	2004
Sample size		Conventional	84	90	143	149	225	200
		Organic	57	61	88	113	126	139
Agricultural area	ha	Conventional	30	27	33	36	37	41
	ha	Organic	39,0	31,8	38,4	39,6	43,2	44,3
Livestock	Live.	Conventional	6	12	11	8	7	4
	units	Organic	6	6	7	7	5	6
Farmer's age	years	Conventional	46	46,3	47	48	47	48
	years	Organic	45	46	47,0	47,0	46,9	48,0
Labour, Farmer and family								
	hours	Conventional	1094	1050	1174	1035	1032	1012
	hours	Organic	1483	1065	1154	1102	1006	997
Labour, Paid	hours	Conventional	511	356	243	175	215	206
	hours	Organic	1000	553	349	224	1312	1334
Labour, Total	hours	Conventional	1605	1406	1417	1210	1247	1218
	hours	Organic	2483	1618	1503	1326	1312	1334

The statistical analysis is based on a linear model of the form:

$$Y_{kij} = \alpha_{ki} + \beta_{ki} X_{kij} + \varepsilon_{kij}, \quad j = 1.,...,N \text{ farms, i} = \{\text{conventional, organic}\},$$
$$\text{and k} = \{1999, 2000,..2004\}$$

α_{ki} , β_{ki} are vectors of parameters to be estimated,
and X_{kij} is a vector of independent variables representing farm production structure,
ε_{kij} is the error tems which is assumed normal and independent identically distributed

Two models are estimated for both the arable and the dairy farms. One model is estimated with Net-Factor Income as dependent variable, Y_{ij}, and one with labour input measured in hours as dependent variables are estimated. The definition of arable and dairy farms is based on the definition in Jacobsen et al. (2004), where the farm types are defined based on the crop rotation. Dairy (cattle) farms are defined as farms where more than 16 % of the agricultural area is used for roughage production. Arable farms are defined as the farms which are not dairy farms, however, excluding farms with high shares of horticultural crops.

In the model for Net-Factor Income, dummy variables are included to account for annual variation in prices and yields, e.g. due to variation in climate. In the model for labour input a time trend is included.

Variables describing the production structure in the model represent conditions that cannot easily be changed in the short-run, e.g. the number of hectare, soil type, land used for horticultural crops and permanent grass, and the livestock size.

Horticultural crops and permanent grass are the only crops explicitly included in the model, because other crops may change from year to year due to changes in relative prices. The production of horticultural crops typically implies a higher share of fixed costs, e.g. specific machinery and know-how, whereas permanent grass is normally located on less fertile soils that are not suitable for rotational crops. Quadratic terms for area and livestock units to account for decreasing marginal productivity of area and livestock are included.

18.4.3.3 Results

18.4.3.3.1 Dairy farms

Table 4 shows the Net-Factor Income for organic farms and a group of comparable conventional dairy farms for the period 1999-2006 based on data from FOI (2005). The selection of the comparable conventional dairy farms is based on the criteria described in the previous section. The revenue from organic dairy farming is around 19,000 DKK per ha which is less than for the comparable conventional farms (81-97 %). However, there are rather high variations over the years.

The costs per hectare are also lower at organic farms compared to the comparable conventional farms (79-100 %). This implies that it is not possible to conclude whether the Net-Factor Income is higher or lower per hectare for organic dairy farms. In 2002 and 2004 the factor income was higher on organic farms than on the comparable conventional dairy farms, whereas the factor income was significantly lower in the other years analysed.

The labour use on the organic dairy farms is estimated to 39-44 working hours per hectare on organic farms. This is 1-11 hours lower than on the comparable conventional farms, i.e. the labour input on organic farms is about 78-96 % of the labour input of comparable conventional farms.

However, from Table 2 it appears that the average area of the organic farms is about 10 % higher than on the comparable conventional farms. Therefore, the livestock intensity is lower on the organic farms and may explain the lower labour input of organic farms.

In Figure 1 and Figure 2 the respective Net-Factor Income per hectare and labour input per hectare are simulated using the statistical model described in the previous section (see also Table 5 and 6) for an organic and a conventional dairy farm located on coarse sand and using the parameters for 2004. In the simulations it is

assumed that the simulated farm has the same production as an average organic dairy farm in 2004 (Table 2), i.e. it uses 0.1 ha for horticultural crops and 11.5 hectare for permanent grass.

Table 4. Comparison of Net Factor Income on organic and conventional dairy farms

Year		1999	2000	2001	2002	2003	2004
Revenue	Conventional	20858	22747	22348	21795	22610	19619
(DKK/ha)	Organic	18205	18405	18145	20215	17679	18982
	Organic %	87.3	80.9	81.2	92.7	78.2	96.8
Costs	Conventional	12094	15643	16208	15745	16292	15115
(DKK/ha)	Organic	12057	12394	12821	13300	13441	13614
	Organic %	99.7	79.2	79.1	84.5	82.5	90.1
Net factor	Conventional	8765	7104	6140	6050	6318	4504
income	Organic	6148	6011	5323	6915	4238	5369
(DKK/ha)	Organic %	70.1	84.6	86.7	114.3	67.1	119.2
Labour	Conventional	52	52	52	48	47	40
(hours/ha)	Organic	44	41	42	41	40	39
	Organic %	85	78	81	85	85	96

Figure 1 shows the expected Net-Factor Income per hectare as a function of livestock units (LU). One LU is defined as the number of animals producing 100 kg nitrogen contained in the manure, e.g. one dairy cow (heavy breed) is 0.85 LU (Miljøministeriet 2002). As expected, the graph shows that for a given agricultural area, the income per hectare decreases with decreasing livestock size, and for a given size of livestock, the income decreases with increasing farm area. Furthermore, the simulations show that the income on conventional farms is lower per hectare except for farms with low livestock density, e.g. farms with 150 ha and less than 100 LU will have the highest income if they are conventional.

Based on the statistical model (Table 5), the income in 2004 can be estimated to 5.035 DKK per ha for conventional dairy farms and 5.106 DDK per ha for organic dairy farms, given the average farm area and average number of livestock units for the two groups of farms (Table 2). The income for a conventional farm with a production structure corresponding to the average organic dairy farm is 4.592 DKK per hectare (Table 2). This shows, as expected, that the Net-Factor Income of organic farms relative to conventional farms will be higher than calculated in Table 4 when the analysis is based on farms with identical livestock density.

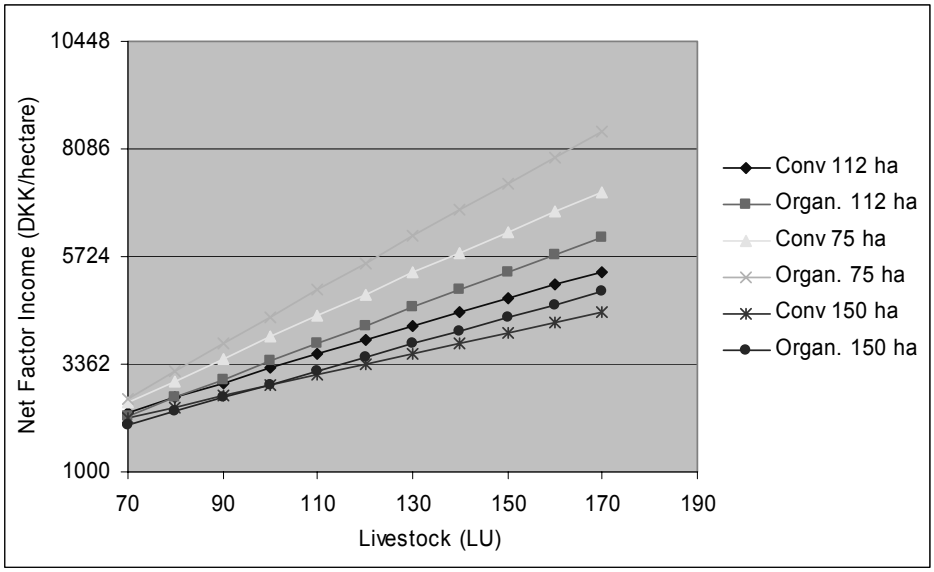
Table 5. Model parameters for Net-Factor Income at dairy farms 2004 located on coarse sand

Variable	Parameter value Conventional farm	t value[1)]	Parameter value Organic farm	t value[1)]
Intercept	-191458	-8.02**	-191458	-8.02**
Year, (2004=1) [2)]	0		0	
Organic farm (conventional farm= 1)	12110	0,59	-	
Permanent grass (ha)	-4628	-17**	-4628	-17**
Horticulture crops (ha)	16220	4.78**	16220	4.78**
Area 2004 (hectare coarse sand)	1853	6.10**	1441	5.10**
Livestock units (LU)	4041	21.5**	4668	12.1**
(Livestock units)^2 (LU^2)	-2.36	-18.9**	-1.07	-0.91

*1) ** Significant at the 1 % level.*

2) The dummy variable for the year was normalised on the year 2004, i.e. the effect of the year is measured as differences between 2004 and the other years in the sample.

Figure 1. Simulated net factor income per hectare as a function of the numbers of livestock units (LU) for conventional (Conv) and organic (Organ) dairy farms with 75, 112, and 150 ha. See text for further explanation. Source: FOI (2005) and own calculations.



In Table 6, the estimated parameters of the statistical model of labour input on dairy farms are reported. Again, the parameters are shown for a farm located on coarse sand. In this model the parameters are independent of the year. Changes in labour input over the years are modelled with a time trend. According to the estimated model, the labour input of an average farm decreased by 73 hours per year.

Labour input to the farm by contracting is not included in the analysis, but it is assumed that organic and conventional farms use contracting to the same extent. This assumption seems reasonable, since the costs of contracting are at the same level for both farms types (FOI 2005).

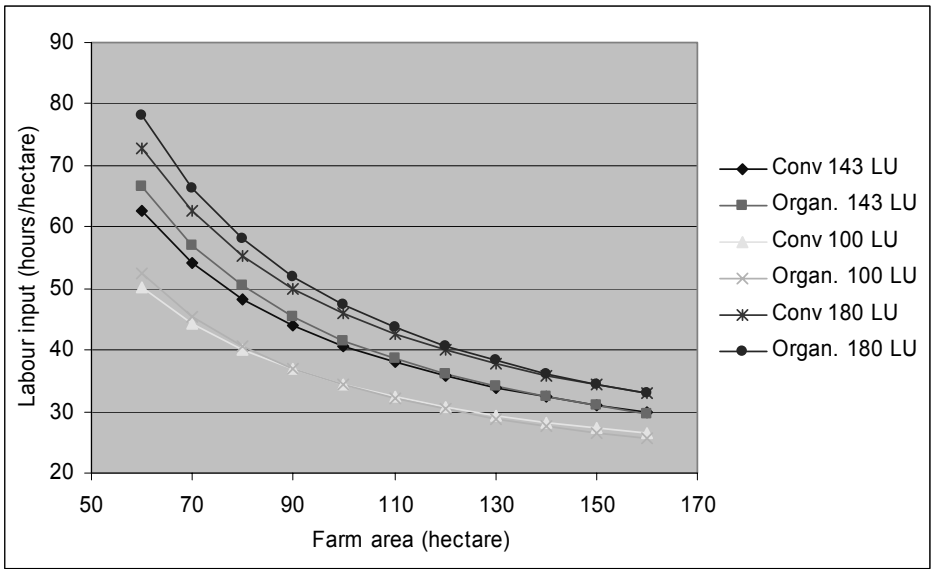
Using the estimated statistical model (Table 6), we can show that the labour input on organic dairy farms relative to conventional farms in Table 4 is lower than when the organic farms have the same livestock density as the group of comparable conventional farms. In Figure 2 the labour input is modelled as a function of farm area for given size of the livestock. The figure shows that the labour input is decreasing with the increasing areas and decreasing livestock size. The figure also shows that the labour input on organic and conventional farms is at the same level for given area and livestock sizes. On farms with high livestock density, the labour input per ha seems to be higher on organic farms compared to conventional farms.

Table 6. Model parameters for labour input on dairy farms 2004 located on coarse sand.

Variable	Parameter value Conventional farm	t value[1)]	Parameter value Organic farm	t value[1)]
Intercept	146915	8.40**	146915	8.40**
Year	-73.3	-8.39**	-73.3	-8.39**
Organic farm (conventional farm= 1)	276	2.63**	-	
Permanent grass (ha)	-9.4	-10.5**	-9.4	-10.5**
Horticulture crops (ha)	247	22.8**	247	22.8**
Area 2004 (ha coarse sand)	18.2	20.6**	16.1	10.5**
(Area 2004)^2 (ha^2 coarse sand)	-0.0113	-4.94**	-0.0079	4.67**
Livestock units 2004 (LU)	11.7	21.8**	16.9	8.8**
(Livestock units)^2 (LU^2)	-0.0031	-7.22**	-0.0187	-3.99
Livestock density (LU/ha)	363	10.8**	456	4.54

*1** Significant at the 1 % level.*

Figure 2. Simulated labour input per hectare as a function of the size of farm area (ha) for conventional (Conv) and organic (Organ) dairy farms with 100, 143, and 180 ha. See text for further explanation. Source: FOI (2005) and own calculations.



18.4.3.3.2 Arable farms

In Table 7 the Net-Factor Income and labour input per ha on organic and conventional arable farms are compared for the years 199-2004. The revenue per ha is lower on the organic farms except for 1999. However, the costs are also lower on the organic farms. The Net-Factor Income is highly variably over the years. In 1999 and 2002, the Net-Factor Income is highest on organic farms, whereas conventional farms have the highest income in the other years analysed. There is no clear conclusion in the case of labour input. In 1999 and 2004 the labour input per ha is highest on organic farms. One explanation for the blurred conclusion might be the small size of the farms considered. Most farms are owned by part time farmers who may manage the farms according to various objectives where profit maximization may play a minor role.

These results were confirmed by estimating the statistical model based on the arable farms. It was not possible to estimate a reasonable model for the organic farms, e.g. the estimated parameters were inconsistent with the theory. Therefore, the results of the statistical analysis are not presented. We can, therefore, not draw definite conclusions from the analysis of the arable farms.

Table 7. Comparison of Net Factor Income and labour input on organic and conventional arable farms.

Year		1999	2000	2001	2002	2003	2004
Revenue (DKK/ha)	Conventional	11883	14097	11679	8073	9353	8418
	Organic	13282	10204	7828	7437	7333	6630
	Organic %	112	72	67	92	78	79
Costs (DKK/ha)	Conventional	9797	11262	9949	8679	8534	8054
	Organic	10159	9258	7372	7672	6910	7120
	Organic %	104	82	74	88	81	88
Net factor income (DKK/ha)	Conventional	2087	2835	1730	-606	819	364
	Organic	3123	947	456	-235	424	-490
	Organic %	150	33	26	39	52	-134
Labour (hours/ha)	Conventional	54	53	43	34	34	30
	Organic	64	51	39	33	30	30
	Organic %	119	97	92	98	90	101

18.4.3.4 Discussion

The above analysis of farm account statistics is partial, i.e. it does not take into account the interactions between the farming organic sector, the conventional farming and other sectors in the economy as was the case in section 2.2.2 (general equilibrium analysis). For example, the production structure at the conventional farms may have been different without an organic farming sector. This implies that the results of the above empirical analysis can only be used as indications of the consequences of future policy changes. Especially, it gives an indication of the contribution of organic farming to the rural economy given the present farm structure.

During the period of analysis there has been an over-supply of organically produced milk. Therefore, it must be expected that the milk price will decrease in the future if there are no other changes in the markets, e.g. changes in the consumer preferences for organic milk. The expected decrease in the price premium of organic milk implies that the Net-factor Income per ha is also expected to decrease for organic dairy farms.

Comparing the organic dairy farms with conventional dairy farms showed that the labour input per ha was lowest on organic farms. Also, the milk production per hectare is lower on organic dairy farms. If we assume that the milk quota is binding for the amount of milk produced, then increased organic production will reduce the conventional production with an equal amount. By this conversion more land is occupied by roughage for producing the same amount of milk. Therefore, organically produced milk will imply less production of cash crops.

The net effect on employment of an increase in the production of organic milk will therefore be differences in the labour input per kg milk between organic and conventional dairy farms, and the effect of substituting cash crops with organic roughage production. In 2004 the labour use per 1000 kg milk was 0.75 hours higher on organic farms compared to conventional farms, and the organic dairy farm used 0.03 ha more land for producing 1000 kg milk (Table 8). An average farm with plant production uses 21.7 hours per ha. This implies that the total employment effect of converting the production of 1.000 kg of conventionally produced milk into organic production is 0,75 hour - 21.7 hours * 0.03=0.1 hours (1.8 % higher than in the conventional production). The analysis shows that conversion from conventional to organic milk production does not have a dramatic impact on labour use even when the lower milk yield per cow is taken into account.

Table 8. Impact on employment of converting 1000 kg of conventionally produced milk to organically produced milk.

		Organic dairy farm	Conventional dairy farm	difference	Plant production
Area	Ha	112	105		146,5
Cows		91	91		
Milk per cow	1000 kg/cow	7.390	8.244		
Labour farm	Hour	4,340	4,279		3182
Labour/milk	Hour/1000 kg	6.45	5.70	0.75	
area/milk	Ha/1000 kg	0.17	0.14	0.03	
Labour/area	Hours /ha	38.8	40.7		21.7

Source: FOI (2005a, 2005b)

18.4.4 Conclusion concerning organic farming

- There is no clear empirical evidence that organic farming is increasing rural income. In the partial analyses above the farming system with the highest Net-Factor Income per hectare depends on the year, country, and farm type considered.
- Analyses of labour input based on Danish and European farm account statistics do not provide clear-cut conclusions regarding the impact of organic farming on employment in rural areas. Analyses applying a general equilibrium model indicate that employment in agriculture and in the processing industry in Denmark will decrease as a result of conversion to organic farming

- Organic farming has environmental benefits but these benefits could be provided at lower social cost than.
- Consequently, conversion to organic farming should be market driven – provided external costs are internalized to all producers. Government policies should focus on ensuring consumer confidence in eco-labelling and information initiatives.

18.5 Bioenergy

Bioenergy is defined as renewable energy produced form biomass. The biomass may be used for solid combustion or processed into liquid or gaseous biomass fuel. The present analysis will focus on biomass from agriculture, i.e. traditional crops, crop residues, energy-dedicated crops and animal waste. In the following we will present an overview of recent analyses investigating the environmental and economic aspect of the different types of bioenergy including the prospects for advances in processing technologies. During the last few years increasing oil prices have triggered considerable interest in bio-based transportation fuels, primarily ethanol and different types of biodiesel. We will start with an outline of the role of biofuels energy supply in the EU and the USA.

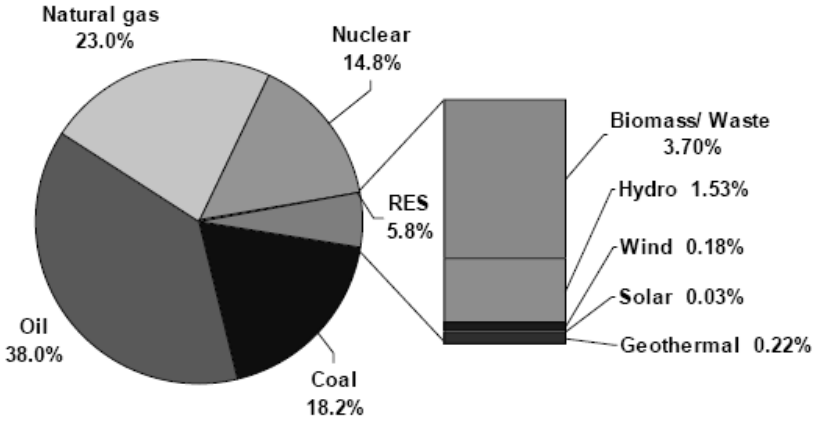
18.5.1 Overview of the role of biofuels

18.5.1.1 Share of biomass and biofuels in total energy consumption

18.5.1.1.1 EU

The EU currently meets 4 per cent of its energy needs from *biomass* (EU-COM, 2005a). About 97 per cent of the energy came from wood (directly from forests or from wood industry residues); organic wastes, agricultural and food processing residues; and manure. Only 3 per cent of the bioenergy supply was from energy crops (Figure 3, op. cit.). The market share of *biofuels* in the EU25 area was 0.8 per cent in 2004 – an increase from 0.2 per cent in 2000. Automotive biofuel in the EU is primarily in the form of biodiesel. About 90 per cent of biofuel consumption is covered by domestic raw materials, 10 per cent by imports (op. cit.).

Figure 3. EU-25 Gross energy consumption in 2002 (Source: EU-COM, 2005b).



About 1.8 million hectares were used in the production of feedstock for biofuels in 2005. This equals 1.9 per cent of EU25's total arable area of 97 million hectares (EU-COM, 2005a). It is an EU target that 5.75 per cent of total transport fuel consumption should be derived from biofuels by 2010 – and fully met by feedstock from home grown crops (EU-Directive, 2003). The European Environment Agency estimates that 4 to 13 per cent of the agricultural area in EU25 will be required to meet this goal (depending on the choice of crops and technological developments).

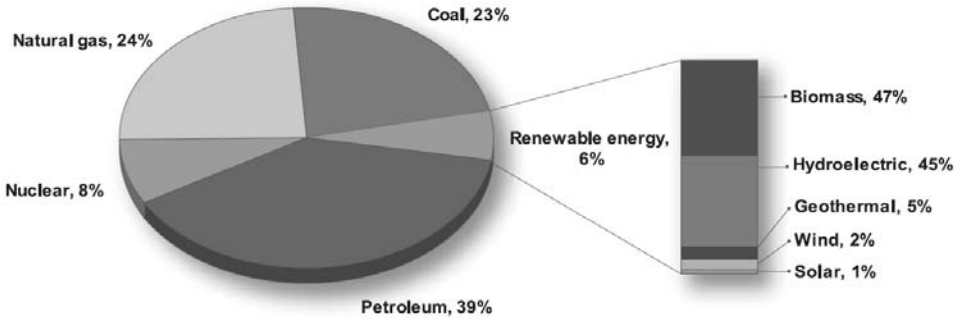
18.5.1.1.2 USA

According to US-EIA (2006b), biomass[86] accounted for close to 3 per cent of total U.S. energy consumption in 2004 (Figure 4). Of this 70% came from wood, black liquor, and other wood waste; 20 per cent from municipal solid waste, landfill gas, sludge waste, tires, agricultural by-products, and other biomass; while the last 10 per cent mainly comes from ethanol blended into motor gasoline. Even though relatively small, biofuels consumption has grown rapidly in recent years. From 1994 to 2004 the share of biofuels increased from 0.6 percent to 1.2 per cent of the transportation fuels market in the U.S. (Manella, 2006). Production of biofuels has increased by 150 per cent

[86] Biomass includes: black liquor, wood/wood waste solids, municipal solid waste, landfill gas, agriculture by-products/crops, sludge waste, tires, alcohol fuels and other biomass solids, liquids and gases.

in the same period. The primary feedstock in the production of biofuel (ethanol) is corn.

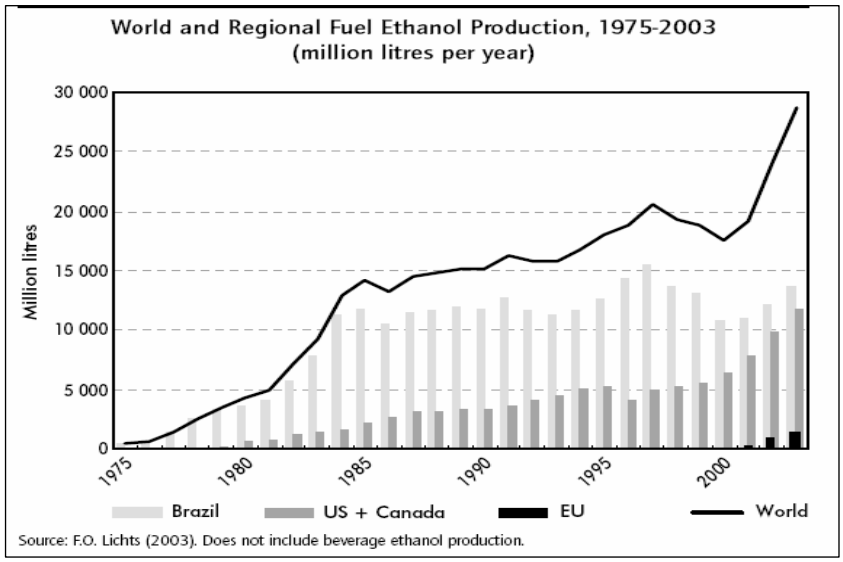
Figure 4. Role of Renewable Energy in the U.S., 2004 (Source: US-EIA, 2005)



18.5.1.2 Trends in biofuel consumption

As noted above there has been a marked increase in the production of bio-based automotive fuels, i.e. ethanol and biodiesel products. Bioethanol is the world's main biofuel. In 2004 world production of bioethanol for fuel use was around 30 billion litres. This represents around 2 per cent of global petrol use. Production is set to increase by around 11 per cent in 2005 (EU-COM, 2006). As can be seen from figure 5 Brazil and North America (US + Canada) are the world's leading producers of ethanol in the world. Brazilian production has not increased significantly since the mid-1980s. In contrast, ethanol production in the US and Canada has seen a sharp increase during the last few years – to reach a level close to Brazil's in 2003.

Figure 5. Ethanol production 1975-2003

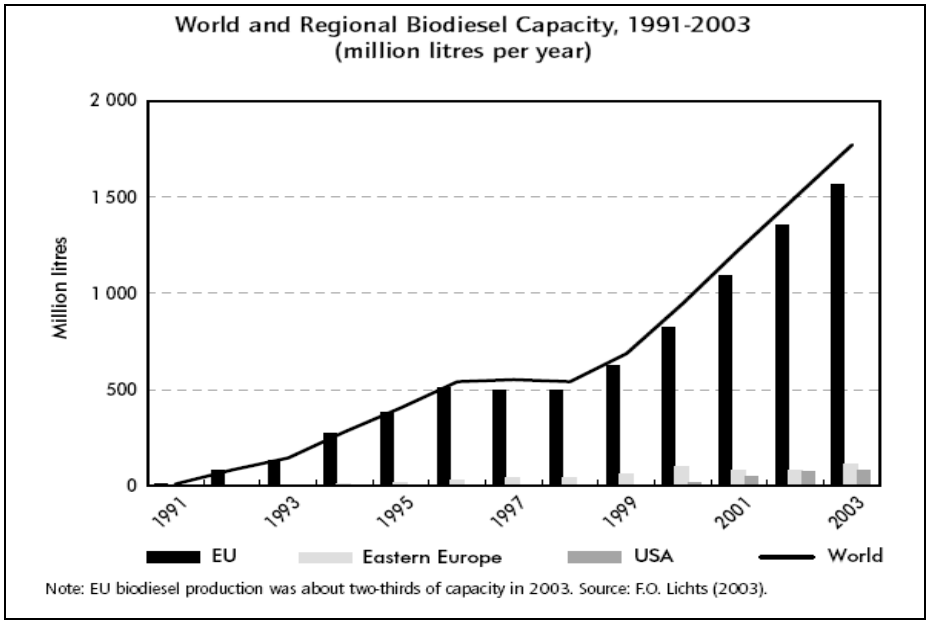


Source: US-IEA (2004)

With production of close to 0.5 million tonnes the European Union is estimated to have produced 10 per cent of the world's bioethanol in 2004. More than 1 million tonnes are expected by the end of 2005 and capacity is likely to treble by the end of 2007 (EU-COM, 2006a).

As can be seen in figure 6 biodiesel was produced almost solely in the EU until recently. The amount of biodiesel produced is still small compared to the world's bioethanol production. However, in 2004 the EU's production of biodiesel increased by more than 25 per cent to 1.9 million tonnes. For mid-2006 an increase in total EU25 biodiesel production capacity to 3.8 – 4.1 million tonnes is expected (op. cit.).

Figure 6. Biodisel capacity 1991-2003



Source: US-IEA (2004)

18.5.1.3 Break even prices (oil) for commercially competitive biofuels

Ethanol production in Brazil (based primarily on sugar cane) is economically viable without government support at oil prices above $35 per barrel (Ugarte, 2005). With the currently available technologies EU-produced bioethanol becomes competitive at oil prices of around €90 per barrel, corresponding to US$108, whereas EU-produced biodiesel breaks even at oil prices around €60 per barrel, corresponding to US$72 (EU-COM, 2006a). Thus, Brazilian ethanol production is considerably more competitive than EU production of ethanol and biodiesel alike. In other

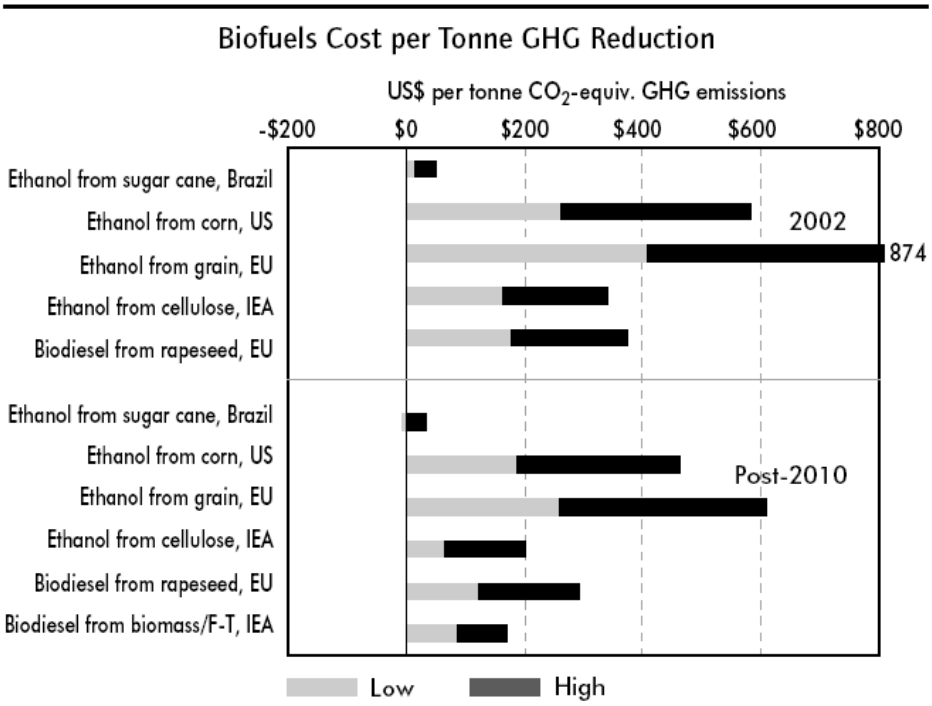
words, trade barriers are required to secure the domestic competitiveness of the EU production of biofuels.

18.5.1.4 Marginal abatement cost (carbon price) for major types of bioenergy

Most available studies indicate that the abatement costs of EU-produced biofuels are quite high relative to the current "carbon price". The marginal abatement cost (carbon price) in the EU emissions trading scheme is about €20 per tonne of CO_2 avoided, while new biofuel technologies (second generation biofuels) are expected to have marginal abatement costs of between €40 and €100 per tonne of CO_2 avoided (EU-COM, 2006b). This means that EU-produced biofuels are not currently the most cost-effective way to reduce greenhouse gas emissions.

Estimates of carbon prices in Fulton et al. (2004) show a similar picture, as can be seen in figure 7. Ethanol from grain is clearly the most expensive carbon reduction alternative. Biodiesel from rapeseed is estimated to yield CO_2 reductions at about half the cost of ethanol, but still at a price far in excess of the €20 per tonne of CO_2 avoided emissions trading scheme.

Figure 7. Biofuels cost



Note: Ranges were developed using highest cost/lowest GHG reduction estimate, and lowest cost/highest GHG reduction estimate for each option, then taking the 25% and 75% percentile of this range to represent the low and high estimates in this figure. In some cases, ranges were developed around point estimates to reflect uncertainty.
Source: Cost data are from tables in this chapter. GHG reduction data are from Chapter 3.

Source: Fulton et al. (2004)

From here we will proceed with some more detailed literature surveys focussing to a greater extent on income generation and employment associated with biomass and bioenergy production.

18.5.2 Analytical framework

The impact on income, employment, and the environment of growing energy crops should be compared with the impacts of the activities that energy crops displace. In several studies it is assumed that the alternative to growing energy crops is fallow land. Under the CAP, farmers have been allowed to grow non-food crops on set-aside areas. Set-aside was required to obtain hectare payment and is required to obtain the single payment after the 2003 reform of the CAP. Given the CAP it is relevant to compare energy crops with fallow land.

The net carbon emission level depends on the way the biomass is produced. Emissions of SO_2 from bio-energy are low because of the inherently low sulphur content of biomass. If energy crops substitute fallow land, growing energy crops could have a negative environmental impact, e.g. increased nitrogen leaching and reduced biodiversity. If energy crops replace food crops, it is more complex to evaluate the environmental consequences. Often the production of energy crops implies less use of fertilizers and pesticides than for food crop, but, on the other hand, replacing food crops will only intensify the production of food crops in other places, resulting in negative environmental consequences.

Sim (2004) and Domac et al. (2005) propose that renewable energy systems are more labour intensive than fossil fuel systems, and to operate bio-energy plants and provide the fuel, employment opportunities are often created particularly in rural areas.

Bioenergy project employment differs from wind, hydro, and solar projects where the work activities mainly consist manufacturing of capital goods, installation, and maintenance. Producing the biomass fuel supply and delivering it to the conversion plant is an essential additional activity component of bio-energy. Therefore, the investment-related jobs tend to be of a smaller proportion relative to the on-going operation and maintenance jobs, when compared to other renewables.

Ideally, the effect of growing energy crops should be evaluated in a general equilibrium framework where the impacts of growing energy crops on other economic sectors are modelled explicitly and where the impacts on income, employment, and

the environment is assessed specifically for the rural areas. Furthermore, the welfare economic costs for society of energy crop should be estimated and compared to the costs of policies which have comparable impacts on rural areas.

No studies found in the literature apply such a framework. However, Schneider and McCarl (2003) analyse the impacts of energy crops using a general equilibrium model but without estimating the employment and rural income effect explicitly. In this study, the shadow value of reducing CO_2 emissions by growing crop is derived and can be compared to alternative measures. If the shadow value of reducing CO_2 by alternative measures is lower than growing energy crops the higher shadow value by energy crops represent a cost. This cost should be compared to the side effects, e.g. environmental or employment impacts, of alternative measures.

18.5.3 Literature reviews

A comprehensive study of the welfare consequences of growing energy crops is found in Schneider and McCarl (2003). They explore the economic potential of biofuels in a greenhouse gas mitigation market, i.e. the production and use of the energy crops switch grass, hybrid poplar, and willow in the US. The analysis is performed applying the U.S. Agricultural Sector Model and potential emission mitigation strategies, or markets are simulated via hypothetical carbon prices. Biofuels are not considered independently but rather in comparison with a total suite of agricultural mitigation options, e.g. tillage alteration, tree planting, fertilization alteration, livestock dietary alteration, and manure management.

Their results indicate that there is no role for biofuels below carbon reduction prices of $40 per tonne of carbon equivalent. Whether biofuels are a relevant mitigation strategy depends on the marginal costs of reducing emissions in other sectors than agriculture. There is no agreement to what this level is, and it is depending on the existence of international markets for emission trading. In Denmark, the prices of CO_2 quotas (allowances within the European Union Emission Trading Scheme) have mostly been traded to prices between 150-180 DKK per tonne CO_2 ($23-27 per tonne CO_2, given the exchange rate: 6.59 DKK/$)[87]. This implies that at a marginal value of emission of around $25 per tonne CO_2 biofuel is not a cost-

[87] Quota prices is from www.dong.dk/portal/page?_pageid=74,38337&_dad=portal&_schema=PORTAL
Exchange rates from www.nationalbanken.dk/DNDK/statistik.nsf/side/FT_Valutakurser!OpenDocument

effective alternative. However, emission reductions via reduced soil tillage and afforestation are more cost efficient than biofuels.

The model computes welfare effects on producers, consumers, and foreign trading partners in the agricultural sector context. As mitigation incentives increase, total welfare decreases monotonically. This decrease can be identified as dead weight loss and provides a measure of the minimum benefits the society must gain from reduced levels of green house gas emissions plus any co-benefits attained through cleaner water or reduced erosion to meet the Kaldor-Hicks potential compensation test. In addition, the transaction costs of policy implementation would need to be considered.

They find that higher operational costs to farmers are more than offset by higher revenues due to increased prices (prices inclusive CO_2 reduction subsidies). Therefore, farmers achieve a higher level of welfare by increasing the demand for green house gas emission reductions through the subsidizing of the CO_2 reduction. This indicates that a market for CO_2 will increase rural income.

Therefore, introducing a market for the reduction of green house gases will increase farmers' income, i.e. the income of rural population. However, the study also shows that the benefit of reducing emissions should be rather high before bio-energy crops will be a competitive mitigation strategy.

The agricultural sector's green house gas emission mitigation measures also have impacts on the emission of other pollutants. The impact of mitigation measures on nitrogen and phosphorous pollution and erosion have been simulated and indicate that the cheapest mitigation measures, i.e. reduced soil tillage, reduces the negative impact of agriculture on the environment, whereas a higher level of mitigation which involves growing energy crops does not further reduce the negative impacts. This is because growing energy crops increases the competition for agricultural land. As a result the intensity of agricultural production increases.

The study does not consider that bio-energy may also yield other ancillary benefits in terms of air quality - due to reduced coal burning. Inclusion of these benefits would have increased the competitiveness of energy crops.

Steininger and Voraberger (2003) analyse the medium term biomass energy potentials in Austria, applying a general equilibrium model for the Austrian economy. The model does not assume full employment, i.e. the labour market does not clear. This allows the model to estimate employment effects of policy changes. They evaluate

the macro-economic effects of economic incentives for increased use of 12 biomass products in different heating and power-generation systems and for biofuels.

In a scenario with a CO_2 tax, the results indicate which biomass technologies become competitive at which CO_2 tax levels. The technologies that are competitive at a tax level of 15 € per tonne CO_2 are wood chips, bark, biogas, and recycled[88] edible oil methyl ester. In the tax scenario, the employment increases by 3100 persons but the GDP decreases slightly. A tax of 15 € per tonne CO_2 is, however, relative low compared to current emission reduction costs. Therefore, other biomass technologies may be competitive with higher taxes.

In a scenario where taxes and subsidies are combined, the positive employment effect increases without further loss of GDP. The reduction in CO_2 emissions increases from around 5,000 to more than 10,000 million tonne by combining the tax with a subsidy corresponding to one third of the tax revenue. In this scenario the increase in biomass use is almost 70.000 million PJ.

However, this study does not estimate the impact on the rural economy, i.e. the agricultural sector of adopting biomass energy technologies. Faaij et al. (1998) analyse the externalities of biomass-based electricity production compared with power generation from coal in a Dutch context. The effects on economic activity and employment are investigated using input-output multipliers. Compared to the analysis above, feedbacks, i.e. changes in relative prices, of using biomass based electricity production, is not included in the model. Therefore, the analysis only applies to marginal changes in energy production.

Valuations of damage from emissions to air are based on generic data from other studies. The external costs of nitrate leaching and the use of agrochemicals are estimated.

The impact of bio-energy production is compared with fallow land. Short rotation coppice willow is selected as the energy crop.

They conclude from the analysis that the average private costs for biomass and coal-based power generation are projected to be 68 and 38 mECU per kWh, respectively, in the year 2005. If the external costs and benefits are included the cost range for bio-electricity amounts to 53-70 mECU per kWh and 45-72 mECU per kWh

[88] Biofuels from vegetable oils after initial cooking use

for coal. The external costs includes impact on GDP, employment benefits, emissions damage for SO_2, NO_2, dust, CO, and CO_2, potential damage from agrochemical use and nitrogen leaching.

However, the external costs are not estimated using standard appraisal methods. For example, the impacts on GDP and employment of the two alternatives are included in the assessment of the external costs. Increased employment is included as an external benefit and is measured as saved unemployment payments[89]. If only external environmental costs are included the range of costs of bio-electricity amounts to 71-77 mECU per kWh and 40-64 mECU per kWh for coal (see Table 9). In the case of coal the CO_2 damage is estimated as being in the range 0.4 – 21 mECU per kWh (based on CO_2 damage cost of 1- 25 ECU per tonne CO_2), i.e. the value of reducing the CO_2 emissions is important for the results. However, even with a value of 25 ECU per tonne CO_2 emission reduction it is still cheaper to use coal as energy source.

Table 9. External costs of energy production used in Faaij et al. (1998)

External cost factor	Biomass mECU/kWh	Coal mECU/kWh
SO_2, NO_2, dust, CO emissions	2.3 - 6.4	1.7 – 4.8
CO_2 emissions	0.0 – 0.6	0.4 - 21
Potential damage from agrochemical use	0.8	n.a.
Potential damage from nitrogen leaching	0.8	n.a.
Total external environmental effects	3.9 - 8.6	2.1 – 25.8
Private costs of energy production	68	38
Total costs of energy production	71.9 – 76.6	40.1 – 63.8

They find that employment is significantly higher in bio-energy systems compared to coal systems, i.e. 0.44-0.53 man year per GWh for biomass and 0.17-0.20 man year per GWh. The authors emphasize that the uncertainty is high with respect to the economic values attached to most external effects of the bio-energy and the coal systems.

A similar comparison of biomass and coal for electricity production is performed by Sáez et al. (1998) but in a Spanish context. They also assume that the energy crop,

[89] In social project appraisals unemployment payments represent transfer payments which are normally not included in the assessment of the social value of a project or policy.

Cynara cardunculus (a cardoon), will be grown on set-aside land. They end up with similar conclusions; that the private cost of electricity production is higher by use of biomass – but when external costs are included the difference between the two energy sources decreases. The external costs and benefits include health costs by emissions of NO_x and particulates from power generation, damage costs from CO_2 emissions (0.52 – 13.17 ECU per tonne of CO_2), the cost of increased nitrate leaching, and the value of reduced soil erosion (Table 10). Due to a high value of reduced soil erosion by growing energy crops on set-aside land the social cost of generating energy using biomass is at the same level or even less than the costs of generating energy using coal. Employment benefits is also included in their study but are excluded in Table 10.

Table 10. External costs of energy production used in Sáez et al. (1998)

External cost factor	Biomass mECU/kWh	Coal mECU/kWh
Health effects	2 – 5	8 - 20
CO_2 emissions, climate change damage	0	1 – 16
Soil erosion	-116 – -52	n.a.
Non-point-source pollution, energy crops	0.1 - 0.4	0
Total external environmental effects	-114 - -47	9 – 36
Private costs of energy production	115	57
Total costs of energy production	1 – 68	66 –93

An increase in employment by biomass production is estimated to be 81 jobs and 42 – 92 jobs generated indirectly in other sectors by establishing and running a biomass power plant, generating 30 MW. Measured per energy unit this is almost three times the labour input by producing the energy at a coal power plant. The indirect employment effects are estimated using an input-output model for the Spanish economy.

The studies by Faaij et al. (1998) and Sàez et al. (1998) only address two specific alternatives. Therefore, the results depend on the choice of the coal-based or the bio-energy-based power generation systems for comparison in their analysis. Furthermore, the private and social costs of the production of biomass are site specific. Therefore, these studies only give an indication of the contribution of bio-energy to income, employment and environment in rural areas. In particular, it is important to notice that the results of the two studies are based on the assumption that energy crops can be produced on fallow land.

Varela et al. (1999) analyse the construction of a biomass power plant in Spain. The optimal sources of biomass fuel in the area were found to be thistles, grown on set-aside land, complemented with agricultural and forest residues. The biomass plant will have a very favourable CO_2 balance, with the most optimistic assumption, the biomass cycle will have a CO_2 sink effect (increasing carbon content in soils where energy crop is grown). They also find positive effects on jobs and GDP of constructing the plant.

In Gylling et al. (2001) the private costs of producing energy crops have been estimated in a Danish context. They find that the production costs are higher than the paying capacity for energy crops of bio-energy power generating plants, even though alternative use of the land used for energy crops has not been considered. However, in this study there has been no attempt to estimate the external costs and benefit of growing energy crops and substituting fossils fuels with bio-energy.

In Gylling (2001) the negative impacts on the aquatic environment of growing energy crops in Denmark is assessed to be lower than for traditional agricultural crops. Therefore, it is suggested that energy crops are suitable for environmentally sensitive areas.

Gylling (2001) estimates that the production costs for willow coppice delivered at the power plant during the harvest season is between 30-33 DKK per GJ (clay soil) and 36-39 DKK per GJ (sandy soil), while big baled energy grain (all year delivery) has a cost between 38-39 DKK/GJ (clay soil) and 43-45 DKK per GJ (sandy soil). The cost of straw is about 28 DKK per GJ. In the same study the paying capacity of a medium size bio fuelled power plant producing heat and power is estimated to be around 20-24 DKK per GJ for energy crops, given an electricity price of 0.30-0.35 DKK per kWh and a heat price of 45-48 DKK per GJ. Co-firing with coal will increase the ability to pay to 30-34 DKK per GJ. The price which power plants can obtain selling bio-energy-based electricity is higher than the cost of producing electricity from the cheapest fossil-based alternative energy source. This is due to policy regulation of the energy markets, where a certain share of electricity should be based on “green energy” sources, and the consumers can be charged a higher price for this share. The study does estimate the cost of reducing CO_2 emission by substituting fossil fuels with biomass.

Corresponding to the results above Olesen et al. (2001) find that energy crops, i.e. elephant grass grown at sandy soils, may be competitive to traditional agricultural crops, if the price of biomass is 30 DKK per GJ. Given this price of biomass elephant

grass on sandy soils there will be negative costs of reducing CO_2 emissions by substituting fossil energy sources with biomass. However, according to Gylling (2001) the price of 30 DKK per GJ used in Olesen et al. (2001) seems higher than the costs of alternative fossil energy sources.

Søbygaard (2002) evaluates the Danish energy policy in the 1990's, including the support of biomass use in power generation. The analysis includes tax deadweight losses. It is concluded that use of straw at power plants have been a rather expensive measure compared to the environmental benefit achieved. The shadow value of reducing CO_2 emission is estimated to be 566 DKK per tonne CO_2 (76 € per tonne CO_2). The shadow value represents here the minimum value of the CO_2 emission reduction which ensures a social net benefit from use of biomass in energy production.

18.5.4 Conclusions

Production of bio-energy on agricultural land is not in general a commercially competitive land use. However, bio-energy reduces the externalities from the use of fossil fuels. Inclusion of external costs and benefits improves the competitiveness of bio-energy from a societal perspective. Still, the competitiveness of bio-energy is sensitive to the value of the avoided green house gas emissions. When biomass is converted to biofuel the oil price plays a crucial role for the competitiveness of the bioenergy alternative. Generally speaking biofuel is an expensive way of reducing CO_2 emissions – at least in the EU.

If energy crop production competes with traditional crops there is no evidence that energy crops generate a higher level of employment. In General energy crops require less labour per hectare than traditional crops, but downstream activities in terms of transportation and handling of the biomass at power plants may be greater than for most traditional crops. However, if the alternative to growing energy crops is fallow land then there will be positive employment impacts of bio-energy production and use. The employment effects will depend on the region, i.e. the "abundance" of abandoned agricultural land suitable for energy production.

The production of crops for power generation has a positive effect on the environment in terms of reduced green house gas emissions. However, depending on the crop and farming practices biomass production may increase nutrient and pesticide pollution from agriculture through intensified land use.

The important aspect is to implement an adequate price structure with pricing of externalities as the central feature. Thus, CO_2 emissions from the use of fossil energy should be taxed at a level compatible with the long run marginal costs of realizing the specified reduction commitments in the EU/Member States. Where fuels are taxed for fiscal purposes biofuels should be exempted from the CO_2 tax element outlined above. Subsidizing/tax exempting bioenergy by more than can be justified in terms of environmental benefits will result in a welfare loss to society.

Whether production of energy crops will be socially competitive depends on the development of fossil energy prices, the shadow value of reducing CO_2 emissions, and future processing costs. The processing cost component may be significantly reduced in the (near) future due to expected technological breakthroughs in terms of the so called second generation biofuels. The right price structure will create adequate incentives for innovations and producers to develop and implement new technologies.

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19 Opponent note no. 5a: The Lisbon Strategy and the common agricultural policy: Impacts on the "common conventional" and "differentiated new" agriculture in the EU-25, and globally

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19.1 Introduction

This opponent paper reviews and analyses the "bigger picture" of the Common Agricultural Policy, agricultural sectors and rural development in the European Union of 25 member states in terms of the overall objectives set for economic, environmental and social sustainability.[90] We have to understand the "bigger picture" and inherent interdependences, for example in the CAP and agriculture of the EU-25, in order to be able to evaluate more specified goals and means.

Moreover, this paper introduces some important additional elements to the discussions at the Forum. These elements include e.g. the ***multifunctional role*** of agriculture and the CAP, the ***targeting and transaction costs*** of policies, possibilities and needs for stronger ***co-financing, or renationalisation/regionalisation*** of the CAP, and ***international*** environmental and rural development aspects of expanding bio-energy production. These can be of crucial significance in policy planning, decision-making and implementation, as well as the evaluation of efficiency and results of different policy alternatives.

When the European Commission launched and relaunched the Lisbon Strategy for the European Union (EU) in 2001, 2003 and 2005, respectively, it was clear already from the very beginning that the overall, common objectives do not easily match with the reality of the (so-called) common agricultural policy (CAP) and the agricul-

[90] Originally, I was asked to respond and reflect on Jens Abildtrup & Alex Dubgaard's case study paper "Support to organic farming and bio-energy as rural development drivers". However, as I found that basically I do share many of the views and conclusions of their paper, i.e. there were not so much to "oppose" especially as we still cannot make very clear conclusions on many of the issues and impacts of either organic farming or bio-energy production, and as the organisers of the Forum later asked and advised me to take a broader view, including conventional agriculture, instead of a plain opponent role in the selected subjects of the case study paper, I have consequently changed my strategy and approach.

tural sectors and operations as such in the EU. The reforms during the early 2000s – Agenda 2000 and the 2003 “Fischler reform” - did not change this situation to any remarkable extent, though they admittedly were attempts to move in the right direction in terms of environmental and social sustainability. Improvements in economic sustainabilility, including and especially job creation in the agri-food sector, however, remains uncertain.

This is typically a policy problem. Most often the problem arises from the inequality or straightforward controversy between the general, overall objectives or goals of the policy/policies and the actual means or instruments that are possible and available. For example, what may be politically feasible may not be technically feasible, or sometimes vice versa (see e.g. Bullock et al. 1999). Moreover, when the EU now covers 25 member states, and further enlargements are forthcoming, the so-called common agricultural policy may not be sufficient to deal with many diverse economic, social and environmental problems of the different member states with highly diverse agricultural sectors, supply chains and rural regions.

When we consider and evaluate agriculture’s potential in the future, in terms of economic, environmental and social sustainability, we have to remember that the major EU policy priority embedded in the Lisbon strategy is to tackle the EU's urgent need for higher economic growth and job creation and greater competitiveness in world markets. Can agricultural sectors do this, and at the same time provide a better standard of living in an environmentally and socially sustainable way to the people employed in agriculture and the people living in the vast rural areas of the EU.

This question is highly time-dependent: How soon we want to obtain the preferred results and how big structural changes for example in the European agricultural sectors we require and allow in order reaching the results. Hence, length-of-run analyses are important when we evaluate policies, their objective, means and impacts, which simultaneously aim at achieving economic, environmental and social sustainability in agricultural sectors and rural regions of the EU.

The EU Commission states that the guiding principle for the contribution of the CAP to the Lisbon Strategy is "strong economic performance that goes hand in hand with the sustainable use of natural resources” (European Commission 2005). The Commission also maintains that “rural development measures, in particular, can play a significant role in fostering and maintaining prosperity in rural areas”. But as the share of rural development measures, including the agri-environmental support

and LFA support, is a mere 10 % in the agricultural budget (EAGGF) of the EU, and as the modulation, meaning the shift of support from basic-CAP subsidies to rural development, remained as very mild in the 2003 reform, we are obliged to raise the question: ***Can we attain these goals with the current policy, or will further reforms, i.e., true reforms, of the CAP be necessary, even in the near future?***

19.2 Multifunctional Agriculture and Policies

Multifunctional agriculture is a remarkable new direction for agricultural policy as a whole. Its objective is to improve the overall welfare of the society. Hence, policy is shifting from the traditional producer- and production-orientation towards wider goals of the society. The multifunctionality of agriculture consists of non-market goods *jointly produced* by agriculture along with food and fibre. The aspects of the multifunctionality of agriculture can include environmental considerations, biodiversity, rural landscapes, socio-economic viability of rural areas, food safety and security, and animal welfare. Yet, the OECD's (e.g. 2001) definitions of multifunctionality are stricter: they mainly focus on environmental and biodiversity elements. On the other hand, the EU Commission's views in both the Agenda 2000 reform and the "Fischler reform" 2003 present quite a broad range of multifunctional elements as key ingredients of the future direction of agricultural policy in Europe.

The reinforcement and promotion of multifunctional agriculture is an important future challenge for agricultural policy. The true challenge is in the fact that multifunctionality involves various kinds of particular, especially ***local, regional*** and national characteristics. This is why the policy instruments should be very ***clearly differentiated and carefully targeted***, with high efficiency in income transfer and low policy related transaction costs. Consequently, it is clear that new and more efficient means are needed in the common agricultural policy of the EU (in spite of the recent reforms), in order to consolidate more effectively the multifunctional role of agriculture, and simultaneously enhance the Lisbon Strategy in agriculture and agricultural policy of the EU.

Although policy reforms have already been made in the EU and the Commission (2005) argues that especially the 2003 reform was a fundamental contribution to the Lisbon process, which also, by definition, should mean a contribution to multifunctionality, comprehensive and consistent analyses are still missing concerning the actual policy means to affect and efficiently enhance the ***true multifunctional***

characteristics of agriculture. In Finland, we have also tried to redress this research deficiency in two recent projects[91] "**Multifunctional Agriculture: Supply, Demand and Policy Design**" in 2001-2003 and **"Multifunctional agriculture and policies"** in 2003-05 (final publications of the projects are: Kola et al. 2004 and Arovuori et al. 2006).

In the first project the research methodology included a large consumer/citizen survey and a choice experiment method for the demand analysis, theoretical and calibrated models for the supply analysis, and the first-stage identification and exploration of socially optimal policy means for the policy design part of the project. Consumers' attitudes towards and viewpoints on multifunctionality have thus far mainly been neglected in both policy planning and research. We provided here one of the first major surveys on consumers' preferences of and reactions on multifunctionality: a modern computer aided interviewing system with N = 1,300. The study revealed that (1) the Finnish citizens consider food safety and animal welfare the most important multifunctional elements of agriculture, and that (2) the aggregate willingness to pay for production of an optimal set of the elements of multifunctional agriculture, derived from the individual consumers' willingnesses to pay, varies between 189 and 377 million €. This was considered as high WTP, as the total support to Finnish agriculture at the same time was about 1,600 million €.

The main objective of the project "**Multifunctional agriculture and policies**" was to study ***which policy instruments are the best and most efficient for promoting multifunctionality*** in Finland (Arovuori et al. 2006). The study was carried out in three sections. The nature and extent of the demand for multifunctionality was analysed on the basis of *expert interviews and an enquiry among farmers*. From the environmental dimension the study of the properties of multifunctional farming was broadened to comprise the *socio-economic viability of the rural areas, mainly through employment effects*. The policy analysis of multifunctionality, which was founded on the two other sections, also included the *transaction costs* of the policy and the impacts of the policy addressing multifunctionality on the agricultural sector *regionally and according to types of production*.

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[91] These projects were jointly executed by the Department of Economics and Management (co-ordinator) at the University of Helsinki and the economics unit of the MTT Agri-Food Research Finland, and funded by the Finnish Ministry of Agriculture and Forestry.

According to the results of the study, the Finnish agricultural policy experts and farmers agree that agriculture possesses a multifunctional role in the society. This role should be realised by means of agricultural policy where the national, regional and local conditions are taken into account better than in the current policy. However, the heterogeneity of the farming conditions poses a serious challenge for implementing the policy of multifunctionality, which in the ideal situation calls for the regional allocation and differentiation of the regulatory and steering instruments. How far we should proceed in the regional differentiation and tailoring of the policy measures largely depends on the policy related transaction costs? In practice the differentiation could mean that the policy measures would be at least regionally differentiated.

Our analysis shows clearly that crop area payments are not environmentally neutral. However, the performance of crop area payments could be greatly improved by incorporating environmental cross-compliance mechanisms into them, such as larger buffer strips, field edges and forest margins. Buffer strips provide multiple environmental benefits; they reduce erosion and nutrient emissions, while enhancing biodiversity and the diversity of landscapes. They also seem to perform well under heterogeneous conditions.

The most extensive topic relating to the multifunctionality of agriculture which calls for *further study* is the impact of the regional concentration of agriculture on multifunctionality. The societies should also consider more carefully what would be the right or desired balance between the development of the efficiency and competitiveness of agriculture and its multifunctional role. The more detailed topics on which further research is needed include the development work focused on the phosphorus policy, special elements of multifunctionality in livestock farming, and possibilities for bioenergy production and their impacts on the multifunctional role of agriculture.

As we see from these two projects only, the multifunctional role of agriculture is in the heart of the Lisbon Strategy for the CAP. The problem remains, whether we will be able to integrate environmental sustainability with economic and social sustainability, i.e. whether we can retain, and even improve, livelihood and vitality in the remote rural regions of the EU-25. Many of these remote rural regions still heavily depend on primary agriculture. Could they find organic farming and/or bioenergy production as possible and profitable alternatives in the changing environment? What are the best and most efficient means to advance these alternatives in these less favoured regions? Transfer efficiency (e.g. Bullock et al. 1999) and

transaction costs (OECD 2002; Vatn et al. 2002; Arovuori et al. 2006) play a major role in these decisions, as is generally implied in the next chapter.

19.3 Transaction costs and efficiency of policies

OECD (2002) has concluded, based on both the analytical framework and empirical work, that transaction costs might affect policy choices. The transaction costs (TC), related to the agri-environmental support system of the CAP, can be defined as administrative costs associated with the design, implementation, monitoring, and enforcement of the policy. One of the key questions is whether policy related TC could be so big that they would determine the optimal policy choice. TC would be decisive if the difference in TC between policy options is bigger than the difference in efficiency between them. For example, while carefully spatially differentiated policy instruments could perform better in the provision of multiple non-commodity outputs (public goods), the better performance can involve higher administrative costs. Thus, there are inherent *trade-offs between the precision (the degree of goal attainment) of a policy and its related transaction costs*. Table 1 illustrates some possible efficiency losses due to TC and other inherent factors in alternative options of conventional agricultural policies.

Table 1. Possible efficiency losses of alternative policy options (OECD 2002, 38)

	Targeted payments	Output subsidies	Price support through tariffs
Transaction costs	Large*	Medium	Small
Lack of precision	None	Yes	Yes
Loss in consumers' surplus	None	None	Yes
Dead-weight loss of tax collection	Yes	Yes	None
Other efficiency losses	None	Yes	Yes
*large, medium and small indicate only relative magnitude and they have no quantitative implications			

According to Vatn (2001), transaction costs play a crucial role in the determination of optimal policy, and the *increased costs of precision* have to be weighed against the potential gains in achieving the objective. Moreover, as precision increases, its marginal utility is likely to decrease while its marginal transaction costs are likely to increase. Thus, when all costs are considered, it is not reasonable to expect that

a precise instrument is necessarily the optimal one (Vatn 2002). In the case of environmental multifunctionality, which could be a very essential ingredient of the realisation of the Lisbon Strategy in the CAP, the trade-off between transaction costs and precision depends on the relationship between the commodity and non-commodity outputs. If the outputs are joint products from a non-allocable input, high precision can be achieved even with quite few measures, but in the case of complementary or competitive outputs, payments must be directed towards non-commodity outputs, which imply high transaction costs (Vatn 2001). Vatn (2002) concludes his analysis on the consequences of multifunctional agriculture for *international trade regimes* by two important observations concerning situations where there is joint production between commodity and non-commodity outputs as well as positive transaction costs. First, if countries are not equally competitive in commodity markets, free trade may not be the optimal solution. Second, because of positive transaction costs, policy measures linked to commodity prices may be used to obtain the efficient supply of non-commodity outputs.

Concerning the use of cost-benefit analysis and TC, it is clear that some data for real or potential transaction costs can be derived and analysed, e.g. administrative costs, but some data are difficult, probably entirely impossible, to reach. For example, there is only very limited data for the transaction, or adjustment, costs of farmers due to changes in agricultural policy aiming at, say, a stronger emphasis on multifunctionality. But these data can be collected from farmers via surveys, as we did (Arovuori et al. 2006). Even then the accuracy of the data may to some extent be questionable, but it will, however, be the best possible that can be obtained for this kind of purpose. This approach is needed also according to OECD (2002), as it states that almost no work has been done to compare TC and efficiency losses associated with different policy options. OECD also recommends that TCs associated with different policy instruments should be measured early in the sequence in order to provide policy makers with a better idea of the relative significance of TC.

These remarks are of crucial importance also in relation to organic farming in particular (e.g. administrative burden in controlling and enforcing the rules), but to some extent also with regard to bioenergy production. As a whole, in order to make better policy recommendations we also need to take a closer look at transaction costs in relation to multifunctionality, including those TCs incurred by farmers when they have to obtain information for the guidelines, prepare and submit applications and possibly alter their production practices. These transaction costs can be regarded as adjustment costs of farmers to follow and dobey the policy. The

same kinds of characteristics are and will be present and valid for organic farming and bioenergy production.

19.4 Is the common agricultural policy common enough? Prospects for co-financing and renationalisation, or regionalisation, of the CAP?

Above I have reviewed the needs and possibilities of increased targeting and efficiency of agricultural, environmental and rural policies, which all are essential elements of and contribute to the multifunctional role of agriculture. Now, we should also consider and assess, whether the current CAP is able to function in an efficient way and to produce these positive impacts and results in the EU-25 of very diverse countries and different agricultural sectors, i.e. *is the current CAP truly able to* contribute to the Lisbon Strategy?

It is obvious that the CAP of the EU does not currently meet the different needs of diverse agricultural conditions of different member countries in a just and equal way. The goal, or attempt, to meet this challenge has become inevitably more difficult as new and diverse Central and Eastern European countries have entered the Community. Several commentators and economists have thus suggested that a renationalisation of the CAP would be an applicable way to proceed in an attempt to pursue a policy that would be sensitive enough to national and regional – and sometimes even to local - needs and priorities. However, for CAP traditionalists, this represents an alarming development. Renationalisation mainly deals with two issues: (i) should member states have more power and freedom on decisions of agricultural policy, and (ii) should there be a shift from common financing back to national funds, or at least to a stronger co-financing principle? For example, Kola (1996, 2002) and more recently Niemi & Kola (2005) have discussed and evaluated these issues from the new political economy perspective. The following text mainly presents the outcome of the aforementioned publications.

The key question in the framework of economic integration is that in what dimension the Common Agricultural Policy is better than a renationalised policy. In terms of economic integration theory, the EU does not need the CAP as such to promote the economic integration and balanced development of the Member States. In fact, in some instances the CAP eventually prevents the EU from achieving these general goals. Common markets can be guaranteed by the common competition and trade policies; it does not require specific “common” agricultural policy. The EU budget allocations can be directed to the objectives and functions that are much more efficient than the CAP in enhancing the economic integration and balanced devel-

opment of the Union, especially in association of the enlargement. Renationalisation would remove a remarkable share of the agriculture-specific, Brussels-based double-bureaucracy. It would also release the decision making bodies to concentrate on true integration of Europe, instead of devoting a big share of their time and resources to so-called sectoral integration in the form of the CAP.

One of the major drawbacks of the renationalisation would be related to the recent and forthcoming enlargements. Many of the new or candidate member states cannot afford having the same kind of institutions or allocating the same kind of resources to their agricultural sectors as what is the case in the old Member States of the EU-15. Hence, this may generate economic and market distortions and political tensions. However, they could be avoided by a more targeted and efficient use of the EU's structural funds and regional policy, i.e. the very rural development, which can be regarded as sensible common policies in the framework of economic integration and efficient functioning of EU institutions. They can also be regarded as key means in terms of advancement of the Lisbon Strategy, especially in the new member states and their large remote rural regions.

Concerning both bioenergy production and organic farming, policies with stronger national and regional emphasis and specification are clearly needed. Serious doubts arise, or just remain, that the current type of the centrally/Brussels-driven CAP is not able to cope with these new, more differentiated activities in the agricultural sector.

19.5 Bioenergy and rural development in the international/global perspective

Biomass is a widely available resource that is receiving increased consideration as a renewable substitute for fossil fuels. Agriculture can play a major role in this development, as Abildtrup & Dubgaard (2006) show in their case study paper. However, we could expand their analysis into the international or global issuen concerning the (future) interactions between bioenergy production and rural development. If developed sustainably and used efficiently, bioenergy production and processing can induce growth in developing countries, reduce oil demand, and address environmental problems.

As Abildtrup & Dubgaard (2006) list both the potential benefits of bioenergy, including e,g, reduction of greenhouse gases, recuperation of soil productivity and degraded land, economic benefits from adding value to agricultural activities and improving access to and quality of energy services, and rural employment impacts,

and potential problems of increased bioenergy production in the Danish and, to some extent, in the EU context, I do not start elaborating the same issues but focus on the broader, international aspect of bioenergy. It may have high significance as we consider the future for farm and food products in the more liberalised trade regime via the WTO Doha round negotiations.

A recent, compact view on the international, or global, aspects of bioenergy developments with regard to developing countries and their rural development is provided by de la Torre Ugarte (2005). Additional insights for international development aspects can be found in e.g. Coelho (2005), Kartha & Leach (2001), Smil (2003), and von Braun & Kola (2005).

De la Torre Ugarte (2005) emphasises that the production of bioenergy involves a range of technologies, including solid combustion, gasification, and fermentation. These technologies produce energy from a diverse set of biological resources, e.g. traditional crops, crop residues, energy-dedicated crops, dung, and the organic component of urban waste. The results are bioenergy products that provide multiple energy services: cooking fuel, heat, electricity and transportation fuels. De la Torre Ugarte points out that it is this very *diversity* that holds the potential of a *win-win-win* for the environment, social and economic development, and energy security. He claims that coherent and mutually supportive environmental and economic policies may be receded to encourage the emergence of a globally dispersed bioenergy industry that will pursue a path of sustainable development.

De la Torre Ugarte (2005) continues that as for many countries a key motivation in the development of biofuels is to diversify energy resources, we should also include the opportunities for rural development as one of the key priorities. Rural development benefits from a dynamic bioenergy sector begin with feedstock production. As agricultural production in many developing countries is characterized by labour-intensive activity, additional demand for agricultural products will increase employment and wages in the agricultural sector. Furthermore, the additional personal income generated has the potential to induce significant multiplier impacts as it is spent by the rural population. Moreover, the use of residues from the production of food and feed grains would not only provide the foundation to build a bioenergy industry, but would also directly support and enhance the production of crops that increase the food security of a region or country. Because bioenergy production facilities in developing countries need to be located in rural areas, i.e., close to where the feedstock is grown, construction and operation of

those facilities, as well as transportation of raw materials and distribution of the fuels produced, will also generate additional economic activity in rural areas.

Consequently, as we plan and foresee the future opportunities for the Danish or European bioenergy production, and its impacts on primary agriculture and rural development, we also have to bear in mind the international development and the balance and distribution of associated benefits and costs, but also comparative and competitive advantages in these new, differentiated production activities.

19.6 Conclusions (mainly with regard to the case study paper by Abildtrup & Dubgaard, 2006 – i.e. Chapter 18)

To start with, as Abildtrup & Dubgaard have chosen to give a title as "*Support* to organic farming and bio-energy as rural development drivers" to their paper, we have to evaluate the efficiency and transaction cost aspects of such *support*. Consequently, I have dealt with some general issues in these aspects in this opponent paper. One can derive important (policy) implications from those reviews also for the future opportunities of organic farming and bioenergy production.

One aspect I have to emphasise is that it is likely that we do currently underestimate the benefits of bioenergy production. We miss the sufficiently accurate calculations for the future opportunities as we are too strongly still stuck to the present situation. One problem or deficiency may be hidden in the too restricted approaches, i.e., national assessment instead of a wider, international "big picture". For example, the conclusion by Abildtrup & Dubgaard (2006) that "production of bio-energy on agricultural land is not a commercially competitive land use, even when bio-energy can be produced on land without alternative uses, e.g. set-aside land", is valid today, but what about in the future? Hence, I fully agree with their assumption that inclusion of external costs and benefits improves the competitiveness of bio-energy from a societal perspective. We need better information and knowledge of these external costs, which will be highly time-dependent (i.e. the evident need for more accurate length-of-run analysis). Moreover, and especially for the remote rural areas of the EU-25 as well as for developing countries, if the alternative to growing energy crops is fallow land, there may be positive employment impacts of bio-energy production and use, which will be enforced by the downstream activities (transportation and handling of the biomass at power plants), as Abildtrup & Dubgaard (2006) argue.

I fully agree with Abildtrup & Dubgaard that positive employment effects of subsidizing energy crops will depend on the region, and on the applied agricultural policy. This emphasises the overall conclusions from our multifunctionality studies (Kola et al. 2004; Arovuori et al. 2006) that we definitely need stronger national, regional and even local orientation in our (agricultural) policies in order to be able to provide socially optimal policy solutions, or should we say "regionally optimal policy solutions".

Moreover, it is easy to agree on Abildtrup & Dubgaard's conclusion that the production of crops for power generation, in general, has a positive effect on the environment, due to the reduction of green house gas emissions by substituting bio-energy for fossil fuels, but bio-energy crops may increase pollution from agricultural production through intensification of land use. Hence, our challenge in research and policy planning is to find the right balance between these opposite factors. Once again, this is very strongly an issue of a high regional variation.

If we stick to "blind" subsidisation of energy crop production, which lacks profitability and true demand, we were just repeating the old mistakes. Instead, we should rely on market-driven incentives and solutions. The true challenge is to integrate economic and social sustainability with the environmental sustainability in the spirit of the Lisbon Strategy.

Within the EU, bioenergy production may become most popular (and relatively more profitable) in the less and least favoured agricultural areas. It may improve economic situation, but its impacts on landscape and scenery may be detrimental, naturally depending on the type of energy crops. For example, in Finland arable area is currently only 8% of the total surface. Hence, there could be major changes in landscape, biodiversity and environment, and in the multifunctional role of agriculture as a whole.

In the traditional agricultural policy and the conventional agriculture, there is an evident need for more accurately defined policy measures, which have low transaction costs, in order to able to create environmental win-win situations in the manner that the EU Commission describes already today. But as is clear that (Commission 2005):

- Agriculture and forestry remain by far the largest land users, shaping the rural environment and landscape. The provision of environmental goods, particularly through agri-environmental measures, can form a basis for growth and jobs provided through tourism and rural amenities.

- The adoption of modern farming techniques, e.g. precision-farming and direct sowing techniques, can improve the economic and environmental performance of farms.

- There are opportunities to expand production of biomass and renewable energy sources. This would not only create new economic opportunities in rural regions, but would help Europe respect its greenhouse gas reduction targets under the Kyoto Protocol. One example of the existing CAP measures is the aid of EUR 45 per hectare available to farmers who produce energy crops.

I believe that we all can agree on and accept these statements by the Commission, at least to some extent. Moreover, when the Commission positively emphasises that rural development policy involves the co-financing by the EU and Member States of a variety of measures, meaning that Member States decide on the most appropriate measures for their rural areas from a menu of measures proposed at EU level, we could only expect that this principle, so-called subsidiarity principle, and practice would be realised also in the Common Agricultural Policy. Only then we could have policy measures that were efficient enough, in all regions of the EU-25, and also in terms of economic, environmental and social sustainability. The recent reforms of the CAP were not sufficient in this respect; especially as the levels and allocation of agricultural subsidies still remained largely the same as earlier has been the situation. As a whole, the responsibility should be more on Member States themselves, in both agricultural and rural development.

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20 Opponent note no. 5b: Support to organic farming and bio-energy as rural development drivers

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20.1 Summary

Given the current competitive strength of North West European agriculture, organic farming and bio-energy production will not expand without subsidies. Technical research shows that high tech agriculture can be viable in the future if it is both efficient with respect to the environment and with respect to energy input. This is a more attractive route to attain the goals of the Lisbon strategy than to bet on organic agriculture. This high tech agriculture will be competitive with respect to large-scale producers from other continents. Roughly the same applies for bio-energy. Here the value for society of producing bio-energy has to be larger than the market value of the biomass produced. This can be achieved by combining functions in rural areas. High tech conversion of various bio-energy streams will provide a competitive advantage for the rural areas in North West Europe. The overall conclusion is that organic farming and bio-energy will not contribute to the Lisbon strategy goals of 2010. However, investments in developing high tech agriculture and bio-refinery will contribute to the Lisbon strategy, although the objectives will be met at a later stage. To fulfil the Lisbon strategy we have to change directions. We do not reach the desired objectives if we focus on minor improvement of current production systems. We have to develop completely new production systems. North West European agriculture has to do what it can do best: focus on knowledge intensive production of agricultural products. The outcome of these new policies is not certain, because the competitive strengths depend also on volatile price differences in commodity markets.

20.2 Introduction

The key questions to be answered by the "Green Roads to Sustainability" project are:

"Can environmental policies underpin the EU goals of improving economic growth, environmental quality and employment – all at the same time?" - and: "What is the potential of broader structural policies in relation to environmental policies?"

The objective of this study is to analyse the potentials of Green Roads to Growth policies, enhancing organic farming and bio-energy production. The focus will be on incentives to convert agricultural production from conventional to organic production and incentives to increase the production of energy crops and biogas. The objective reduces to two research questions:

- Can production of bio-energy enhance growth, create more jobs and improve the environment at the same time? If so:
- Which incentives can be identified to stimulate this preferred situation?

The outline of this opponent paper is as follows. First a few prerequisites for sustainable growth are presented; these are used to analyse the case study paper. The opponent paper is broken into two sections with an identical set-up. Organic farming is treated first in sections 3 & 4; thereafter bio-energy is presented in sections 5 & 6. Both cases start with a summary of the case study's conclusion paper. Points on which I agree of the case study paper by Abildtrup and Dubgaard (2006) are discussed briefly. Omissions found in their study are discussed and illustrated. In chapter 4 bio-energy production in the Netherlands is reviewed and research is indicated that may suit the objectives of the Lisbon agenda. Finally, conclusions are drawn.

20.3 Short background on economic growth

In this opponent paper questions will be addressed from a spatial economic perspective (alike the Abildtrup, Dubgaard paper). First the spatial context has to be identified. To be applicable for the Danish situation we focus on North West Europe.

Economic growth in a competitive world requires competitive strengths (advantages) on competing suppliers of the identical good or service. In this opponent paper I assume that the protection of EU agriculture will decline; therefore the Green Road to sustainability has to be met in a competitive world based on international trade. On the land market, organic agriculture and bio-energy crops have to compete with other possible land uses. The yield has to be larger than alternative uses. The market mechanism is in North West Europe the most important incentive to attain the goals of the Lisbon Strategy. If externalities come into play, and they will, the market will not reach the social optimal solution and the government has

to formulate environmental policies (policy measures) to achieve this social optimum.

Potential measures have to be evaluated using a Social Cost-Benefit Analysis to find out whether society's objectives are better met with these measures. The EU has formulated the Extended Impact Analysis (EIA) to evaluate potential measures on their environmental impact, their economic impact and their social impact (see for an example Kuhlman et al., 2005). This EIA-approach is suitable to evaluate measures to attain the objective of the Green Roads to Sustainability project.

To combine economic growth and improve the environmental quality can only be reached simultaneously if production factors explicitly including the environment are all employed efficiently. Efficiency can be divided into technical efficiency and economic efficiency (Reinhard, 1999). Technical efficiency can improve by movement of the production possibilities frontier due to technological change (Oude Lansink and Reinhard, 2004). It is clear that inefficient use of environmental resources will reduce environmental quality, while inefficient use of labour will increase employment (in the short run), but will reduce economic growth.

20.4 Conclusions case study paper on organic farming

Abildtrup and Dubgaard (2006) present the following conclusions on organic farming.

- There is no clear empirical evidence that organic farming is increasing rural income.
- Analyses of labour input based on Danish and European farm account statistics do not provide clear-cut conclusions on the impact of organic employment in rural areas.
- Organic farming has environmental benefits but these benefits could be provided at a lower cost than by subsidizing organic farming.
- Consequently, conversion to organic farming should be market driven. Government policies should focus on ensuring consumer confidence in eco-labelling and information initiatives (research and extension).

20.4.1 Comment

The case study paper provides us with a clear analysis of the current state of the art in organic farming. However, it does not take the future into account. The conclusions are drawn upon research based on realised production. Possible developments are not accounted for. Potential future scientific breakthroughs that will provide us with new efficient production possibilities are not described. These may be more efficient with respect to the environment and conventional inputs than the technologies applied today. In the following section the state of the art of Dutch organic farming research is presented, thereafter, new techniques are adderssed.

20.5 Organic farming

20.5.1 The Dutch experience

Recent Dutch research concluded that the objectives of the Dutch Government with respect to organic agriculture will not be met without additional measures. The Dutch government's objective of 10 % of the area of cultivated land being farmed organically in 2010, and a 5 % share of consumer spending on organic products in 2007, can be described as very ambitious. The current percentages are 2.5 % and 1.7 % respectively. Primary agriculture makes a considerable contribution in the higher costs at the consumer level. Various measures have been taken to encourage organic production. Approximately 50 % of the budget was destined for research and 25 % was intended for the stimulation of investment schemes. Non-buyers of organic food have a relatively low income. It is striking that price fixing does not come to the foreground in the researches analysed, or at least not explicitly, while the price of organic foods at consumer level are often more than 50 % higher than conventionally produced products. To reach a larger group of consumers, price reductions are necessary, or the positive characteristics attached to organic food have to be proven irrefutably (Wijnands et al., 2005).

Growth in the number of primary producers of organic products has stagnated in recent years. Potatoes, carrots, onions and cabbage represent the most important crops in turnover. Until a few years ago the economic achievements on organic arable farms were better than those on conventional farms. The physical yields are around 75 % of those of conventional farms and the costs are around 150% per hectare. This results in a product price that is twice as high. Labour is an important point for attention. More additional costs arise from extra labour. The amount of

pesticide residues has fallen (organic rather than chemical, of course), more enterprises are meeting the standards for nitrogen and phosphates and the energy consumption is lower. Scientific research confirms greater biodiversity through organic farming. Organic farming has its own critical success factors, specific to each category of consumers. Competitive price and 'one stop shopping' weigh heavily for the "calculating" category whereas the intentions of organic farming are the decisive for the "responsible consumer" category.

20.5.1.1 Conclusions

Due to lower yield and higher labour input, organic products are more expensive than traditional. This price difference will limit the expansion possibilities of organic farming. Only for a relatively small portion of the consumers the intrinsic value of organic food (including the environmental value) is large enough to justify the high consumer price. While conventional agriculture has to improve its environmental performance, due to more stringent regulation (e.g. EU Water Framework Directive), the intrinsic value of organic products (compared to conventional products) will be smaller in future. A lower price of organic products will attract more consumers, but this reduction can only be achieved if labour input decreases, due to technological research after mechanisation. This does not correspond with one of the pillars of the Lisbon strategy.

20.5.2 High tech agriculture

Organic farming can be characterized as 'low tech' agriculture, based on traditional technologies. A reduction of emission to the environment can also be attained applying high tech production facilities. The application of technology can result in environmental problems, but technology can also offer the key to the solutions of those problems. After a period of 'cleaning up afterwards', these days there is a much greater focus on technology that can prevent environmental problems. Economics and ecology can go hand in hand, for example regarding economizing scarce resources as energy and artificial fertiliser. Three types of environment-technological solutions can be identified (Silvis and de Bont, 2006)

- 'end-of-pipe' solutions. Negative effects of the production process are corrected afterwards (e.g. discharge water is purified)
- Process-integrated solutions. The occurrence of pollution is prevented or reduced (example: biological pest control).

- System innovation. This involves taking an integrated look at the organization of production. This can take place at chain level or in combination with other agricultural or non-agricultural sectors (closure of cycles through the mutual use of residual products).

In the last decades technologies have been developed for greenhouses that reduce the use of water and the emission of nutrients dramatically. This is achieved by for instance recycling waste water and using biological control. These high tech solutions have consolidated the competitive strength of Dutch greenhouse horticulture. They can play a competitive role on the land market and on the EU market for vegetables and world market for flowers. Meanwhile they employ a huge labour force in the greenhouses, in the supply industry and in the food chain.

Product innovations take place on a regular basis in horticulture, such as vine tomatoes, new colours of sweet peppers, and countless varieties of plants and flowers. In arable farming and livestock production, new products emerge less frequently. Alls sectors strive for improvements in quality. The post-harvest process is also important in this: storage conditions, the effective monitoring of microorganisms that cause food to perish and/or give rise to toxicity, and transport conditions, for example.

20.5.2.1 Policy

One of the new focus points of greenhouse technology is the use of energy. The greenhouse horticulture sector wants to change to a system in which the use of fossil fuels is replaced by renewable energy sources the whole year round. Many different energy sources could be used, such as solar energy, photovoltaic power, geothermal energy, hydropower and wind power. The rate of innovation and development of demonstration projects must be increased. It is time for decisive action towards sustainability.
The Dutch Ministry of Agriculture, Nature and Food Quality (LNV) and the Farmers Organizations Horticulture have formulated ambitious goals on the theme of energy.

One of these ambitions is to create a sustainable and publicly respected greenhouse horticulture sector which will be independent of fossil energy sources within the foreseeable future (2020), and in which growers can operate commercially using safe and environmentally sound cultivation methods. Achieving such ambitious goals requires radical system innovations, and this in turn depends on col-

laboration between several parties. The Energy-producing Greenhouses competition is expected to produce one or more 'innovative solutions' with which greenhouse horticultural enterprises will not only produce flowers, plants and vegetables, but also supply energy all year round for their own use and for distribution.

Greenhouses in The Netherlands receive more solar heat energy than they need. In conventional greenhouses the excess heat is removed by opening windows. Recent innovative greenhouse designs store this excess heat in deep aquifers through a sophisticated system of heat exchangers and pumps. The stored heat is used for warming the greenhouse during the nights or in winter. Energy balances show that there is sufficient energy left to heat a block of houses. The 'energy-producing greenhouse' has been the starting point of a design for a self-sufficient neighbourhood that closes water and nutrient cycles at a decentralised scale.

20.5.2.2 Conclusion

The organic farming sector will not expand in the future in a competitive market, due to higher production costs. Policy to reduce the production costs are not likely, because except for a reduction in the emission of nutrients and pesticides, organic farming does not attain objectives of society more than conventional farming. Given the competitive environment of North West Europe agricultural policies should stimulate high tech agriculture, whose produce can meet the environmental objectives, social goals against a competitive market price.

This stimulation has to be in the form of R&D subsidies for developing high tech agricultural technologies and subsidies to accelerate adoption of those techniques. Agriculture based on these new economically and environmentally new techniques will also provide more employment and will be a pillar for rural development. This high tech agriculture will only flourish in regions that are very suitable for agriculture (all necessary inputs including labour are available) and near the markets. Less favoured areas are not suitable for high tech agriculture, these areas have to specialize to environmental and landscape services to attain an income from agricultural activities. Another option is to specialize on niche markets to incorporate the specific characteristics of the region (and the product) in the price.

20.5.2.3 Arable farming

The harmonization of European pesticide policy will continue. It is expected that the European standards will become more stringent; however, the Netherlands already has a stringent policy for the agricultural use of pesticides. Consequently;

this issue will have little influence on the country's arable farms. The standards for nitrogen use imposed on arable farms will be more stringent than current standards; this will ultimately result in a reduction in the use of manure. The effects on the yield will be minor, since current application levels are often excessive; however, this will increase the risk of poor seasons.

The development of new products for the consumer generally takes place in the foodstuff industry. Such products are generally aimed at consumers with greater purchasing power. The processing industry has a need for good quality starting materials, and then wishes to create the added value itself by making specific products and supporting those products with a whole range of marketing techniques.

Two technological areas are of importance to arable farming. The first relates to ICT, which has already entered into wide-scale use. Opportunities will become available for precision agriculture during the coming 15 years. Automation will boost the current trend towards increases in scale and efficiency improvements. Precision agriculture will provide for the improved tailoring of the dose, time of application, the form (or variety) of the seed, the nutrients, pesticides and mechanical weed control to the spatial variation within fields. This will result in an improved use of cultivation aids, and will make a major contribution to the reduction of use of nutrients and pesticides. Biotechnology constitutes a second important development for arable farming. Its implementation can result in higher yields and the more efficient use of cultivation aids. Biotechnology is also being used in a search for improved or new products that can open up extra sales opportunities.

In environmental terms there are high expectations of biotechnology; for example, more efficient plants that require less in the way of inputs or that are optimally suited to specific circumstances; clean plants of which all the waste is usable. One particular interesting innovation is the idea to produce vegetable food proteins directly using algae and solar energy (so-called blue biotechnology). Other innovations with such perspective include:

- Bioremediation: the biological breakdown of environmentally harmful substances using bacteria, algae, fungi and yeast or higher plants.
- Technology to add value to residual and waste flows.
- Technology to optimise agrologistics
- Ecogenomics: working towards healthier soil life.

A number of technological developments are a source of concern for consumers. Biotechnology is a salient example of this. People are concerned about food safety and there is a greater demand for quality guarantees and information regarding production methods.

20.6 Conclusions case study paper on bio-energy

Abildtrup and Dubgaard (2006) present the following conclusions on bio-energy.

- Production of bio-energy on agricultural land is not a commercially competitive land use. If energy crop production competes with traditional crops there is no evidence that energy crops imply a higher level of employment.
- Bio-energy reduces the externalities from the use of fossil fuels. Inclusion of external costs and benefits improves the competitiveness of bio-energy from a societal perspective.
- Generally, the production of crops for power generation has a positive effect on the environment due to the reduction of green house gas emissions by substituting bio-energy for fossil fuels. However, bio-energy crops may increase pollution from agricultural production through intensification of land use.

20.6.1 Comment

These conclusions are valid, but they are based upon research and assumptions that stem from the past. In the Abildtrup, Dubgaard (2006) paper bio-energy production is compared with coal production; the conclusion is that the electricity production based on biomass has identical total costs (including social costs) as that based on coal. However these studies are based on prices in the 1990s, whereas the prices for the different costs components may vary largely in the future.

The Netherlands (and North West Europe) is not a suitable location to grow bulky bio-energy crops at a large scale. Due to the large pressure on space the land price is too high to produce bio-energy crops competitively. If we approach this question from international trade perspective, the crops (or animals) grown by EU farmers have to compete with crops from abroad. The competitive power of western European agriculture is not in the bulk production of crops. Value has to be added by the farmers and this value has to be transformed into streams of money above the world price for bulk agricultural products to make it commercially interesting. Large scale production of energy crops is more likely to be in Brazil, assuming that agricultural land is not scarce in future overthere. A disadvantage of importing bio-

energy is the adverse effect of the production of these crops (reduction of biodiversity, increasing food prices) in the production countries.

20.7 Bio-energy

20.7.1 The Dutch experience

A recent study of LEI (Janssens et al., 2005) analysed the prerequisites to grow rapeseed by Dutch farmers. To replace 2% of fossil gasoline by bio-gasoline 109.000 hectares are necessary (assuming a yield of 3300 kg rape seed per hectare). Rapeseed is only competitive on set-aside land, if it can be harvested using own machinery. In France and Germany production of rapeseed is more competitive than alternative crops. The changes in the CAP (including the energy bonus and lower prices for sugar beets) will not change the competitiveness of rapeseed compared to other crops. The market for bio-energy is constructed by the EU, indicating that a specific minimum percentage (5.75 %) of fuels has to consist of bio-fuel at 31st December 2010. The demand for bio-energy is likely to rise enormously. At present bio-fuel has a large tax exemption in the major EU member states. Production costs are far higher than fossil fuels, while they are favourable to combat the emission of greenhouse gases.

Current policy is a tax exemption on bio-ethanol and bio-gasoline in a lot of EU-countries. In the Netherlands the government wants to facilitate the use of bio-fuels to reduce the emission of GHGs by traffic. The transport sector currently emits 23 % of all GHG's in EU-25.

Figure 1. Production of biodiesel in tonnes

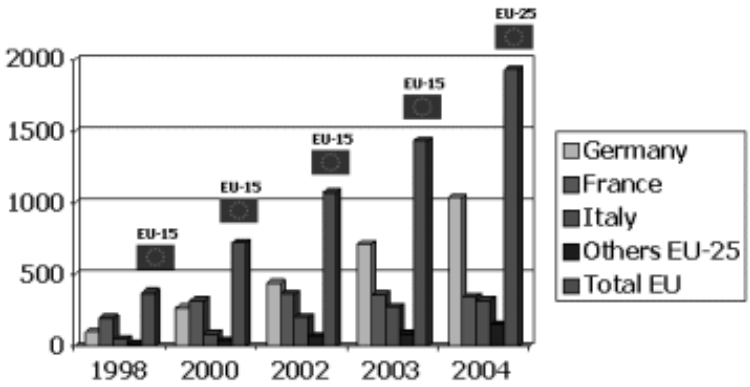

Figure 1 shows the development in biodiesel production in the EU in recent years.

To convert conventional farming into production of energy crops, the value produced per hectare should be quite high; especially compared to other competitive producers like Brazil. This value can be incorporated in the crops produced for the market (and result in direct income of the farmer) or the value can accrue to the society (without money directly connected to it). The value for the society can be a contribution to a reduction in emission of GHGs (Green House Gases), due to substitution of conventional energy sources into bio-energy. Other possible social values connected to the production of bio-energy are the improvement of soil quality or purifying water. To valuate bio-energy production in future we perform a cost benefit analysis of potential attractive bio-energy production systems (and compared to alternatives).

The externalities of growing bio-energy may warrant a policy to stimulate the production. One obvious externality is the reduction of GHG that are emitted. This externality can be internalized by CO_2 certificates and quotas of bio-energy in automotive fuel. However these mechanisms are not tied to the location of production. The current prices of these certificates are not high enough to offset the higher production costs. In the Netherlands other externalities of growing bio-energy are identified by combining multiple functions. An example is the production of green cane. Cane can be used as biomass for energy production and it also is a helophyte filter that improves the water quality. To fulfil the requirements of the EU Water Framework Directive the Dutch waterboards have to take measures to reduce the nutrient content in the water. One possible measure is to percolate water through a helophyte filter that consists of green cane that has been planted for this purpose (green maize is replaced by green cane). The value of the water purification of the cane is determined by the costs of alternative measures to attain the objective. A case study has been set-up to measure the actual water cleaning potential of the cane in this setting and to assess the value of this water cleaning function and the value as biomass. This year will be the first productive year for this cane.

20.7.2 High tech applications

The use of (ligno-) cellulose biomass, under which a large array of low value biomasses (straw, grass from the verge of a road, waste wood etcetera) but also from harvested bio-energy crops (e.g. switchgrass) offer perspectives for a large scale production of both bio-ethanol and bio-gasoline against a lower cost price and with a higher environmental turnover (more environmentally efficient). The technology

for these fuels is under development now, and is often called “second generation bio-fuels”. These second generation bio-fuels can be used in combustion engines. Nowadays worldwide two pilot plants produce bio-ethanol from ligno-cellulosis at small scale. The Dutch focus on second generation bio-fuels, because they are more sustainable, although they are only available on large scale by 2015. The second generation bio-fuels (based on woody sources and waste materials) will be cheaper by then (according to experts), and they require less energy and farmland. The emission reduction will be more than 80% (Annevelink, Bakker and Meeusen, 2006).

Although the first generation bio-fuels are relatively expensive and they require a lot of farm land, steps are set to stimulate these first generation fuels. The objective is that firms can prepare themselves for the second generation bio-fuels. Improvements can be made at every step of the supply chain, and it is reasonable to expect large gains in efficiency and concomitant reductions in cost as easily implemented modification made to current systems begin to streamline commercial production (Heaton et al., 2002). Disadvantages of first generation bio-fuels are the possible negative impact on biodiversity and nature reserves and the competition with food production and a possible lock-in effect of these first generation fuels. A reduction in livestock production will affect the waste product streams in animal feed industry. More waste material will be used to produce bio-fuels instead of the current use in animal feed. The market for waste material is very dependent on small price differences, hence these developments are uncertain. For instance due to the lower wheat prices in the EU the import of tapioca from Thailand has decreased enormously the last years. Also is the development of bio-fuels strongly dependent on the price of alternative sources of energy, it is extremely difficult to predict these prices. Therefore, the market for bio-energy crops is uncertain. If the price of energy is high enough to enable economic viable production of bio-energy crops, the impact will by gigantic. Amongst others food prices will rise, this will affect developing countries most. Also will the value of organic waste material that high that it will be hardly used as fertilizer, this will increase the erosion risk.

The Dutch Ministry of Agriculture, Nature and Food Quality wants to stimulate a stepwise approach to attach value to biomass in the future. The first step consists of high venerable applications (like materials and chemicals), the rest fraction will be used for bio-fuel. Finally the waste materials are used for electricity. The government needs to support market parties optimal to stimulate the knowledge development. The production of rapeseed, grains and other crops for the production

of first generation bio-fuels can meanwhile be a chance on firms and parcels of land that do not have higher valued alternatives. On the mid-term chances for crops will increase, due to the development of bio-refinery chains for high valued products, bulk chemicals and energy-carriers from crops. The implementation of second generation bio-fuels grass and woody waste streams play a specific role in the production of bio-ethanol and Fischer-Tropisch-gasoline from lignocelluloses containing biomass.

Understanding the financial and non-financial factors that influence farmer adoption is critical for designing public policies that will facilitate the adoption of practices and technologies with the greatest potential to mitigate climate change. Change in agriculture has historically followed the "adoption curve", with a small number of innovators trying an untested practice and refining it, followed by the more numerous early adopters, and then the bulk of the farmers. The combination of farm demonstrations with socioeconomic analysis will lead to rapid adoption of project findings, particularly those that have low capital requirements and those where we can clearly demonstrate multiple benefits to farmers, communities and local industry.

20.7.3 Conclusions

Bio-energy production is not viable in North West Europe, except if it is rewarded for its contribution to the objectives of the society. CO_2 certificates are not bound to our region, and they will not provide a comparative advantage over Brazilian bio-energy. Cultivation solely for energy purposes would not appear to be of economic interest; a link with another function, such as water purification, recreation, water storage or the use of marginal land would appear to offer better prospects. To stimulate bio-energy production these benefits have to be attached to flows of money. In the future, if second generation techniques can be applied to transform biomasses into energy, the production of bio-energy will be more environmental efficient. Given possible major changes in the price ratio of fossil fuels and bio-fuels in the future, it is possible that bio-energy is a competitive agriculture product.

20.8 Conclusions

Given the current competitive strength of North West European agriculture organic farming and bio-energy production will not expand without subsidies. Subsidies can be supplied because of the positive external effects of both organic faming and

bio-energy production. For bio-energy flows of money are already attached to the environmental benefits, by CO_2 certificates. It is expected that prices of fossil fuels will rise in the future, hence bio-energy production will be more competitive with respect to fossil fuel, but production in North West Europe will not be competitive compared to production in Brazil.

Technical research shows that high tech agriculture can be viable in the future if it is both efficient with respect to the environment and with respect to energy input. This is a more attractive route to attain the goals of the Lisbon strategy than to bet on organic agriculture. This high tech agriculture will be competitive with respect to large-scale producers of other continents. A policy that corresponds with the Lisbon strategy is to invest in research that will make these new techniques available for farmers and stimulation of the adoption of this high tech agriculture.

Roughly same applies for bio-energy. Here the value for society of producing bio-energy has to be larger than the market value of the biomass produced. This can be achieved by combining functions in rural areas, for instance increasing water quality to comply with the Water Framework Directive. The value of CO_2 certificates is not tied to the location, and will not lead to comparative advantages over production in other continents. High tech conversion of various bio-energy streams will provide a competitive advantage for the rural areas in North West Europe. Here again, research after multiple land-use and high tech conversion of multiple biomass streams will lead to competitive advantages, towards improved environmental quality and to more employment. The required policy is an investment into new technique and fast adoption of these techniques.

The overall conclusion is that organic farming and bio-energy will not contribute to the Lisbon strategy goals of 2010. However, investments in developing high tech agriculture and bio-refinery will contribute to the Lisbon strategy, although the objectives will be met at a later stage. To fulfil the Lisbon strategy we have to change directions. We do not reach the desired objectives if we focus on minor improvement of current production systems. We have to develop completely new production systems. North West European agriculture has to do what it can do best: focus on knowledge intensive production of agricultural products.

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Part VIII

Case Study #6

21 Case study paper no. 6: Renewable energies – environmental benefits, economic growth and job creation

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21.1 Abstract

Whereas most renewable energy chains are "cleaner" than conventional ones in terms of pollutants causing acidification, eutrophication, summer smog or in enhancing the greenhouse effect, as well as in terms of wastes and impact on biodiversity, due to the many differences one has to look at the specific processes to judge on the contribution of renewables to environmental quality.

The contribution of RES to economic growth and job creation requires distinguishing between gross and net effects. Spending money on RES creates value and jobs. However, due to the high cost of RES more value and jobs may be destroyed. In general it seems out of place to expect high impulses for economic growth from an industry with a relatively small share of GDP. In particular it depends very much on the way the financial resources necessary to develop RES are collected. The present framework of protecting RES cannot be an answer compatible with international competitiveness. A large section of the paper therefore is devoted to discussing policy alternatives.

21.2 Introduction

It is generally agreed that the enhanced deployment of renewable energy sources (RES) is a crucial measure for the improvement of environmental protection and the enhanced security of energy supply. In this context, the European Union has set defined objectives within the Green Paper "Towards a European strategy for the security of energy supply" from 1997 to increase the share of renewable energy of total energy consumption from 6 % in 1997 to 12 % in 2010 (EU15).

The potential contribution to innovation, economic growth and creation of new jobs is another aspect, which has gained importance in the debate on renewable energies. More than 100.000 new jobs that have been created in the German renewable

energy industry during the last 10 years raise hope that the renewable energy industry could be a job motor for many countries in the EU.

Thus, it seems at first sight that renewable energies can guarantee both – protection of the environment and economic growth and job creation. Therefore, the deployment of renewable energies seems to be the ideal solution to achieve the goals set in the Lisbon Agenda - i.e. environment, economic growth and job creation.

To identify those policy measures which can contribute to the attainment of these goals by the promotion of renewable energies, a close and critical look on the assumptions concerning the advantages of RES is inevitable. First of all, this requires a good understanding of the influence of RES on the environment and the macroeconomic effects of the promotion of RES. Section 21.3 and 21.4 are dedicated to these two aspects whereas the policy instruments for the promotion of RES are presented and assessed with regard to specific criteria of success in section 21.5. This section also includes a paragraph where the dispute on quotas versus feed-in tariffs is illuminated due to the current discussion. Section 21.5 is completed by the presentation of the development of the promotion of wind energy in Denmark during the last two decades is presented as a case study.

The results enter into the final recommendations for the design of policy concepts for the promotion of RES that enables policymakers to establish successful strategies and minimize possible negative effects.

21.3 Environmental effects of renewable energy utilisation

The deployment of renewable energy is very often pointed out as one of the most important steps on the way to a more sustainable future for Europe. Wind power, solar and geothermal power and heat, biofuels and other forms of renewable energy are often called “green”, for they are believed to have no adverse effects to the environment. Even though this is only partially true, generation of power and heat from renewable sources per se has indeed very little impact on the environment in terms of emissions of polluting substances, unlike the conventional fossil fuel-based technologies.

It is important to understand, however, that in order to produce the conversion technologies, install them, operate, maintain and dismantle them, a broad spectrum of activities and industries needs to be involved. Thus, in order to assess the environmental impact of renewable energy utilisation, one needs to take into account several points:

- Impact needs to be measured in **comparison** to the source of energy substituted
- A **life cycle assessment** is necessary to reflect the actual impact of renewable energy technologies (RET). This implies following all environmental effects (emissions, acidification, eutrophication, etc.) of the energy chains from the manufacturing of the technology through the generation to the delivery of the respective energy service to the customer. Some older studies include data only for the generation of electricity or heat through the use of the respective technology (for example, IEE, 1994). Such a methodology tends to underestimate negative effects of RET and presents them as neutral to the environment.
- A life cycle assessment needs to include also the emissions and other effects inflicted by power generation from other, usually conventional fossil fuel sources, due to the **intermittent** character of some RES. For example, gas turbines or coal-based thermal power stations are usually used to complement power generation from wind.

This does not mean to say that renewable energy utilisation is not an 'environmentally friendly' option for the power, heat and transport sectors, in comparison to conventional fossil fuel technologies. On the contrary, emissions and other negative impacts to the environment are certainly lower for renewable energy technologies. Due to the generally higher costs of these technologies, however, it is important to be able to compare the costs and benefits of the introduction of these sources in the European energy mix. Therefore, it is necessary for decision makers to understand the extent of the possible environmental benefits of different RE deployment strategies.

This section aims at providing an overview of the latest research in the field. The first part is concerned with general environmental and nature conservation issues related to RE. The second part focuses in more detail on the currently most important environmental issue, reduction of CO_2 emissions due to the substitution of fossil fuel technologies with RET. It compares on the one hand the results of different methodologies and assumptions and on the other the estimated effects of different policy options.

21.3.1 Comparison of the environmental effects of renewable and conventional energy utilisation

It is certainly difficult to compare renewable with conventional energy technologies in general. The comparison depends on a large number of context dependent parameters, (BMU 2004, 13) e.g.:

- The technology configuration examined (e.g. polycrystalline, monocrystalline or amorphous silicon or thin-film solar cells, steam turbine or combustion engine CHP units, etc.);
- The type of energy source used, especially in the case of biomass, and its specific properties (fuel inventory, transport distances, etc.);
- The geographical location, topographical situation and local conditions of the plant (crucial for solar radiation, full-load hours, expenditure on barrages for hydro power, etc.) and
- Integration in the local infrastructure (e.g. integration of photovoltaic in the building).

Nevertheless, some general trends can be noticed, even if through a qualitative, rather than a quantitative comparison. **Table1** provides a gross survey of the scale of impacts from different RET in comparison with the effect from conventional technologies. The methodology is adopted from a table in a report by the Watt Committee on Energy (1991, cited in IEE 2004, p.), and somewhat changed as to include the whole lifecycle of energy production, rather than just the power generation component. This is a more comprehensive approach, taking into account the so-called energy chains or fuel chains, as used for example by Nitsch for Germany and by E4Tech for the United Kingdom. (Nitsch et. al., 2005; E4Tech, 2003; IEA 2002, p.5). It includes the technical properties of the renewable energy systems as well as of the "background systems"[92]. It takes into account fuel cultivation, harvesting, collection, transportation and processing, as well as power plant construction, operation and decommissioning.

[92] Systems that do not form a direct part of the system investigated, but are necessary for its creation, use or disposal, for example the power stations for the provision of production energy (BMU 2004, p.12)

Table 1. Qualitative analysis of the environmental effects of some renewable and conventional energy chains

	Source	Wind		Solar		Hydro		Geothermal		Biomass		Conventional		
Effect	Technology	Onshore	Offshore	PV	Thermal	Large	Small	Hot dry rock	Aquifers	Gasification	Combustion	Coal	Gas	Nuclear
Air	Emissions	0	0	S	0	0	0	0	0	S	S	L	L	S
	Aesthetics and noice	M	S	0	0	0	0	S	S	0	0	L	L	L
Soil	Sterilisa-tion	S	0	0	0	M	0	S	S	L	L	M	M	M
	Erosion	0	0	0	0	M	0	0	0	+	+	M	M	M
Water	Flow	0	0	0	0	L	S	0	0	0	0	M	S	L
	Pollution	0	0	S	0	0	0	S	S	S	S	L	L	L
Other	Climate change	0	0	S	0	0	0	0	0	S	S	L	L	S
	Blodiver-sity	S	S	0	0	M	S	0	0	S	S	S	S	L
	Materials	M	M	S	S	M	0	0	0	0	0	M	M	M
	Catastro-phes	0	0	0	0	L*	0	0	0	0	0	M	S	L**
	Finite ES	S	S	0	0	0	0	0	0	0	0	L	L	L
	Wastes	0	0	0	0	0	0	0	0	S	S	L	S	L

+, positive effect
0, no effect
S, small-scale negative effect
M, medium-scale negative effect
L, large-scale negative effect

21.3.1.1 Effects of renewable energy utilisation on air quality

The first type of environmental effect, emissions of polluting substances, is the main reason for critique of fossil fuel-based energy production. Impacts on air quality from the utilisation of renewable energy sources and all supporting activities are generally lower than from conventional energy chains. An exception is the possible higher contribution to summer smog of waste wood-based power and straw-based heat generation.

Figure 1, Figure 2 and Figure 3 provide a comparison between the emissions of three GHG gases from renewable and conventional sources for electricity production based on a life cycle analysis (without co-generation (CHP)).

Figure 1. CO_2 emission of energy chains[22]

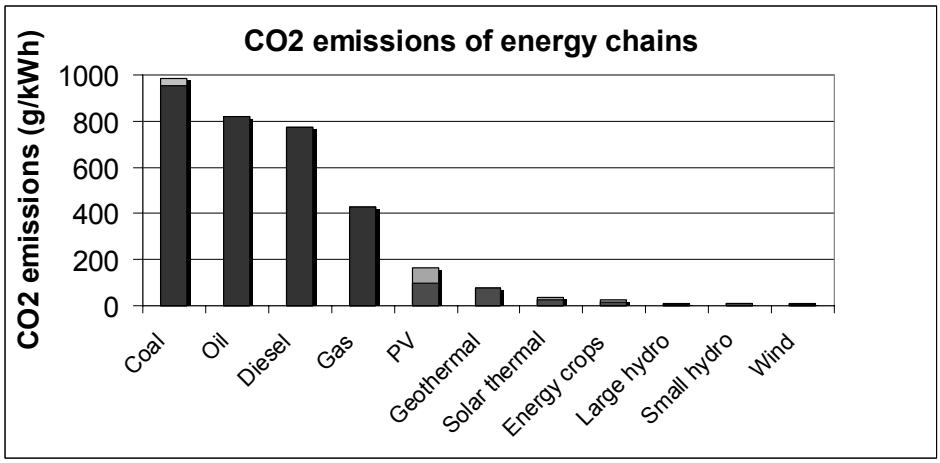


Figure 2. SO_2 emissions of energy chains[22]

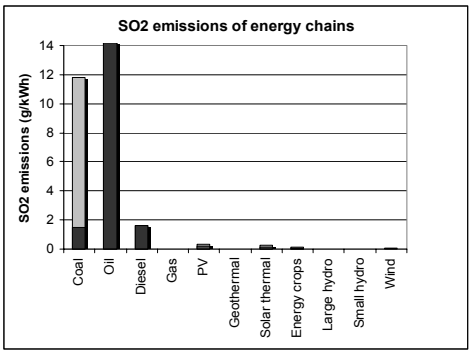
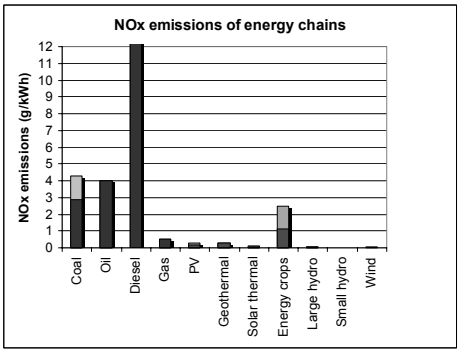


Figure 3. NO_x emissions of energy chains[93]



The only instance when emissions from renewable energy (RE) may in some cases be higher than from fossil fuels is in the case of NO_x from energy crops in comparison to combined cycle gas turbines. Even so, the CO_2 and SO_2 emissions of energy crops are more than ten times lower than those of natural gas and by far offset the difference in NO_x quantities. Emissions from biomass utilisation are usually due to the agricultural support system and the transportation of the biomass from the

[93] Sources[93]: IEA 1998, ETSU, Cited in IEA 2002, p.6

source to the processing plant. These characteristics do not apply for any other renewable energy sources (RES).

The main sources of pollution from the wind and photovoltaic energy chains come mainly from the demand for raw materials and from the steel industry. It is impossible to give a generalised account of the emissions per kWh from wind, if one considers also the impact of the sources used to fill in the generating capacity whenever winds are not strong enough. Such emission levels depend strongly on the specific wind potential dynamics of the area, as well as on the back-up energy source used. Coal and diesel, though currently cheaper than gas, would necessarily increase the emissions of the generation cycle much more.

In the case of geothermal energy, in comparison, possible pollution levels are endogenous to the source itself. Hot water heated up deep in the Earth's crust carries dissolved chemicals, such as CO_2, hydrogen sulphide, traces of ammonia, hydrogen, nitrogen, methane, radon, boron, arsenic, and mercury. (IEA 2002, p.7)

All in all, for the renewable energy chains analyzed by Nitsch et. Al., 2005[94], the inputs of finite energy sources and emissions of greenhouse gases are very low, compared to a conventional energy system:

- In the power sector, the environmental effects of renewables are only 20% of the respective effects of a conventional system in 2010;
- For heat this is a maximum of 15 %, and
- Using biofuels saves up to 45 % of the environmental effects of a future diesel car.

Substitution of fossil fuels with renewables can also help solve the problem of summer smog in cities, both in the power and the transport sector. Only waste wood and straw used for in the heating industry could induce smog at a higher rate than conventional sources.

As far as aesthetic and acoustic disturbances are concerned, there is a hot public debate on the effect of wind farms, for example. Wind turbines are believed to dis-

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[94] **Hydro**: small run-of-river; **PV**: 3 kW with polycrystalline solar silicon; **Wind**: onshore; **Solar thermal**: parabolic; **Geothermal**: HDR; **Biomass**: steam turbine with forest wood; **Solar collector**: local heat with long-term heat storage; **Straw**: straw-fired heating plant; **Wood**: central heating with forest wood.

turb the landscape and decrease the value of land nearby. This category, however, is very hard to assess, as it has a very subjective character. Nevertheless, it can be said that wind farms and large-scale hydropower plants are the examples of RET with negative aesthetic and acoustic effects. Looking at the entire lifecycle, however, one should also mention similar problems with high-tension transmission networks and their impact on the landscape.

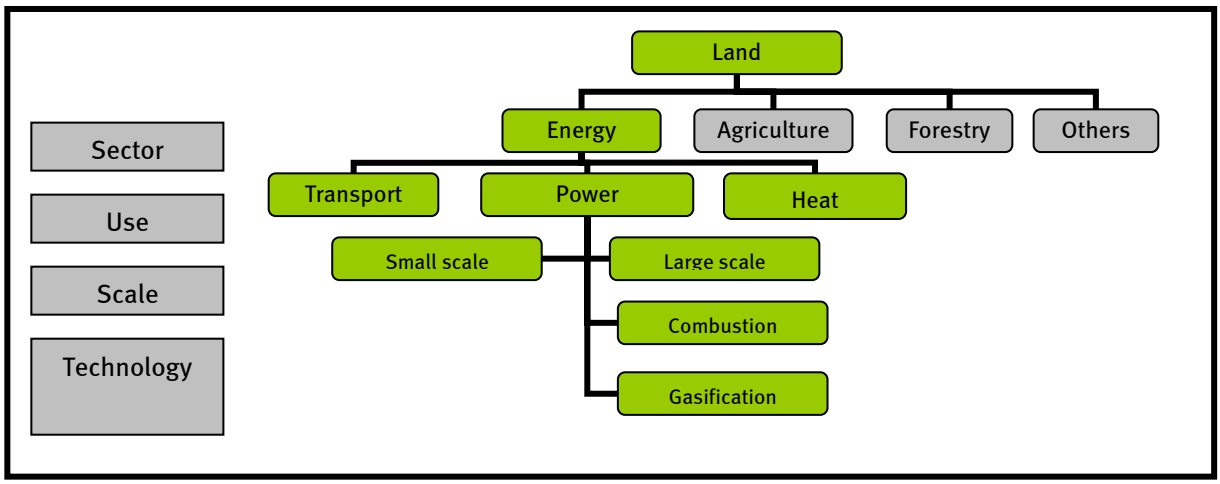
Renewable energy technology must be located close to the RES, for example wind power stations close to the coast. This often results in the installation of electricity production sites in significant distance from the existing grid. Thus, the deployment of RES can demand the extension of the grid. Grid extensions are also necessary for the compensation of fluctuations of electricity from RES.

Whether the aesthetic and acoustic effects from RET are stronger than from coal, gas, or nuclear plants, is largely disputable.

21.3.1.2 Effects of RE utilisation on soil quality and land availability

Land sterilisation, or the prevention of its use for any other purpose, could be mentioned as somewhat problematic around wind turbines and geothermal plants and very problematic as far as large-scale hydropower is concerned. For conventional power plants it is true that this is also an issue. Thus, these technologies require a careful selection of the site and consultation with all potential stakeholders, as to minimize low acceptance problems. What is more interesting from the point of view of the expansion of the renewables sector is the competition for land between the energy, agriculture and forestry sector as well as nature conservation areas, infrastructure, etc. Figure 4 illustrates this point.

Figure 4. Competition for land among different economic sectors



In Europe this may present a serious problem with the potential for the expansion of biomass production for energy uses. It is necessary in this case to make effective policies that solve the problem. For example, nature conservation restriction to the use of land can be used to actually increase the potential biomass resources, by providing access to residues from forest margin maintenance, compensation areas and biotopes, as well as from coppice and composite forests. In the case of Germany, for example, nature conservation regulation would most probably decrease the potential area for production of biomass from 2,500,000 hectares to about 200,000 hectares in 2010. Within the following four decades, however, this area could steadily grow to as much as 4,150,000 hectares, given the abovementioned harmonisation of the two sectors. (BMU 2004)

Another way to combine the growing of energy crops and nature conservation measures is to plant perennial plants suitable for energy generation on sites with high erosion risk. Perennial plants stabilise the soil and prevent erosion and flooding. Similarly, larger hydropower projects may affect the transportation of sediments. In many cases, the regulation of the water flow of rivers through dams prevents floods, which wash away the upper and most fertile soil layer. The construction of hydropower plants, however, leads to irreversible ecosystem changes, including of the soil layer, for the flooded areas.

21.3.1.3 Effects of renewable energy utilisation on water quality

There are several effects that can be connected to energy systems that concern hydro resources. The first type of effects is physical, and involves changes in the flow rates and temperature of rivers, as well as changes in the water table. It is important to mention large-scale hydropower projects, which distort the natural flow of rivers and with this the hydrological characteristics of the areas around. This problem can be somewhat tackled by the introduction of minimum flow rates for dams. It should not be forgotten, however, that coal and nuclear power plants also affect rivers, as they use large amounts of water for cooling purposes. Thus, the water that leaves the plants has a temperature much higher than the natural level.

The second type of effects concerns changes in the chemical content of rivers and lakes.

Acidification is a problem usually connected to mining activities, especially of coal. In many coal producing areas in Europe, such as the region around Cottbus in East Germany there is still no real solution to the heavy environmental pollution. The use of renewable energies can thus be of help in avoiding acidification. There exists only one exception, i.e. utilisation of biogas for electricity and straw in the heat sector which imply higher acidification levels. This effect, however, in the case of biogas is connected to ammonia emissions from the agricultural system providing the biomass. In case organic farming is used, these effects can be overcome. In the case of straw, there are emissions of gases with chlorine and sulphur content and NO_x.

The agriculture sector leads also to the feeding of large amounts of nitrates and other nutrients in the water, leading to eutrophication. This is the development of algae, bacteria and plants that feed on these nutrients on the water surface, and thus do not allow sunlight to penetrate the lower layers, thus disturbing the natural balance. Conventional energy chains, especially from fossil fuels, however, lead to much higher levels of eutrophication, than all other renewable energy chains.

21.3.1.4 Other effects of renewable energy utilisation

The effects of fossil fuel extraction and utilisation on **biodiversity** range widely in scale, but in general it can be said that mining, as well as oil and gas extraction, lead to severe pollution problems from heavy metals and other substances. Such long-term disturbances of ecosystems affect the biodiversity not only in their immediate vicinity, but also in entire watershed areas. Oil spills and other accidents have also lead to extremely rapid and severe changes in the natural balance of entire areas and lead to heavy losses of flora and fauna. In comparison, the risks of the utilisation of renewable energy are minute, with the exception of large-scale hydropower. There exists a certain risk of endangering birds through installation of wind turbines along routes of migratory birds and near nesting areas, but this problem can be avoided by careful planning (see BMU 2004, pp. 17-19). Hydropower projects also need to incorporate alternative routes for fish in their planning and construction, in order to minimize the effect throughout the lifetime of the plants. There is still, however, the problem of converting large areas into aqueous environment and thus changing the whole ecosystem through the construction of dams in large-scale hydropower plants.

An important consideration in the expansion of the renewable energy sector is the growing demand for **materials**. The demand for iron ore for solar and wind tech-

nologies in both power and heat generation exceeds that for conventional technologies. Moreover, PV cells make use of other more rare materials, and a large-scale expansion could bring a shortage of material and may necessitate recycling.

The risk of **catastrophic events** is usually brought up in connection to large-scale hydropower (the risk of floods due to breaking dams) and nuclear power plants (accidents such as Chernobyl, as well as the fact that there is no long-term solution to the issue of nuclear waste). There is, however, a certain risk of severe air pollution in cases of malfunctions in coal and gas thermal power plants, oil and gas storage facilities and tankers, etc. Due mainly to the much smaller scale of the technologies and the lower levels of polluting and hazardous substances involved, all other renewable energy chains could help avoid such disasters.

Finite energy sources may be used in certain quantities in each energy chain. For renewable energies, that concerns the support systems and the quantities are negligible. The only exception could be fossil fuels used for power generation to fill in for wind capacity. Naturally, these quantities are much lower than if the filling in technology would operate at 100% capacity instead.

Power and heat generation from RES is generally not associated with **waste.** The only sources of residues could be the supporting systems. Quantities, however, are minute in comparison to those of conventional energy chains. Radioactive nuclear waste is particularly problematic and is the main reason why renewable energy is preferred by many over nuclear power even in the context of CO_2 emission reduction targets.

Climate change is a topic of particular relevance to the energy sector. Accumulation of greenhouse gases (CO_2, CH_4, SO_2, and NO_x, among others) due to anthropogenic activity can enhance the natural greenhouse effect. A wide spectrum of research on the topic shows that this may lead to severe consequences, such as a several degree rise in average temperatures, and the climate becoming extreme, leading to much higher frequency and impact of natural disasters, ranging from severe draughts to inundations of vast populated and agricultural areas. Also expected are general deterioration of health, increased risk of famine, wars for water supplies, or even a sudden transition to a new glacial period[95]. The main factors increasing

[95] The word "sudden" in this context is used in geological terms and refers to periods of two to five decades.

drastically the natural greenhouse effect are transportation, industry, electricity generation.[96] This makes energy policies a crucial factor for the mitigation of greenhouse gas emissions. As was shown in Figure 1 to 3, greenhouse emissions from renewable energy chins are in most cases negligible in comparison to those of fossil fuel chains. In this sense, renewable energies are seen as an important instrument for the mitigation of climate change. The actual extent to which expansion of the use of renewable energies can decrease the adverse effects of the energy sector on the global climatic system will be discussed in more depth in the following section. It should be mentioned that nuclear energy is also proposed as an alternative to fossil fuels, as far as climate change is concerned. Given the very low emissions of greenhouse gases (GHG) from the nuclear energy chain, the comparison between renewable and nuclear energies needs to be made on basis of other environmental impacts or social and economic costs.

21.3.2 CO_2 emission reduction

By far the most discussed feature of renewable energy is the low amount of CO_2 emissions associated with its utilisation, compared to fossil fuels. The propagation of renewable energies in Europe's energy mix is seen as one of the most important steps towards keeping up with demanding national and international targets related to climate change. There exists a variety of research on the topic, aiming at assisting policy makers assess the effectiveness and efficiency of different policy options. The following section is meant to provide an overview of the most recent research and look for traces of consensus among researchers on the ability of Europe to reduce emissions by adopting renewable energy promotion strategies.

21.3.2.1 Methodology

Different research projects have used different methodology in order to assess the effects of renewable energy utilisation on CO_2 emission levels. The first option is to assume different policy options, such as a certain level and duration of subsidy or a tax, and extrapolate their effect in future scenarios. Such studies then use factors to calculate the respective emission (reduction) levels for each scenario and compare them. Examples are the FORRES 2020 project (Ragwitz et.Al. 2005), and the

[96] For more information on climate change, turn, for example, to the United Nations Framework Convention on Climate Change's *Climate Change Information Kit* (2002)

study on ecologically optimized expansion of the renewable energy sector in Germany (BMU 2004)

Another option is to assume certain targets and compare different strategies that could achieve the objective. This approach is used, for example, in cluster of models (POLES, MARKAL, PRIMES are the ones relevant to the present study) in the CASCADE MINTS project (ECN 2005). Another approach is to develop general socio-economic visions of the future (including specific emissions and RE targets) and backcast developments in the energy sector that may have lead to such conditions. Examples of this type can be found in IPCC, 2000 as well as in the COOL project for the Netherlands (Treffers, 2004).

21.3.2.2 Variables and assumptions

Independent from the methodology used, studies are also based on different assumptions and utilise different variables. Thus, results of different projects can very rarely be compared. Given the long timeframes of the execution of such research projects, however, this is actually an advantage. Even though results cannot be checked against each-other easily, this approach provides a larger spectrum of cases and policies analyzed. Variables of highest relevance to the deployment of renewable energy are the countries and regions included, the economic sectors to which the policy apply, the time frame of the policy, the accounting of factors such as the openness of the system and technological learning, the characteristics of the energy sector and the overall aim of the policy.

Due to the different technical potential, learning factor for each specific technology, possible political, administrative and social barriers, etc., the same policy would produce very different results in different countries. As much as studies on the effect of policies in the US have little relevance for Europe, studies concerning Western Europe can not inform policymakers on an EU-level. Different sectors (industry, households, transport, energy, agriculture, etc) need different strategies in order to achieve the same result. Thus, it also makes a difference whether a study considers emission reduction or any other goal in the power or in the transport sector.

The Green-x model, used in the FORRES 2020 project, presents the possibility to compare Western Europe with Eastern Europe and most European countries to one another. It provides interesting insights on the contribution of different sources and sectors to the emission reductions due to renewable energies in different European countries for both BAU and 'policy' scenarios. For Germany most impact has on- and off-shore wind and biomass in the power sector. If aggressive policies are applied, solar thermal and biomass for heat could significantly contribute to emission reductions. Altogether, Germany contributes with 60% to the European emission reductions until 2010, and about 40% by 2020 under the current policy mix in Europe. Spain would account for about 12% of the EU-25 emission reductions by 2020 from on-shore wind and solid biomass for the power sector. Biofuels in the transport sector would grow substantially between 2010 and 2020. The electricity sector is most important in the UK, where nearly all reductions come from wind and biomass expansion. In case of strong policies, tidal and wave energy could be utilised after 2010, leading to substantial CO_2 cuts. In Italy wind and biomass have strongest environmental effects as well.

An important variable with regard to renewable energy in Europe and its environmental effects is also the "**openness**" of the system in terms of international trade. In many cases, technical potential within specific European countries or Europe itself may be limited. Thus, costs of reducing emissions through renewable energies may be much higher within the countries themselves, than if international trade is allowed.

A clear example is the availability of land for growing energy crops. In Europe there is a fierce competition for land between agriculture, forestry, nature conservation and the energy sector. This could be avoided if countries could import biomass from developing countries, where there may be more territory available for growing energy crops. Another alternative would be to invest in the power generation from biomass in countries with abundant and cheap resources and account for that in the investor country's own emissions budget. (see for example Treffers et. al 2005)

One of the most important variables in any research project is the actual **overall aim**. There are different options:

- Concerning RES penetration:
    - A set of policies can aim at the **maximisation of the use** of renewables within some cost constraints and time frame.

- Another aim can be to achieve a certain **targeted level of penetration** of renewable energies in general or for each source, each sector, etc.

- Concerning CO_2 emissions
  - A certain level of CO_2 emission reduction target can be achieved in many ways, depending on the RES mix, the substituted source, and the total cost. It is therefore important to model different strategies and find out the **least-cost** ones. Usually least-cost scenarios for emission reduction do not rely only on introduction of renewable energies.
  - Another option is to set as initial conditions a time frame and a cost limit and model the **maximisation of the emission reduction** level.

The possible reduction of CO_2 emissions according to the reviewed studies is substantial. However, it varies very much according to the policy used and the aim of the policy. While the utilisation of renewable sources per se involves less CO_2 emissions than that of fossil fuels, this effect may be lost or outweighed by ineffective policies. Moreover, the level of penetration of renewables in the energy mix is certainly not in a linear dependency with the amount of emission reductions. This is due to the interference of various factors, such as electricity and fuel prices, learning rates of RET, the level and type of subsidy/quota/cap, etc.

A variable used according to the overall aim is for example the conventional source of energy substituted by the RES. The following example illustrates this point. The MARKAL model (ECN, 2005) assumes a policy framework aiming at a certain share of renewable energies in the primary energy mix (as proposed by the European Commission in Berlin, 2004), rather than at the reduction of CO_2 emissions. The substitution that occurs in the power sector is of the more expensive natural gas thermal power plants, rather than of more carbon-intensive coal power plants. This leads to an actual increase in the share of coal in the energy mix and thus to high emissions levels. Thus, the model does not predict any substantial emission reduction due to the introduction of more renewable energies in the energy mix. If the aim would be shifted to CO_2 emission reduction, more carbon-intensive coal plants would be excluded from the energy system and gas power plants would be kept. The difference between the two scenarios would be substantial. This conclusion is supported also by, Palmer and Burtraw (2005) who show clearly that in case it becomes too expensive to produce electricity from natural gas, the reliance on coal may actually outweigh the CO_2-savings from the introduction of renewable energies.

21.3.2.3 Examples of study results

Figure 5 and Figure 6 illustrate the possible emission reduction levels resulting from the increase of the share of renewable energy in the total mix. Even though this section offers some numerical representation of possible emission reduction levels, it is not meant to show the effect of specific policies or technologies. As already mentioned, all projects reviewed in this paper use specific methodologies and assumptions that cannot be reasonably compared. The section below is rather meant to show the possible range of emission reductions caused by different RES deployment strategies – from rather pessimistic ones, such as the PRIMES model, to overoptimistic ones, such as FORRES 2020.

Figure 5. Model results from the CASCADE MINTS project, presented in ECN 2004

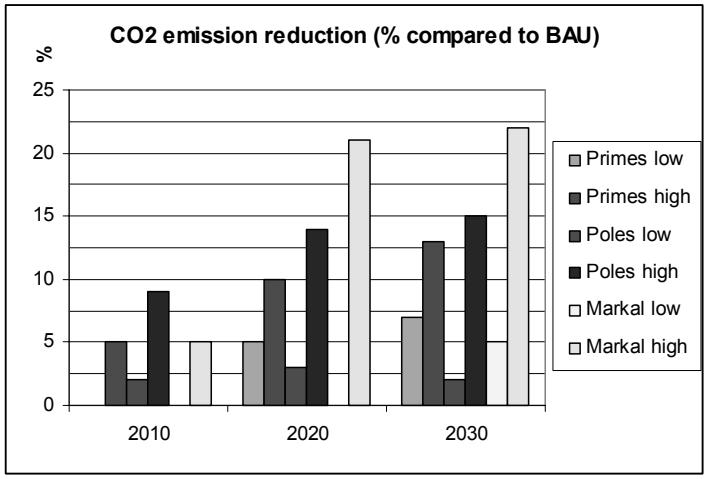


Figure 5 gives a summary of the CASCADE-MINTS project (ECN 2005). The three models used analyze two targets each: a high target of 20% renewable energy in the gross inland primary energy consumption in the year 2020; and a low target of 12% share for the same year. Consequently, they create different scenarios, depending on the region assessed, additional targets (e.g. on electricity consumption), subsidy levels, etc[97].

[97] PRIMES assumes a growing feed-in tariff, the cost of which is passed to the consumers through higher electricity prices. For the Low target the tariff reaches € 18 / MWh, while for the high target, it is € 40 / MWh in 2020. The model encompasses the EU25 member states.

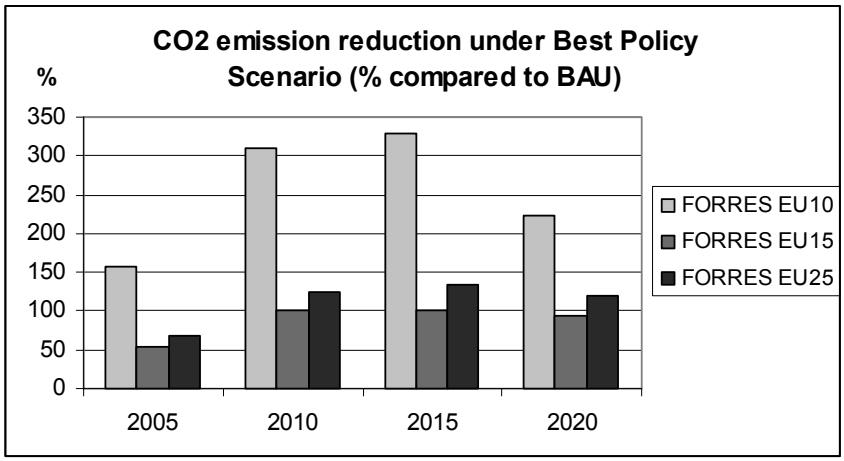
POLES uses additional subsidies, uniform for 7 specific RES. The subsidies are constant throughout the study period. The coverage of the subsidy is EU, plus Romania, Bulgaria, former Yugoslavia, Norway and Switzerland (EU30)

MARKAL has different sectoral policies: lower bound on the share of RES in the total share of electricity generation; an indirect carbon tax equal to € 0.25 / l gasoline; an emissions trading system for the industry sector, with a cap increasing from 125 Mton to 200 Mton. The model comprises EU15 and Norway (except in the power sector) Iceland and Switzerland.

The resulting range of emission reduction levels can be seen on Figure 5. The levels of emission reduction vary substantially, for 2020 between 10% and 22% compared to a business-as-usual (BAU) scenario. The cost for the subsidies for the POLES model high target scenario, for example, are about 0.48% of GDP each year, an amount that no government is likely to approve of.

In contrast, the FORRES 2020 project aims simply at the maximisation of renewable energy penetration in the energy mix (Figure 6). For this reason, the"best" policies, specific for each technology, are selected and applied in all countries. The result is an overoptimistic scenario, showing the possible effect of very strong European directive, enforcing the explicit support for renewable energies in each of the 27 countries considered.[98]

Figure 6. Model results from the FORRES 2020 project, presented in Ragwitz et al. 2004)



The result is a stunning average of about 100% less emissions than under BAU for EU 25. For EU 10 these levels reach over 300% for the years 2010 and 2015 (Figure 6). The costs of such a substantial CO_2 reduction grow from 0.14% of GDP for 2005 to about half a percent of the GDP in 2020 for EU 25. This scenario, however, assumes no socio-economical, political, or technological barriers to the deployment of RES. Even though it is highly improbable, it is still a good illustration of the upper boundaries of societal effort towards the deployment of renewable energies.

[98] EU-15, the 10 new Member states and Bulgaria and Romania

Despite the differences between the studies, most research agrees that as far as CO_2 emission reductions are concerned, RET deployment may not be the cheapest strategy. The social welfare costs of renewable energy policies are usually very high[99]. There are other measures that could lead to significant emission reductions and possibly at a lower cost. Such options are energy efficiency, emission caps, and carbon taxes. It is important to note, however, that these policy options are not competing, but rather complementary. The relative importance of RES for the reduction of CO_2 emission levels thus varies from country to country.

21.3.3 Conclusion

In conclusion, most renewable energy chains are "cleaner" than conventional ones in terms of pollutants causing acidification, eutrophication, summer smog or enhance the greenhouse effect, as well as in terms of wastes and impact on biodiversity. An exception is biomass, which (depending mainly on the use of fertilizers and pesticides in the agricultural processes) may have higher emissions of ammonia, pollutants with chlorine and sulphur content, NO_x. Most environmental effects, such as ecosystem disturbance, particulate matter emissions, catastrophes, etc. could be avoided. Possible solutions are specific filters and processes, avoidance of areas of high ecological importance, creation of passage ways for fish and other river fauna. Such measures however would lead to increased generating costs of power, heat, and fuels. Thus, a cost-benefit analysis is needed to find a compromising solution for the environment at acceptable prices.

As far as reduction of GHG emissions is concerned, renewable energy sources could become very important. It should be clear, however, that the deployment of renewable energies in the energy sector per se will not necessarily bring about the entire potential of emission savings. It is important to build up an effective strategy that is tailored for the energy potential, needs and capacity of each country and sector and has clearly defined aims in terms of environmental effects.

[99] For various estimation methodologies, see for example Palmer and Burtraw (2005) (including a comparison with EIA studies) or ECN (2005)

21.4 Macroeconomic aspects of RES

Besides their positive impact on environment, RES are supposed to contribute to job creation. In this context, mostly the number of jobs created in the RES industry due to investment in RES and operation of the RES installations is cited as evidence. (ERECa (2004), UBA (2004). Recent studies state that the present investment in RES amounts to more than € 10 billion and that over 200.000 jobs have been created in the renewable energy industry in the EU (EREC a 2004), among them more than 100.000 in Germany. (Mitre (2004), UBA (2004)). This raises hope, that RES industry could be a driving force for economic growth and employment in many countries in the EU.

To gain a realistic estimation of the influence of RES on economic growth and employment, we will deal with this problem in two steps:

- Some general remarks on the methodology, and
- An examination of the macroeconomic effects in detail.

21.4.1 General remarks on growth prospects

Economic growth depends on a number of driving forces. The most important are:

- Development of population including age distribution, availabilities of skills etc.
- Availability of natural resources and their production cost
- Technology and capital
- Age distribution of existing capital stock and the technology embedded in this capital stock
- Ability to produce innovations
- Institutions and regulations. Existing institutions and regulations referring to all parts of economic life have important implications for economic growth and development (e. g. taxation, labour market regulation, distribution and policies etc.)
- Cultural aspects. A lot of soft factors maybe mentioned here like development of social values, education, motivation, achievement orientation etc.

What are the implications of the transition to a more renewable energy economy for economic growth?

1. The share of energy in current GDP is relatively small. The importance of increasing energy efficiency which is clearly one of the most important instruments to reduce greenhouse gas emissions will also reduce this share potentially. It therefore does not seem to be a very meaningful exercise to try to find out the implication of higher or lower share of renewable energy for economic growth in general. A very small change in the exchange rate between the Euro and the Dollar as an example or a very small change in the wage settlements negotiated between employers and trade unions have far more important consequences for economic growth and development.
2. If we want to study the implications of different energy strategies for economic growth and development and employ modelling exercises for this purpose we implicitly have to consider a lot of the driving forces of economic growth to be constant. So even if general equilibrium models [100]are being employed the results are in many aspects "partial". This important restriction is often forgotten when looking at the results of such modelling exercises.
3. Modelling exercises trying to analyse the impact of changes in the energy system on the overall performance of the economy crucially depend on many parameters. The empirical basis for parameters like elasticities is often weak, particularly as they are derived from the past and thus reflect the overall conditions of the economy of the past. Some of the driving forces of economic growth mentioned above can be modelled, others not. This is why such models tend to be "pessimistic" about the results of transitory measures.

We know from many exercises where future projections had been later compared to actual development, that projections were wrong. Therefore there is no absolute truth in such modelling exercises. The truth is always relative to the assumptions

[100] An excellent survey of recent modeling studies can be found in the paper by Herman R.J. Vollebergh: Increasing the Role of Renewables in the EU: Gloomy Prospect or Pitfall

and the assumptions are relative to reality that however, we can only partial incorporate.

From an economist's point of view therefore to judge on general economic effects of the transformation of the energy system we should therefore, rather than looking at quantitative results of modelling exercises concentrate on the general framework of the economy and ask the following questions:

- Is there wide acceptance for renewable energy policies?
- Are the markets open and are there proper incentives to promote efficient changes in the energy system?
- Does the market framework support international division of labour in the production of renewable energy?

To avoid misunderstandings:

- The transformation towards more renewable energies above a certain level is a difficult task. Many renewables are more costly than conventional energy which puts a strain on the economy.
- In the longer term relatively rich societies can use their GDP in any way they want. The important economic question therefore is that there is a sufficient willingness to pay for renewable energy and their quality aspects. This may not be the case due to the public good dilemma connected with the environmental quality aspects of renewables. Therefore policy decisions discussed in chapter 21.5 of this paper are so important.

Another problem arises from relative international competitiveness within the European Union. Strangely enough after the opening the internal European market and the removal of many barriers to international exchange between European countries promotion of renewable energy although being a European target is established by using national policies that differ in many ways between countries. Thus, efficiency gains from international cooperation and using the natural advantages of different locations in Europe with their different conditions for renewable energies are not available. This is certainly an important obstacle to realizing economic gains from an increase of the share of renewable energies. Even if there is a sufficient willingness to pay on the side of the domestic consumers (which can be

doubted), different cost of renewable energy in different countries caused by different schemes of promotion and different natural conditions change the relative competitive situation of all economic factors for which energy is an important cost factor. My conclusion therefore is that to avoid harmful effects from expending the renewable energy sector we need to have a harmonisation within the Union and we have to make sure that we are as efficient as possible in order to avoid economic losses. This however, requires a strong role of markets.

21.4.2 Macroeconomic effects of the deployment of RES

To go somewhat into details: The introduction of renewables causes a typical structural change. New products replace partly old products or at least reduce the increase in old products if demand is rising. Such a structural change produces winners and losers (e.g. if wind energy replaces coal in the electricity industry). To get an idea of the implications of such changes we have to balance the winning and losing sectors. In addition indirect effects have to be considered caused by price and demand effects.

This includes the consideration of creation and losses of workplaces, the investment which is redirected to RES, the influences on external trade by the increase in use of domestic energy resources, etc. Direct influences results from investment in renewable energy technology (RET), services for operation and maintenance. Indirect effects come for example from the redirecting of capital and the substitution in the fossil energy sector.

The results of this approach show, that

- the overall effect of RES on economical growth is of minor importance under current conditions and
- job creation in the RES sector is thwarted by reduction of jobs in other sectors due to displacement of financial resources

Part of the motivation to promote renewable energy is to substitute imported energies by local production and in this way to promote economic activity locally and increase employment. Basically we have to distinguish between economic effects of the investment phase of renewable energies and the economic effects of operating the newly created plants and their impact on the economy and employment. It is also important whether renewable energies produced replace domestic energy

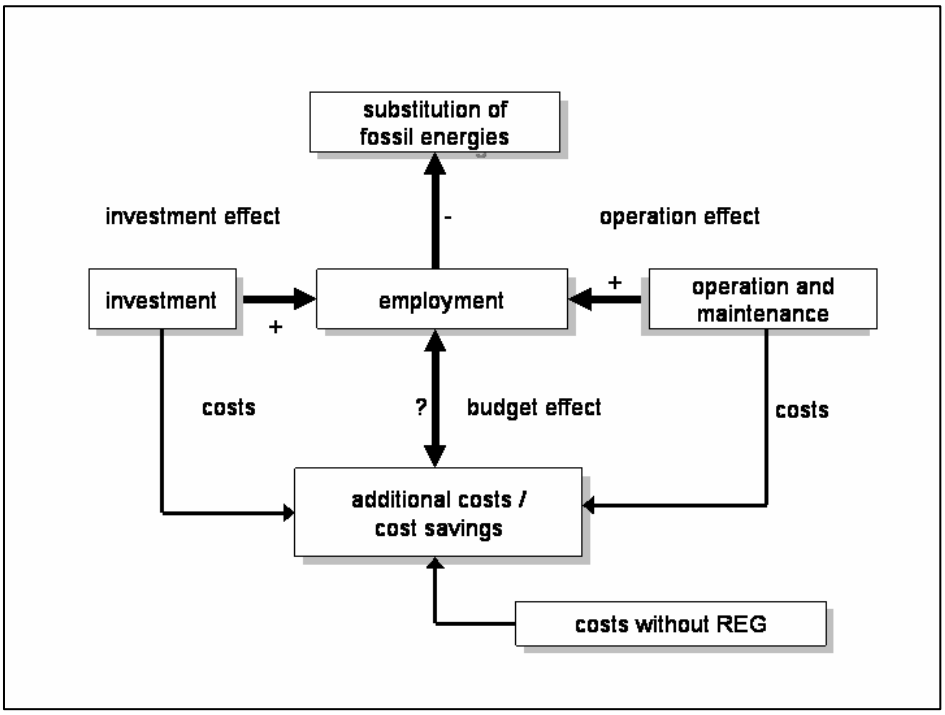
production or imported energies and whether renewable energies produced add to the growth of energy consumption and thereby replace potential domestic or imported energies. **Table 2** shows these four cases that in reality of course cannot be separated as clearly, but are useful to understand the different mechanisms in the influence of economic development and employment.

Table 2. Cases of substitution

Energy consumption	Renewable energy substitutes	
Stable	(1) Domestic energy	(2) Imported energy
Growing	(3) Additional domestic	(4) Additional imported

Figure 7 shows the value effects that have to be considered. It is typical for renewable energies that a relatively high investment is necessary to start production, but afterwards the cost may be relatively small because the energies processed are free in some cases (hydro power, wind, solar).

Figure 7. Employment effects



If we start with the first case (replacement of domestic energy by renewable energy in case of stable energy consumption) we have to balance the replacement effect in the traditional energy sector (like production of coal or natural gas etc.) against the employment effects of the new renewable source that to a large extend exists on the basis of the initial investment. So here we can expect a strong economic effect of the investment in the renewable source and then afterwards a remarkable negative effect because existing energy production is being replaced by a renewable source. If the renewable source is a free good it does not have any economic effects associated with it except that the renewable energy plant needs to be serviced and operated. The only renewable energy remarkably different is biomass where production, collection and transport cause considerable cost and therefore also would add to the employment balance during the phase of operation.

So in short if we substitute domestic energy resources by renewable resources where the resources are free, the overall balance depends on the relation of the investment effect versus the operation and employment effect in the traditional energy system. Replacement of employees in the traditional energy sector is likely and it is very likely that the overall balance will be negative for the renewable source.

The overall balance however, also depends on the relative cost of renewable energy system versus the traditional energy system if consumers have to pay more for the renewable energy than they had to pay for the traditional energy that additional value created by the renewable energy sector corresponds to a replacement of consumer purchasing power that went into other products outside of the energy sector. Then the balance of the energy sector may be positive but at the cost of a negative balance in other industries.

So in the first case (stable demand, domestic energy) a negative effect can be expected because of replacement of other former energies and an additional possible negative effect depending on the relative cost of renewable energies from the so-called budget effect (replacement of purchasing power due to higher price of renewable energy).

In the second case (stable demand, imported energy) the balance may look better because in this case a domestic renewable energy replaces an imported traditional energy. This imported energy creates value and employment in the country of origin but only very low value and employment in the country of destination (due to transport mainly). In this case you would expect a positive balance for the renewable

energy as a source of import substitution but the overall balance again would depend on the relative cost-price-situation of traditional and renewable energy. The argument in this respect is the same like in case one.

In the third case renewable energy does not replace existing energy but replaces potential growth of traditional energy sources. In this case no replacement occurs, the traditional energy sector remains stable and the value and employment balance depends solely on the relative cost-price-situation between renewable energy and potential other energies used for the same purpose. So in this case it is mainly the budget effect that is decisive.

Case four is not different in this respect and the same arguments hold as in case three.

As was mentioned before the four cases are helpful for analytical reasons but in reality we can expect a mixture of these different cases. If renewable energy grows faster than energy demand we will have a combination of cases one/two or cases three/four.

In the longer run additional effects may be important:

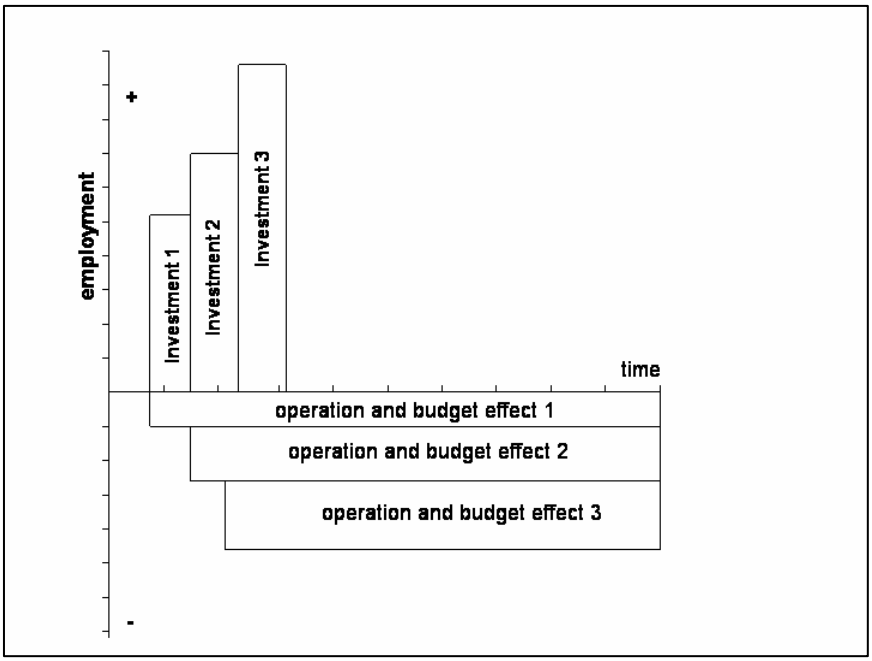
1. Growing export capabilities: an industry that is able to produce investment goods for the renewable energy industry (wind energy converters, photovoltaic cells etc.) can add value by exporting these goods. There may be positive effects on the economy as far as the exported goods contain values created domestically. This is of course, relative to a lot of macroeconomic factors determining the comparative advantage of one country against other countries in the same industry. This comparative advantage may be higher in industries with a high technological specificness than in other areas.
2. The economic benefits from using renewable energies depend on the environmental policy regime. The present scheme of greenhouse gas reduction puts a considerable fine on all prices of energies with carbon content. It puts renewable energies in a relatively better position.
3. In the longer term the effect of a growing renewable energy industry depends on the relative effects of the investment versus the operation and budget effects as it is shown in Figure 8. A layer of investment carried out in a specific year leads to operation and budget effects for a sequence of

years corresponding to the lifetime of this equipment (Investment one and operation and budget effect one in the diagram).

Assuming that the operation and budget effects are negative, which is very likely for many renewable energies, this negative effect can be compensated if additional investment is carried out in the next period etc. However, a problem arises when investment stops. In the time after investment three in the diagram strong negative operation and budget effects will have negative influences in the economy in the time period after the investment boom of renewable energy has come to an end. In other words building up renewable energies can add positive economic effects in the phase of investment but when investment slows down or stops the effects associated with higher price of the energy will be dominant and will have negative impacts.

This can be summarised in a very simple and distinctive conclusion: the more economic renewable energy is from the beginning, the better will be the effect on employment and economic development.

Figure 8. Dynamics of effects



21.4.3 Effects of promotion of RES for selected sectors

As mentioned above, the discussion about RES and job creation is mostly limited to the direct effects – i.e. the creation of jobs within the sectors which benefit from the investment in RES installations and the subsequent operation.

Looking at these sectors, one can distinguish between two kinds of effects of the promotion of RES: those which were already registered during the past and those which are predicted by simulation models.[101] Both will be presented in this paper, whereas the results of simulation are more useful for the valuation of the future effects than the historical data.

21.4.3.1 Recent development of employment in the RES sector

During the last two decades, a remarkable number of jobs were created by the enhanced deployment of RES. Data for selected countries are listed in Table 3. The numbers from different sources show, that renewable energy industry is a note-

Table 3. Gross Employment in RES-related sectors

Source	Region	Sector	No. of Jobs in 1998[1]	No. of Jobs in 2002[1]	Comment
EREC b 2004	EU-15	all RES		200.000 (in 2003)	
EWEA 2004	EU-15	Wind	28.100	72.300	calculation based on EUROSTAT data
ECOTEC	EU-15	all RES	39.000 (in 1995)	145.000 (2005)	data for 2005 from simulations
UBA 2004	Germany	all RES	66.600	118.700	
UBA 2004	Germany	Wind	15.600	53.200	
Staiß 2003	Germany	All RES		58.000	
Pfaffenberger 2003	Germany	all RES		61.000 (in 2003)	Own calculations, based on an inquiry of RES industry associations

[1]: numbers approximated to hundreds

[101] There exists a broad range of simulation models, which are classified and described in detail in Kempfert (2002).

worthy sector with about 200.000 jobs in the EU in 2003 (EREC b 2004), between half and one third of them in Germany.[102] Wind energy contributes approximately one third of those in the EU and 50% in Germany. Regarding these numbers one can state– despite the different figures in the studies -, that RES industry is growing and upcoming industry sector.

For the assessment of the future contribution of RES to economic growth and the increase of employment, the projected contribution of RES industry is of higher significance than the recent status. Therefore, some studies were evaluated regarding the development of employment due to RES (Table 4).[103] Due to the fact, that presently a great part of the jobs in the RES sector in the EU is located in Germany, studies were selected, which refer either to the EU or to Germany. The studies differ in many aspects – time range, the presumed development of deployment of RES, incorporation of different indirect effects.

Although one can state an impressive increase of employment in RES-related sectors, RES are not a job machine in the macroeconomic context when indirect effects as the budget effect are taken into account. With rising prices for fossil fuels due to price increase or the price of CO_2 certificates, the positive impact of RES on employment could increase.

21.4.4 Conclusion

Looking more closely at the results of the studies, one can state that the results depend very much on the underlying assumptions, the time scale and the treatment of substitution and budget effects.

Nonetheless one can conclude that:

- All studies predict increase of the gross employment of RES.
- The lion's share of this increase is attributed to the biomass/agricultural sector. Most of these jobs require only low qualification.(MITRE 2004) [104]

[102] The numbers vary according to different source due to different approaches for the calculation of numbers of jobs, especially for the indirect effects.

[103] The underlying models will not be described in detail; only the main features will be mentioned.

[104] Mitre 2004 In 2010, in the CP-scenario 324 of 450 workers will be unskilled. In the ARS-scenario 610 of 838. In 2020, in the CP-scenario 577 of 813 workers will be unskilled; in the ARS-scenario 1037 of 1439.

- Budget effects are negative in all cases, as currently the production of electricity from renewable sources is much more expensive than from conventional sources and has to be subsidized
- Those studies, which consider budget effects of the increased deployment of RES predict low or even negative net employment effects from RES deployment.
- The low impact of increased deployment of RES on employment is due to the fact that RES technologies are not yet competitive with fossil fuels.
- None of the studies has already taken into account the recent increase of energy prices, which will tend to increase the positive effect of RES on employment.
- The effects of emission trading are not yet included in these studies.

Another observation that could be drawn from a dynamic representation of the macroeconomic effects concerns the accumulation and balancing-out of positive and negative effects. Those studies, which take into account budget and substation effect, show that new capacity boosts demand and employment only in the year(s) when investment is made. The combined effect of operation, maintenance, and financing, in contrast, lasts for the whole technical lifetime of the installation, and it is normally negative. Thus an accumulation of the negative effects can be observed, which balances out the positive investment effect and can even lead to losses.

It is important to note that the budget effect will change if prices of conventional fuels such as coal and natural gas change. The current trend of rising prices for fossil fuels, combined with carbon taxes and other policy instruments may have beneficial effect on the standing of renewable energy.

21.5 Policy instruments and measures

The previous remarks point out, that a significant development of RES in the EU took place during the last decade. Nonetheless, further efforts are necessary to carry forward this development as intended by the EU. Against that background, experts discuss intensively about the appropriate instruments for further promotion of RES.

Table 4. The development of employment due to RES from selected studies

Study	Model(s)	Region	Time range	Investment in RES (billion €)	Net employment effect (1.000 jobs)		Comments
MITRE (2003/2004?)	Safire / RIOT	EU-15	2010 / 2020:	---	2010: CP: ARS: 450 2020: CP: 813 ARS: 1.439		2 scenarios: current policies (CP), Advanced Renewable Strategies (ARS) base line: 2000 Without export and job security effects in agriculture
EREC a 2004	??	EU-15	2010 2020	2010: 140 2020: 443	2010: with Biomass/Biofuel: 2020: with Biomass/Biofuel:	305 1.067 881 2.023	Substation effect included, budget effects not regarded Assumptions for investment are very low
ECOTEC 1999	Safire / RIOT	EU-15	1995 – 2005 1995 – 2020		gross effect: with biomass: gross effect: with biomass:	106 414 346 861	only gross effects, budget and substitution effects not regarded
MITRE (2003/2004?)	Safire / RIOT	Germany	2010 / 2020	---	2010: CP: ARS: 38 2020: CP: 77 ARS: 141	8	2 scenarios: current policies (CP), Advanced Renewable Strategy (ARS) Without export and job security effects in agriculture
Hillebrand et al. 2005	RWI-Model	Germany	2004 - 2010	ca. 12,6	net effect gross effect	-6,10 19,37	Reference scenario: 2003, doubling of RES deployment until 2010, CO_2-permit: 10€/to
Pfaffenberger et. al. 2003	MIS	Germany	2002 - 2022	ca. 100	Net effect gross effect	-4,0 84,5	Constant increase in RES capacity, Basis: 2002, Export effects not included constant energy prices (2002)
Ragnitz 2005	Own model ?	Germany	2001 - 2010		Net effect gross effect	7,3 51,0	
Ziegelmann, 1999	Markal-IKADAT / MARES	Germany	2000 – 2015	---	Scenario I: gross effect: Scenario II: gross effect	36,8 44,5 90,25 113,35	2 scenarios with enforced introduction of RES, Energy saving measures included!

There are various policy instruments which intend to influence the behaviour of actors in the energy market in way that leads to enhanced deployment of RES. In the following we will try to answer the following questions:

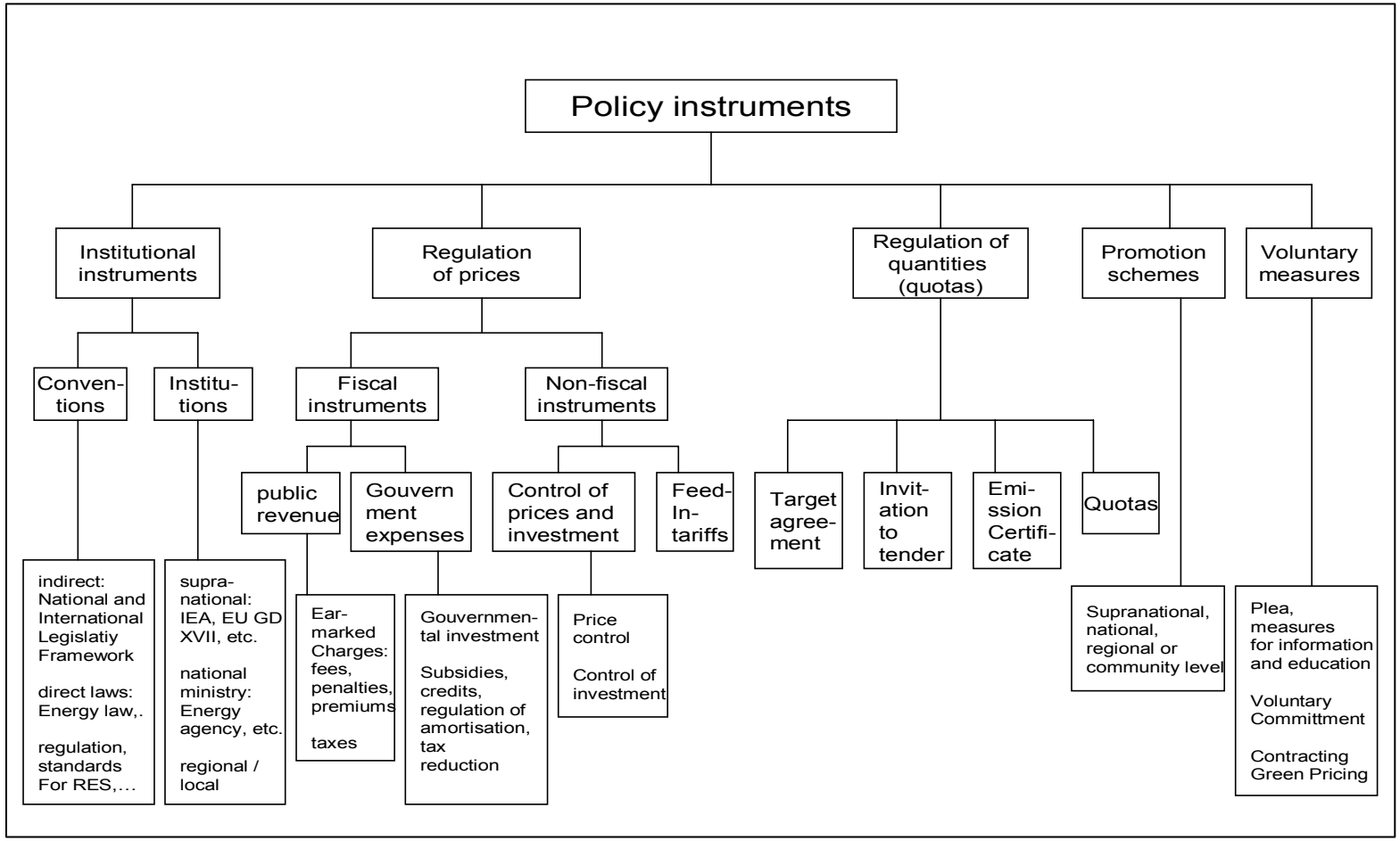
- Which policy instruments are available?
- Which instruments fit to different market sectors (electricity production, heat, transport)?
- Which instruments are appropriate for different RES?
- How can the instrument (measures) be financed / financial resources?

This paper will follow the structure of a study of Espey (2004), where RES Policies of the EU and eight selected countries were evaluated and systematically analyzed. In the first subsection, the policy instruments will be characterised and evaluated according to their suitability for different RES and market sectors. Section 21.5.2 is dedicated to the assessment of the instruments. The instruments are assessed in section 21.5.2.1 with respect to their applicability for different stages of readiness for marketing. In section 21.5.2.2.1, the criteria of success for the assessment of policy instruments are presented and elucidated. Section 21.5.2.3 contains the assessment of the policy instruments for the promotion of RES regarding the criteria mentioned before. The last section 21.5.3 summarizes the recent discussion "Quotas versus feed in tariffs".

21.5.1 Characterisation of policy instruments for RES

Depending on the respective point of view, there exists a large variety of classification schemes for policy instruments for RES. In this context, a top-down-perspective was chosen due to the fact that policy instruments are regarded from a governmental viewpoint. According to that approach, one can distinguish five categories of instruments for the promotion of RES: institutional instruments, regulation of prices, regulation of quantities (quota), promotion schemes and voluntary measures (see Figure 9). In the following, the different instruments will be characterised and their advantages and disadvantages will be presented.

Figure 9. Classification of Policy instruments for the promotion of RES (according to Espey 2001)



21.5.1.1 Institutional instruments

To achieve the aims concerning RES, the state has to establish appropriate institutions. In this context, the term “institutions” includes conventions, i.e. laws, policy programs, framework plan, as well as organisations, like the ministry of energy, national, regional and local administrations and energy agencies, etc..

Conventions define the framework for the actors on the energy markets. This can be a matter of indirect regulation like building laws, which contain for example regulations of energy standard for heating systems, the environmental law that limits the impact of emissions pollutants in the atmosphere or the approval process for new power generation plants. These indirect regulations will not be the subject of this paper. In this paper only direct regulations will be regarded, i.e. regulations which refer explicitly to RES.

Regulations have some serious advantages:

- They are due not cause fiscal expenses for the national budget.
- Sometimes the announcement of regulations is sufficient to achieve the desired reaction of the relevant actor.
- Obligations for the deployment of RES can induce a market development for technologies which would otherwise not take place.
- Laws and regulations are mandatory for all affected actors
- Market conditions are calculable, transparent, and controllable, which leads to higher planning reliability.
- The chances to achieve the desired behaviour of the actors are high if sanctions are imposed.

There exist also some disadvantages:

- Financial resources are necessary for the administration and control of the compliance with the regulations.
- Interest groups will always try to influence the definition process of the regulations as well as the interpretation after their coming into force.

- As the decision process is often time-consuming, there is a risk that the regulations do not consider the recent technical development.
- The regulations are often static and cannot be easily adapted to fast dynamic developments.

Despite the disadvantages, regulations are indispensable for the implementation of more detailed policy instruments and for a general acceptance of the aims concerning RES in the pubic.

Example: Solar building regulations

One regulation that aims directly at the implementation of solar energy systems is the solar bylaw for buildings. First proposed for the city of Berlin, established in 1999 in Barcelona and meanwhile in various Spanish cities, the solar bylaw for buildings makes the installation of solar thermal systems mandatory (mainly) in newly constructed building. Within one year after the entry into force, the total amount of square meters of solar thermal applications quadrupled in Barcelona. Additionally, the houses equipped with solar thermal appliances became relatively more valuable.

21.5.1.2 Regulation of prices

Regulation of prices can be achieved by fiscal and non-fiscal measures. Fiscal measures can either concern the public revenue or the public expenditure.

21.5.1.2.1 Fiscal instruments

Public revenues

The best known fiscal measure in connection with RES is the ecological tax. Here, energy and CO_2-taxes can be distinguished.

CO_2-taxes are chosen when the reduction of CO_2 as most important green house gas is the aim. CO_2-taxes are not incurred for nuclear energy and RES, thus privileging these sectors. However, CO_2-taxes can also induce the substitution of CO_2-rich energy sources like coal by energy sources with lower CO_2-content like gas.

With energy taxes, also other green house gases than CO_2 can be affected. In any case, energy taxes can also support energy saving measures. Energy taxes can refer to primary energy as well as to useful or end energy. Taxation of pri-

mary energy incorporates conversion losses, whereas taxation of secondary or end energy has the advantage that energy imports can be taken into account.

Most energy and CO_2-taxes are defined as surcharges on the price or a fixed amount per unit. The taxation rate must be chosen sufficiently high to achieve the intended control function. The validity period of the taxation must be sufficiently long to ensure a reliable basis for the planning of future investments. On the other hand, the regulations have to comprise a certain flexibility to allow an adaptation to changes in the general economic framework.

The tax income from ecological taxes can be used to raise the income of the state, to finance promotion schemes for RES or to reduce tax loads in other field, for example the non-wage labour costs. Thus it is claimed that ecological taxes have a multiple dividend: reduction of emissions, promotion of RES and rise of public revenues.

Disadvantages of these taxes, which often lead to special regulations, could be:

- Creation of financial problems for people with low income.
- Deterioration of the conditions for public transport leading to an increase in individual transport which is accompanied by an increase in CO_2-emissions.
- In case of a national ecological tax: deterioration of conditions in the international competition for industry sectors with high energy consumption.

Concerning the effect on RES it must be stated, that ecological taxes are of minor importance for RES as long as other possibilities of substitution of energy are more cost-effective.

Public expenditure

Governmental financial support for RES can be delivered in form of public investment or subsidies for RES.

Subsides

Due to the high cost, public investment in RES-projects can only be limited. Public investment is not suitable as an impulse for mass production or cost reduction. It is, however, money well spent for research and demonstration

projects which helps to achieve technical improvement, to display a role model and raise of awareness of RES.

Despite the direct governmental investment, subsidies can be classified in the following categories:

- Promotion schemes
- Grants for investment or operation
- Credits
- Tax or amortisation relieves
- Bonus

One type of subsidies, the promotion schemes, will be presented in more detail in chapter 21.5.1.2.2. In general, subsidies are an important incentive for the deployment of RES. They are indispensable for research, as companies often would not engage in research if they had to bear all the costs on their own.

A second, very important function of subsidies is the support of the rollout of RES. Well designed subsidy programmes can strongly stimulate investment in RES. For the design of a successful programme, the following point should be regarded:

- The sector which receives subsidies is well defined.
- The duration of the program is clearly established and is not too short.
- Stop and go situations must be avoided because they can create serious problems for the RES industry due to high fluctuations in demand.
- The program and the formalities for application are transparent and easy to handle to reduce the barriers.

The appropriate type of subsidies depends on the special situation of the respective target group(s): Often a project that is of economic interest for an investor is not implemented due to a lack of credit rating. This problem can be overcome by the provision of favourable state loans. On the other hand credits are of no use, if the investor expects an encouraging signal from an official institution. In that case, grants for investment should be chosen.

Despite the fact, that subsidies are a useful instrument to support market introduction (rollout), they also have considerable problems:

- Information and transaction costs are high, both for the state and for the beneficiary.
- Long lasting subvention programs are hardly to abolish, therefore the duration of the programme should be well defined from the beginning on.
- Windfall gains cannot be excluded.
- The contribution of subsidies to the development of RES can hardly be quantified.

Nevertheless, subsidies remain an indispensable instrument for market introduction.

21.5.1.2.2 Promotion schemes

Promotion schemes are one kind of subsidies. They are applied for the promotion of selected RES. Promotion schemes can be designed for different phases of the development of a RES technology – research and development activities as well as demonstration and pilot projects or the rollout of RES products. They can aim at different target groups from research institutes to producers and end-consumers of RES technology.

Two characteristics that distinguish promotion schemes from quotas or feed-in tariffs are the limited duration and a maximum limit of the budget. Promotion schemes can be either grants for investment or operation, credits at a reduced rate, tax or amortisation relieves or bonus. The specific design depends always on the specific RES and the target groups.

Often promotion schemes are accompanied by an evaluation to identify the result of the programme, the barriers that exist for the application of the RES as well as for a proper performance of the program and the resulting amelioration potential.

Problems that arise often with promotion schemes are:

- The provision of money from the public budget depends strongly on political decisions.
- The effects that can be achieved are restricted due to limited budget and duration.

- There often arise bottle-neck situations when the budget is too small to accomplish a high number of applications.
- In many programs the application and approval procedures are intransparent and time consuming.
- There often exist different promotion schemes on different levels (national, regional, local), and it is difficult to find the corresponding information and to identify the optimum combination of promotion instruments.

Despite all the problems mentioned above, promotion schemes are an important instrument for all RES which are still far from marketability.

21.5.1.2.3 Non-fiscal instruments

With this type of measure, the government can influence the prices of RES without touching national budgets. The costs are shifted to the producers or the consumers of the respective energy. Non-fiscal instruments can be classified into two types: control of price (or investment) and feed-in tariffs.

Control of investment

In this context, the keywords are least-cost-planning (LCP) and integrated resource planning (ICP). These mechanisms oblige the utilities to verify whether investment in RES (or reduction of consumption) is possible (or even favourable) when they intend to substitute or extend their existing production capacities. This type instrument provides a certain support for energy saving techniques, but is not appropriate for RES which are often not competitive with fossil fuels.

Feed-in tariffs

The state obliges the network operators to feed electricity from RES into the network and to pay a fixed price for it. Normally, the conditions for the feed-in and the feed-in-tariffs are specified by law. The price can be either determined by avoided costs of substituted electricity from fossil fuels or a fixed amount that depends on the respective kind of RES. The latter gives the possibility to stimulate investments in technologies which are not yet competitive with fossil energy sources, for example photovoltaics.

Feed-in tariffs with a long- or medium-term scale provide

- Provide a high planning reliability for investors and
- Support strongly the market introduction,
- Induce price reductions due to mass production.

Therefore, feed-in tariffs are an important non-fiscal instrument to support market introduction.

Nevertheless, feed-in tariffs retrieve some problems:

- They are feasible only for network-fed energies like electricity.
- Windfall gains can not be excluded.
- The burden charging for the network operators and their clients can be asymmetric due to regional differences in the deployment of RES. Thus, feed-in tariffs can turn out to be a competitive disadvantage.
- Long-term feed-in tariffs can inhibit innovation processes. Therefore, tariffs should decrease gradually with time.

The discussion about advantages and disadvantages of feed-in tariffs will be deepened in chapter where feed-in tariffs, quotas and emission certificates are discussed in detail.

21.5.1.3 Regulation of quantities

These instruments aim at the energy quantities, delivered from different energy sources, and not at the prices. The definition of quantities can either refer to produced energy quantities, production capacity or emission quantities.

In the following, four different instruments are presented: target agreement, invitation to tender, emission certificates and quotas.

Quantitative target agreements

Targets for the deployment of RES are fixed on a medium-term or long-term scale. They can refer to a certain percentage of energy supply (gross or net) from RES or to the production capacity. A target on its own is not an instrument for the promotion of RES. But it can give strong signals in context with future investment. Target agreements must be support by other efficient instruments like subsidies or tax reduction or they should be combined with penalties.

Invitation to tender

For this instrument, a fund is established for investment in new production capacities based on RES. Potential investors are identified by an invitation of tender. The price is the dominant selection criterion. Either all tenderers who submit offers below a price fixed in advance are chosen, or those with the most favourable terms receive an acceptance of bid until the maximum limit of the stock budget or the intended amount of production capacity is reached. Concerning the payment of the produced energy, the tender price or an average price can be fixed. The network operators are obliged to feed in the electricity from the selected projects and pay an average tariff comparable to the reimbursement for electricity from fossil fuels. Thus, the price of the renewable energy has two components, the reimbursement from the network operator plus the premium form the fund.

The concept intends to create a market for electricity from RES with predictable quantities at a certain price or range of prices. The main objectives of the concept are to generate competition between the producers of electricity from RES during the tender procedure and to keep the prices of electricity from RES as low a possible.

Characteristic features of this concept are:

- Competition takes place amongst the producers of electricity from RES
- The risk of the cost recovery remains with the investor.
- Reduction of costs after the acceptance of the offer leads to higher earnings for the producer. This mechanism can favour technical innovation.
- A mix of electricity from different RES can be achieved by fixing certain target figures for different RES.
- The difference between actual cost of electricity from RES and from fossil fuels is covered by the fund. From the feed-in of electricity from RES there do not arise additional cost for the network operators.
- The instrument can be easily adapted to changed framework conditions.

- Financing of the fund can be organized without impact on the national budget, for example by a surcharge on the electricity prices for consumers.

Despite a number of advantages, the invitation to tender exhibits also some problems:

- There doesn´t exist a guarantee that the production capacities will be really built.
- A reliable planning basis is given only for those investors, who have gained a contract.
- Larger companies, who have a good access to planning and financing capacities, are clearly privileged in the tender process because they can overcome long planning and decision periods.
- There are no stimuli to build RES capacities additionally to those which are constructed due to the tender process as long as electricity from RES is more expensive than from fossil fuels.
- There doesn´t necessarily exist a long-term perspective, because the tender conditions can change in short terms, for example every year. This can turn out to be a barrier for innovations and for a continuous planning for the manufacturers of RES energy systems.
- The expenses for the organisation of the tender process are high, for the administration as well as for the tenders.

Emission certificates

The objective of this concept is to limit and reduce the greenhouse gas emissions. For that purpose, a cap for emissions is fixed by law. In the beginning, the total start emission volume is allocated in the different economic sector in form of emission certificates. Companies have the possibility to sell or buy emission certificates. Depending on the price of the certificates, this instrument can stimulate energy saving and RES technologies. Due to the fact that most of the energy saving measures and substitution of CO_2-rich fuels are still more cost-efficient than RES, RES will benefit only little from this concept (Reinaud, 2003). This situation can improve, when the prices of emission certificates rise

make investment in RES economically more interesting than purchase of emission certificates.

The advantages of the concept of emission certificates are the following:

- Emission trading complies with free-market economy mechanisms.
- There arise no (or only little) cost which must be covered by the national budget.
- Market mechanisms result in cost-efficient solutions for the reduction of greenhouse gases.

Concerning the RES, there are some critical disadvantages:

- Emission trade is an instrument that supports only those RES which are already nearly competitive with energy saving technologies.
- As the prices of the emission certificates are subject to fluctuations and as the trend is unknown, they do not permit a reliable planning basis for long-term decisions on investment in RES capacities.

Quotas

Regulation of quantities by quotas requires a state controlled specification and fixation of a minimum level for RES production capacities or fraction respectively absolute amount of electricity from RES. When the quota system is coupled with trade of certificates of RES capacities, respectively RES electricity, this will provide a market instrument to create competition and to achieve cost efficient solutions. The costs for the additional RES capacities will be transferred to the consumers.

The certificate has a double function: First, It provides a verification of the fulfilment of the quota which is required. Second it can be traded on a market for RES certificates. The second function permits the owners of certificates to gain additional income by trade of certificates.

Quotas can be fixed for all kinds of RES, not only for grid-connected ones. Thus not electricity from RES but also heating energy can be included in the concept of quotas.

The proper design of a quota system requires a proper conceptual design. Important aspects are.

- In the beginning quotas must be fixed which regard the already existing RES capacities, and the available RES technologies.
- The initial quotas should be sufficiently high that an extension of RES capacities is necessary. But they should induce a moderate increase to limit the costs of these additionally capacities and – consequently – the prices of the certificates.
- The RES which shall be applied for the fulfilling of the quotas must be defined.
- The development should be outlined on a long-term scale to deliver a reliable basis for investment.
- It is necessary to define who has to fulfil the quotas – consumers, those who sell energy to the end-consumers, the producers, etc. pp.. To limit the expenses of certification, one tends to limit the numbers of actor. On the other hand, cartelisation should be avoided, to guarantee the proper function of market mechanisms. This mostly leads to the selection of the vendors as the one in charge for the compliance with the quotas.
- The time within which the quotas have to be fulfilled must be adequate to enable the investors to perform a proper planning and construction.
- Penalties must be defined in case the quotas are not accomplished in time.
- A certification system for RES capacities / Energy from RES must be installed.
- A trading system for RES certificates has to be established.

The effects of a quota system depend strongly on the design of this instrument. In principle quotas show the following advantages:

- It complies with free-market economy mechanisms.
- Market mechanisms result in cost-efficient solutions for the construction of RES energy production capacities.
- The influence of the state is limited. State is only involved in the definition of the quota system, the installation of the certification and the re-

spective trading system, the supervision of the compliance with the quotas and the imposition of penalties.

- When the system is once established, there arise no (or only little) cost which must be covered by the national budget.
- Thus it is an instrument that can be applied until RES has achieved competitiveness with fossil fuels. It is an instrument that can induce a broad effect.
- The involvement of energy utilities has the advantage, that their financial resources and planning capacities can be activated. Thus RES are not longer restricted to a niche market, but can be broadly integrated in the energy market.
- For those who must fulfil the quotas, there exist different options to act: investment in RES, buying certificates or paying the penalties.
- The influence on competition processes is little, because the conditions are predictable and the same for all market participants.
- Quotas are an instrument that can be easily transferred on an international level.

Despite the positive aspects of quotas as an instrument for the implementation of RES, there do exist some disadvantages, which are often claimed:

- Quotas can act as a cap, if they are not designed dynamically.
- It does not deliver a sufficiently reliable basis for decision on investments.

The first problem can be dealt with by a quota that is chosen sufficiently high on a long-term scale and which is divided into sub-quotas that have to be reached after well defined periods.

The second critical point can be avoided, when the quota system is accompanied by subsidies for those RES which are far from competitiveness.

21.5.1.4 Voluntary measures

There exist several instruments to support voluntary efforts of end-consumers and industry for the application of RES: information and education. All theses instruments are “soft” instruments because they do not necessarily have the

strength to change the behaviour of the target groups: Voluntary measures are not connected with legal regulations, penalties or financial support. They try to influence behaviour by information, education, appeal, voluntary obligations or recommendation of RES-products like green electricity. All these measures do not interfere with market mechanisms, i.e. they comply with market economy.

The following instruments which belong to this type of measures will be regarded more closely: offering of information and education, voluntary obligations and green electricity.

Information and education

Often the deployment of RES technology fails due to a lack of correct information on the possibilities, the prerequisites, the costs and the limitation of these technologies. Information and education programs tend to transfer the specific knowledge and to increase the awareness of end-consumers as well as of experts like planners, craftsmen and architects. For the information, all modern communication marketing methods are applied, for example emissions in radio, tv, the press and the internet, publications like handbooks, flyers and leaflets and event marketing. Conferences and training courses are often chosen for further training of experts. In the field of information and education, non-governmental actors are of high importance because they are supposed to deliver neutral information free from individual economical interest.

Depending on the chosen tool, information and education measures can be connected with high expenses. Unfortunately, their efficiency is hardly to verify. Nonetheless, they are indispensable for the stimulation of the interest of target groups of several other instruments, for example promotion schemes.

Labelling

One kind of information source that has proven its suitability in context with white goods is labelling. Labelling can refer to energetic quality of buildings as well as on solar thermal systems, photovoltaic systems or green electricity. Recently labelling in Germany has been extended to low-energy buildings, solar thermal and photovoltaic systems.

This instruments aims at two aspects: It signalises the energy efficiency of the product and it indicates its environmental benefit. In this way it can act a decision criterion for people with high environmental awareness.

That fact, that the efficiency of the measure can not be determined, applies also for labelling. On the other hand, it is an instrument that can be organised without state interference, it needs no financing by the national budget, it complies with competition and it can act as a marketing instrument for producers.

Voluntary obligations

Voluntary obligations are mostly contracts between national or regional governments with industry which gain at the achievement of a RES-related objective or the compliance with emission limits. Normally, the measures which are taken to reach the aim, can be chosen freely by the industry partner.

The conclusion of voluntary obligation is undertaken with the hope that official regulations with high administration expenses and high financing cost can be avoided and that cost effective solutions for the achievement of the aim can be realised easier.

Unfortunately, the experiences with voluntary obligations are so far not encouraging. They often didn´t deliver the results desired, but delayed the implementation of the intended measures.

Green electricity

In the course of the liberalisation of the electricity market in Germany, many new suppliers appeared with offered of green electricity. Meanwhile, there are only a few actors left who operate on a national level. Most of the green electricity products are offered by local power suppliers and are limited regionally or locally. In the mature of the cases, they include electricity from RES that are already nearly competitive with electricity from fossil fuels.

Due to the fact, that electricity from RES is strongly supported by the feed-in law in Germany, and because of the comparably high prices, green electricity products do not play a significant role.

In general one can state that green electricity is appropriate to skim the willingness to pay higher prices for energy from RES, but it is not an instrument for a broad market penetration of RES.

21.5.2 Assessment of instruments

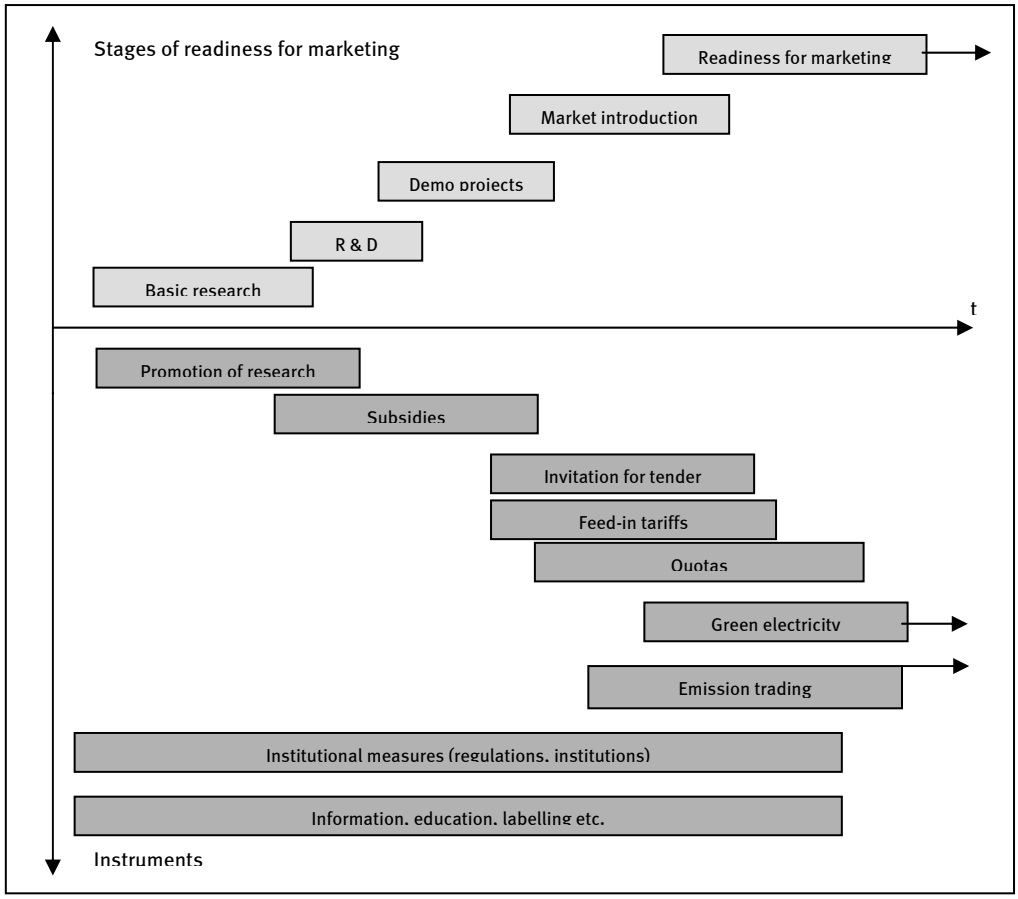
There a two approaches for the assessment of instruments for the promotion of energy from RES:

- The appropriateness of the instruments for different stages of readiness for marketing and
- The valuation of the instruments concerning criteria of success, i.e. the achievement of objectives (effectiveness), the efficiency of the deployment of financial resources and the social, regional and economic equity.

21.5.2.1 Instrument for different stages of readiness for marketing

In the following, the instruments presented in the chapter above will be valuated regarding the aspect of readiness for marketing. For this purpose, Figure 10 gives a survey of the different instruments. The upper part of the diagram displays the different phases of RES technologies, the lower part the corresponding promotion instruments.

Figure 10. Instruments for the promotion of RES and readiness for marketing (according to Espey (2001))



21.5.2.2 Evaluation according to criteria of success

An instrument for the promotion of RES can be called successful, if

- The intended objectives are achieved with
- A minimum of financial and administrative expenses and – simultaneously-
- It achieves high acceptance of the instrument by different interest groups in the country but also on an international level.

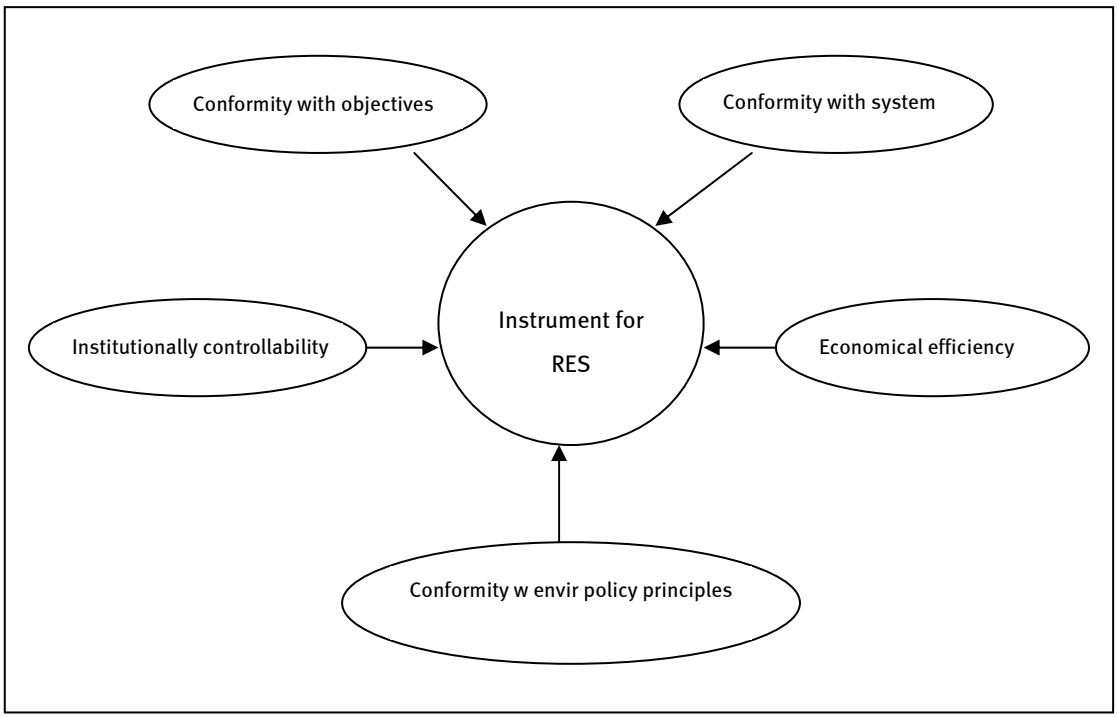
Or in other words:

The instrument must be **effective** concerning the objectives, **efficient** regarding the expenses and in compliance with **equity**, i.e. with social an economical requirements on a national and international level.

According to Espey (2001), this results in five domains of requirements, which are illustrated in Figure 11:

- conformity with objectives
- conformity with environmental policy principles
- conformity with the system
- institutional controllability
- economic efficiency

Figure 11. Requirements for RES instruments (according to Espey (2001)



It is obvious that not all the requirements can be fulfilled completely: An instrument that is accepted by all interest groups – national and international – does not exist. And if everybody would be content with a measure, it is for sure that the expenses would be excessively.

So, the purpose of this valuation will be to find out the most appropriate instruments for different tasks. The first step is the careful consideration of the criteria of success.

21.5.2.2.1 Criteria of success

The criteria mentioned above shall be regarded more closely in the following.

Conformity with objectives

The most important criterion is the conformity with the objectives. If an instrument is not adapted to reach the intended objectives it will fail, even if it fulfils the other criteria. Possible objective could be an absolute or relative increase in energy production from RES, a reduction in prices for energy from RES or acceleration of the implementation of RES.

As already indicated in chapter 21.5.2.1, the various instrument are designed for different market situations. Furthermore, not all instruments are appropriate for all the different kinds of energy: Electricity, heat and transport require specific measures. One also has to differentiate between the dimensions of the RES technology: Solar thermal systems for individual houses can be promoted by other instruments than wind power plants. And last but not least, the instruments, respectively the mix of instruments will vary with the overall strategy. If a broad mix of RES is to be achieved one has to select other set of instruments than for a strategy that focuses only on one RES.

Conformity with environmental policy principles

The superior objective of RES promotion is a sustainable energy supply. Therefore, the four principles of environmental policy should be considered when selecting instruments. These principles are:

Polluter pays principle:	Those who are responsible for the pollution have to bear the cost of the disposal of the pollution

Principle of cooperation:	Measures should be taken in reconciliation with the relevant actors to achieve a high acceptance
Principle of main focus:	Measures should be taken in the field where large improvements can be achieved with limited expenses and not in sector where small effects are gained with much effort.
Precautionary principle:	governmental decisions and measures must be taken in such a way that negative impact on environment is avoided, but a development towards a sustainable development is induced.

Conformity with the system

The instruments should take care of the general framework: competition, national and international legislation and liberalisation of the market. In any case they should have no or little influence on competition on the market and the influence should be restricted in time. This means that the instruments should comply with the free market thus leaving the freedom of action to the actors on the market to ensure efficient competition and unrestricted formation of prices.

Additionally further economic and social objectives as the prevention of windfall gains and a uniform distribution of the costs of deployment of RES (regionally and socially), should be regarded in the conceptual design of policy instruments for RES. Last but not least, the impacts of changes of the political conditions on the instruments, as for example the election of a new government, should be minor.

Economic efficiency

The cost of a measure should be as small as possible compared to the benefit obtained, thus ensuring an efficient allocation of financial resources. A measure should be designed in such a way that it encourages innovation dynamics and provides at the same time a reliable basis for planning. This means, that for example subsidy programmes should have a sufficiently long duration and that they should include a sunset clause reflecting the limitation of the programme as well as a decrease of the height of subsidies.

A crucial point is the guarantee of the financing of the chosen instruments of the complete duration. This includes that the instrument should be affected by the usual economical fluctuations as little as possible. This means for example that problems with the national budget should not result in an abrupt termination of a measure.

Institutional controllability

One aspect of institutional controllability is the political decision process for the introduction of RES instruments. High transparency of the instrument and an early involvement of relevant interest groups in the decision process facilitate the achievement of a consensus and later on the enforceability of the instrument.

To ensure a smooth implementation of the instrument, the administrative procedures should be as simple as possible and the rights and obligations of the involved persons or institutions should be well defined. All institutions which are responsible for the implementation and administration of the instrument must be equipped with the appropriate competences

The concept of the instrument should have a compulsory character and should include penalties which are sufficiently high to favour the implementation of RES to the omission of the intended measure.

21.5.2.3 Evaluation of RES instruments

The instruments regarded in chapter 8.5.2.1 will be valuated on the basis of the criteria described in the previous chapter. This assessment can only be quantitative whereas

- The conditions in different countries vary substantially,
- The explicit design of an instrument influences its quality with regard to effectiveness, efficiency and equity,
- General conditions may change and modify the assessment.

Regarding the requirements of effectiveness, efficiency and equity, those instruments were pre-selected for further analysis, that have - according to the characterisation in chapter 21.5.1 - the potential to promote RES significantly:

- Regulations – in particular solar bylaws
- Subventions (promotion schemes)

- Feed-in tariffs
- Taxes
- Invitation for tender
- Emission certificates, and
- Quotas

The following instruments were not regarded in detail:

- control of investment - main impact on energy saving, little influence on RES,
- target agreement - due to poor results in the past,
- voluntary measures - important as accompanying instrument, but measurement of effectiveness and results difficult

The assessment of the measures includes also the aspect of the suitability of the instruments for different applications, i.e. electricity, heat and transport.

Table 5 (p. 476) displays a summary of the assessment. The scale of rating was:

Rating	Correspondence with criterion
O	no effect / impact
S	Small effect / impact
M	Medium scale effect / impact
L	Large effect / impact

The results shown in table 5 (below) correspond well with the main findings of the EU funded study GREEN-X from Ceijne et al. (2004), where a range of policy instruments and their combinations were assessed applying an elaborated dynamic model. In the following, the main results for the different models will be elucidated in detail.

Subsidies

Subsidies in form of promotion programmes are an instrument mainly applied during the pre-market stage for research and development and demonstration projects and in the early phase of market introduction. They can be tailored corresponding to the intended aims thus ensuring an achievement of objectives, if the instrument is accepted by the target groups as predicted. During the early phase of market introduction, the financial aides help to diminish the cost difference between energy from RES and fossil fuels. Promotion programmes

Table 5. Valuation of the instruments for RES regarding the criteria of success (according to Espey, 2001)

Instrument Criteron	Subsidies	Regulation	Feed-in tariff	Invitation for tender	Quota with certificates	Tax	Emission certificate
Applicability for stages of marketing	R & D, demo projects, introduction	Introduction, readiness	Introduction, readiness	Introduction, readiness	Introduction, readiness	Readi-ness	Readiness
conformity with objectives							
Increase of RES energy production	S – M	L	L [1]	L [1]	L [1]	S	S
reduction in RES prices	M	S	S	M	M - L	O - S	S
Reduction of CO_2	S – M	S – M	S – M	S – M	S – M	L	L
acceleration of the implementation of RES	L	M	L	M	M - L	O - S	O - S
conformity with environment policy principles							
Polluter pays principle	O	S – M	S – M	S - M	L	L	L
Principle of cooperation	L	S	S	M	L	L	L
Principle of main focus	S – M	S – M	S - M	L	L	L	L
Precautionary principle	L	L	L	S	L	L	L
conformity with system							
Intensity of impact on markets	O - S	L	L	S	L	S	S
Reduction of freedom of action	O	L	L	O – S	O	O	O
Promotion of competition	O – S	O	O	M - L	L	L	L
Market integration	S – M	S – M	S – M	L	L	L	L
Negative side effects	O – S	O	O – S	O – S	O	O	S – O
Stability versus political changing	M	M	M	M	L	L	L
Durability	M	M	M	M	L	L	L
Institutional controllability							
Enforceability	L	M	M	M	M	M	M
Administrative expenses	M	S	M	L	M	S	M
economical efficiency							
Cost-efficiency ratio	M	M	M	L	L	L	L
Promotion of innovation	M - L	M	M	M	L	S – M	S - M

[1] if the tariff / quota / budget is sufficiently high

mostly provoke a fast reaction of those members of the target groups who show interest in this instrument. This instrument leaves a high freedom of action to the target groups, which results also in a high institutional controllability.

The duration is normally limited and they are mostly financed by the national budget. Therefore they accord to the precautionary principle, but depend – for the same reason - on the political framework. The administration expenses are limited, because normally the institutions which are responsible for the implementation have much experience with promotion schemes.

The economic efficiency as well as the effects on CO_2-reduction and the achieved increase of the deployment of RES is difficult to predict, due to the voluntariness of the use of promotion programmes. Promotion programmes often support research and development, thus inducing innovation.

Regulations

Regulations can be applied during the phase of market introduction of RES-technologies or to products which are ready for marketing. They can be tailored corresponding to the intended aims thus ensuring an achievement of objectives. In contrast to subsidies, the obligor has little freedom of action.

The effect of regulations on the reduction of CO_2, the increase of the energy production from RES and the degree of acceleration of the implementation of RES depend on the specific configuration of this instrument. One example of a successful regulation is the solar bylaw hat was introduced in Barcelona for the first time. Within the first three years it resulted in an increase of the number of installed solar thermal systems by a factor of four. The administrative expenses of regulations are low and – after the implementation of the regulation – they were restricted to the control of compliance.

Regulations can support cost-efficiency and can induce price reductions for RES

Feed-in tariffs

Feed-in tariffs are an effective instrument for the increase of network-related electricity production from RES. They have been established in many countries and have proven to be a success in Denmark, Germany and Spain inducing remarkable increases in electricity from wind power.

Nonetheless, their ability to acceleration the implementation of RES and increase energy production from RES depends on the detailed design, for example the height of tariff and the continuity of the instrument. The influence of feed-in tariffs on CO_2-reduction and as a consequence – on the compliance with the precautionary principle - depends on the type of production capacity which is substituted by wind energy.

In most cases, the polluter pays principle is considered only partially, because the financing costs of this instrument are allocated only on (?) the standard consumers. Also cooperation takes place only during the design of feed-in tariffs. Once feed-in tariffs are established, the parties who have to finance this instrument are no longer free to choose cooperation or refusal.

Concerning the conformity with market mechanisms, one has to state that feed-in tariffs do not induce competition, that they permit windfall gains and can comprise negative side effects like financial disadvantages for regions with high rates of RES electricity if compensation mechanisms are not provided.

From the viewpoint of the state, feed-in tariffs exhibit high economic efficiency because the expenses for the implementation of this instrument are low. Ragwitz, Held (2005). Regarding national economy, this instrument is not necessarily efficient because it does not favour the cost efficient solutions.

The enforceability of feed-in tariffs has degraded during the last years due to the transition from monopolistic markets to liberalised electricity markets which was accompanied by an increase of resistance to feed-in tariffs by the power utilities.

Invitation for tender

The effect of this instrument on the acceleration of the implementation of RES and the increase of energy production from RES depends strongly on the available budget and the kind of financial support. If the allocation of the fund is carried out regarding the resulting price of RES energy, this instrument is suited to create competition and to induce price reductions. One disadvantage of invitations is the fact, that it is not guaranteed that the selected projects are implemented.

As in the case of feed-in tariffs, the influence on CO_2-reduction and the compliance with the precautionary principle depend on the type of production capacity which is substituted by the RES. Due to the fact that invitations for tenders aim at techniques which have achieved readiness for marketing, this instrument complies with the principle of main focus. The polluter pays principle is only applied when financing by energy taxes or surcharges on the electricity price are chosen. As the participation in invitations is voluntary, the cooperation principle is valid and the energy producers have full freedom of action.

The efficiency of invitations for tenders depends strongly on the volume of the available budget. This instrument is capable to induce high extension rates if an appropriate financing is guaranteed. But it does not necessarily ensure a continuous growth. (Ragwitz, Held, 2005) Therefore, this instrument can only be durable if the budget is guaranteed over a long period. Thus, it depends strongly on political conditions.

Invitations create a niche market and the transfer to a free market situation is not assured. The administrative expenses for the handling if tendering processes are comparably high and wind fall gains can not be excluded.

Quota with certificates

A model including quotas and trade of certificates can be designed specifically to achieve increase of RES energy production. The height and the rise of the quota determine the development of the RES. Additionally, the development of the price of the certificates has an influence on the promotion of RES.

As already marked out for feed-in tariffs and invitation for tenders, the influence on CO_2-reduction and the compliance with the precautionary principle depend on the type of production capacity which is substituted by the RES.

The instrument complies with all the environmental principles quoted above and gives a high degree of freedom of action to the market partners. Quotas also comply with market mechanisms and show conformity with other system aspects: They support competition, help to reduce the prices of RES and comprise little or no risk of wind fall gains.

Consequently, the cost efficiency of quotas is high as well as their promotion of innovations. On the other hand, the expenses of the installation of a quota system with certificates and the control of compliance are not negligible. In chapter 21.5.3, the quotas and feed-in tariffs will be compared in detail.

Taxes

CO_2-taxes, eventually also energy taxes increase the prices of energy from fossil fuels. These taxes support substitution potentials and offer an effective tool for the reduction of CO_2-emissions. (Palmer, Burtraw 2005) CO_2- and energy taxes comply with market mechanisms and leave a high degree of freedom of action to the market partners. These taxes can be easily integrated in the tax system and the administration expenses are low. The effect of taxes on the increase and the acceleration of the implementation of RES is judged to be of minor importance. Taxes can be an additional stimulus – together with other instruments – for the implementation of RES.

21.5.3 Quotas versus feed-in tariffs

During the last decade, two of the above presented instruments emerged to be the favourable ones for the promotion of RES electricity:

- Feed-in tariffs - in 8 countries of the EU-15 and Cyprus, Czech Republic, Estonia, Hungary, Latvia and Lithuania and
- Quota with certificate - in 6 countries; Experts

Currently discuss the advantages and disadvantages of these two instruments very intensively. One group of experts outlines the progress in RES deployment induced by feed-in tariffs in Germany, Denmark and Spain, while the other party focuses on the for higher degree of compliance of the quotas with market mechanisms, which is advantageous for a broader market implementation of RES.

In a recent publication (Häder, 2005) the results of several studies are analysed and evaluated regarding the criteria effectiveness, efficiency and compliance

Table 6: Main instruments for the promotion of electricity from RES

Country	Feed-in tariffs	Quota with certificate	Taxes	Invitation for tender
Austria	●			
Belgium		●		
Cyprus	●			
Czech republic	●			
Denmark		●		
Estonia	●			
Finland			●	
France	●			
Germany	●			
Greece	●			
Hungary	●			
Ireland				●
Italy		●		
Latvia	●			
Lithuania	●			
Luxembourg	●			
Netherlands	●			
Poland		●		
Portugal	●			
Sweden		●		
Spain	●			
UK		●		

with the EU market (Häder, 2005).[105]

Häder points out, that the direct comparison of results of both instruments is difficult due to the fact that there exists a lot of experience with feed-in tariffs, whereas quotas are a relatively "young" instrument for the promotion or RES. He analyses the evaluation of feed-in schemes and quotas and argues from economical theory for promotion schemes.

The main conclusions are as follows:

- Feed-in tariffs and quotas are two instruments with high effectiveness for RES promotion.
- Feed-in tariffs are a reliable and attractive promotion scheme for investments in RES electricity capacities lowering the risk of investments and providing long-term stability, if an appropriate feed-in tariff is chosen.
- Uncomplicated and fast approval procedures, appropriate network structures and well adapted regulations for the network access are basic requirements for the successful implementation of both instruments.
- Feed-in tariffs support the development of technology and the creation of new RES industry sectors in an early market phase.
- Feed-in tariffs do not sufficiently encourage innovations and the exploitation of cost reduction potentials. Thus, they are not very efficient instruments.
- Feed-in tariffs do not promote the integration of RES in the electricity market.
- With increasing expansion and rising readiness for marketing of RES, feed-in tariffs have structural disadvantages with respect to competition, market integration and innovation.
- Quota mechanisms contain price, volume and balancing risks for the renewable energy generation. Therefore quotas are a mechanism that favours large, integrated companies which can overcome these risks. This is not possible for small companies. (Mitchell et. al. (2006))

[105] The last criterion is not absolutely identical with the above mentioned "Equity" but is related to the aspect "conformity with the system.

- Existing quota systems result in higher prices of RES electricity due to the higher risks compared to feed-in tariffs. (Mitchell et. al. (2006))
- Quotas support the development versus competitiveness of RES on the market activating cost reduction potentials and innovations.
- Quotas promote the integration of RES in the electricity market.
- Quota systems can be easily transferred to the EU-level without the creation of complex systems for the equitable cost distribution.

These results match well with the valuation of the instruments for RES summarised in Table 4-1 and the results of Sawin, Flavin (2004).

An evaluation of Ragwitz and Held regards the aspects effectiveness and efficiency of feed-in tariffs, quotas and invitation of tender. (Ragwitz, Held 2005) They emphasize that the analysis of instruments applied in the EU for renewable electricity shows that at present, feed-in tariffs are more efficient than quota systems. But for both instruments a framework with long-term stability that allows sufficient time for project planning, realisation and operation under reliable conditions is an inevitable basis for investments in RES. (OPTRES, 2005)

Additionally to the aspects mentioned above, one argument against feed-in tariffs is that they do not encourage innovation. This problem could be overcome by regular adjustment of the tariffs to the technical development. For this purpose, experts would be required who can determine the appropriate height of tariffs.

On the other hand, quotas are said to have the disadvantage, that technologies which are far from readiness for marketing will no longer be developed. (Ragwitz, Held 2005) To ensure the desired mix of technologies, a general quota can be divided in sub-quotas for different technologies. This would correspond to existing regulations for feed-in tariffs which vary for different RES technologies.

Although the feed-in tariffs resulted in high rate of growth of RES electricity, it is not necessarily a success. In fact, the individual design of the promotion instrument is an important factor for success– in connection with the above mentioned conditions, a coherent mix of different instruments and a conclusive political conception. Only when the relevant investors, i.e. the industry, are convinced that the conditions for investments in RES are favourable and stable in the long run, they will install new production capacities and create new jobs.

Another aspect not yet regarded is the applicability of the two instruments to other sectors than electricity, .i.e. heat and transport. As recent evaluation of the status of RES in the EU show, the activities in these sectors must be enforced to meet the goals set for 2010 in the EU (Ragwitz et. al. 2005).

One can conclude state, that both instruments - feed-in tariffs as well as quotas - have the potential to be introduced easily into the transport sector – in a modified form - due to the limited number of actors in the mineral oil distribution sector.

For Germany, Nast et al. (2000) developed a concept based on quotas, which was improved later on (Nast 2004). In the quota model, the operators of RES production capacities would receive certificates and the distributors of fuels would be obliged to buy a certain amount of certificates depending on the quantity of sold energy (percentage of sold energy) to fulfil the quotas. The quotas would rise in pre-determined periods and would be divided into sub-quotas for different technologies.

A concept for feed-in tariffs would encounter the problem that prices for the produced energy must be fixed sufficiently high to encourage investment in RES heating technology but sufficiently low to limit wind fall gains and to induce innovations. This requires advisory boards who can fix prices at appropriate levels. Another problem is the equitable distribution of the of the cost of the instrument: In contrast to electricity, where a small number of network operators can allocate the resulting cost on the network tariffs which are finally paid by the consumers, a comparable mechanism does not exist for heat, because heat is not fed into a form of network.

With respect to the discussion “quotas versus feed in tariffs” one can conclude:

- Feed-in tariffs are an effective tool for the initiation of the market introduction of RES and the creation of new RES industry sectors as they provide low risks of investments and long-term stability.
- With increasing expansion and rising readiness for marketing of RES, quotas are an appropriate instrument for the creation of competition, the activation of cost reduction potentials and the market integration of RES on a national and EU-level.
- Both instruments can be transferred to the transport and heating sector, whereas the adaptation of the quota concept is easier.
- Uncomplicated and fast approval procedures, appropriate access to energy transport structures (i.e. mostly network) and well adapted regulations for this access are basic requirements for the successful implementation of both instruments.

21.5.4 Case study Denmark

The development of wind energy in Denmark since the early 80s[h] can be taken as successful model for promotion concept for the introduction of RES. Along the time scale from the decision to promote RES until the establishment of wind energy on the energy market, the Danish strategy combined the following main instruments (Meyer, 2004):

Danish government energy planning and targets on a long-term scale:

- Information campaigns and the establishment of national and local energy offices for the promotion of RES
- Long-term government support for research, development and demonstration for the development of appropriate technologies
- National test and certification procedures which guarantee quality assurance to acquire a credible market reputation
- Government-sponsored analysis and documentation of energy potentials of RES (wind atlases) to facilitate the selection of appropriate installation sites for wind turbines
- Local ownership and careful selection of sites to ensure high acceptance of wind farm installations
- Feed-in tariffs and regulations and (decreasing) investment subsidies to ensure a reliable basis with low risks for investments in wind turbines.[106]

As a result of this continuous strategy, Denmark became a leader in wind turbine installations and wind turbine production, covering 50 % of the world market in 2002.

Since 2000, the situation has changed due to the liberalisation of energy market and a redirection of the Danish energy policy. The new Danish Energy Act, approved by the EU-Commission in September 2000, introduced a shift from the

[106] Investments subsidies decreased from 30% of the turbines pruchase in 1979 to 10% during the 80s and were eliminated in 1989.

feed-in model to a quota system with trade of green certificates. This transition proved to raise problems for the further development of wind energy:

First, the introduction of the trading of green certificates was delayed drastically due to operational complications of the system including high transaction costs at a small national market.

Second, the installation of land-based wind capacity dropped from 600 MW in 2000 to 100 MW in 2001 because of the uncertainty of the conditions in this new system and the higher risks of investment especially for private wind power investors.

Future has to show, whether these are only transition problems or serious barriers for the further development of RES.

21.6 Conclusions and forecast

One of the current challenges of European energy policy is not to find the one and only instrument but to create a reliable framework for the investment for the increased deployment of RES. As shown above, there is no single policy which is appropriate for all countries in the EU. In fact, the optimum strategy:

- Depends always on the objective that is chosen: The appropriate strategy for "Enforced development of RES" differs from that one for "CO_2-reduction" or "Short/Medium term creation of jobs".
- Is always a combination of well co-ordinated instruments.
- Depends on the specific national condition concerning availability of RES, economy, infrastructure, legislation, social aspects and key actors.

If the focus is on "Enforced development of RES", the instruments should be chosen according to the readiness of marketing of the specific technology. For those RES which are close to competitiveness with fossil fuels feed-in tariffs and quotas are possible instruments. Feed-in tariffs have proven to ensure a reliable basis for investment and to induce impressive developments of RES. Quotas haven been introduced recently in some EU countries. They imply higher risks for investment but tend to match better with market mechanisms and

competition. Future will show which of these aspects dominates and whether quotas are capable to promote RES.

Future policy should not only provide sufficient incentives for the development of a market of renewable energy, but also promote technological research and development and public acceptance. Moreover, the policy framework for the renewable energy sector needs to be harmonized with many other sectors and issues, such as agriculture and forestry, nature conservation, transport, energy efficiency, construction industry, economic policy, etc. One common trend that can be followed through all studies is the rating of the relative importance of different renewable energy sources for Europe in the next decades. The literature review clearly shows that the most utilised RES would be wind and biomass, especially for power and heat generation, at least until 2020. The further increase in the deployment rate of photovoltaics is necessary in order to keep up with ever more stringent direct and indirect national and international targets. Geothermal energy is also meant to have a certain smaller role in the future, especially as hydropower potential is almost exhausted. This brings up several conclusions for the "green" development of the European energy sector:

- There will be an ever-growing competition for land for energy crops, which needs to be regulated.
- The limited wind and hydropotential would make it necessary to invest in repowering (upgrading) of existing generation capacity.
- The future energy system will increasingly rely on intermittent energy sources (wind and solar). Therefore, technological research and development are needed in order to optimize the use and storage of renewable energy through hydrogen, seasonal storage heat pumps, etc.

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22 Opponent note no. 6a: Increasing the role of renewables in the EU: Gloomy prospect or pitfall

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22.1 Abstract

This paper discusses the Lisbon strategy for a particular application, i.e. the increase of the use of renewables in Europe to improve the environment, create jobs and increase growth at the same time. Although it is (almost) obvious that a partial evaluation of this strategy will be beneficial on all three dimensions, this is much less likely if also indirect effects are included. I argue that in a general equilibrium framework this scenario is likely to be less gloomy overall. Switching to such carbon-extensive technologies is without much doubt beneficial for the environment, but the shimmering light of dividends on jobs and growth seem to be overstated.

Keywords: Climate change, Renewable Energy, Policy Evaluation

22.2 Introduction

According to the Lisbon strategy sustaining and improving economic growth together with creating jobs and securing the environment is the major policy strategy for the EU in this decade. One particular implementation of this policy might be increasing the share of renewable energy to total energy consumption from 6% in 1997 to 12% in 2010. In contrast to politicians who tend to be optimistic about finding policies that promise dividends on all three dimensions at the same time, economists are generally more skeptical. They usually do not believe that free lunches are on the table and that opportunity costs should be included in the analysis.

Indeed, this paper argues that it is unlikely that there would be no trade-offs involved in the Lisbon strategy. Also the Case Study Paper by Pfaffenberger,

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Jahn and Djourdjin (2005), hereafter called PJD (2005), hints on these less gloomy prospects of an expansion of Renewable Energy Technologies (RET). However, I will claim in my comment that things might even be worse compared to their assessment and the literature they review. Nevertheless, I still believe that the policy strategy on renewables itself is worthwhile though on somewhat different grounds and that go beyond the goal of this short note.[108]

The structure of this note is as follows. Section 22.3 briefly discusses criteria for strategy evaluation proper. Then sections 22.4 to 22.6 focus on the three dimensions for evaluation, environment, jobs and growth, and discuss for each of them the likelihood of trade-offs as discussed in the economic literature. Section 22.7 concludes.

Note that this note focuses on strategy, i.e. the choice of a (or a set of) policy goal(s), and therefore has little to say on the useful discussion in PJD (2005) about the choice of policy instruments to attain a given goal (see also Fisher and Newell, 2004).

22.3 Goals and Instruments

The idea behind the Lisbon strategy is clear. If we aim for a better environment, low unemployment and long run income, one would certainly be happy if some policy strategy, say X, would exist that serves each of these goals at the same time. In other words, a policy strategy X would be strongly Pareto improving if it reduces emissions to the environment, x_1, boosts employment in the renewables sector, x_2, and has long run positive effects on economic growth, for instance because it promotes technological change, x_3. Thus, increasing the role of RET in the EU by doubling its share relative to Non-Renewable Energy Technologies, like fossil fuel based electricity generation, in Total Energy Production (TEP), certainly makes sense if it would be favorable to all of these goals at the same time. At face value this policy indeed reduces emissions because RET technologies usually emit less air, soil and water pollutants, additional jobs are involved to produce and exploit these technologies, and growth seems likely because of the expansion and technological change in the RET sector. Closer

[108] RET usually also reduce oil dependency and therefore hedge against the risk of oil price shocks (e.g. Liski and Murto, 2006).

inspection, however, suggest this is far too optimistic because proper evaluation also includes indirect effects as also the Case Study Paper of PJD (2005) argues.

In general, economists evaluate a policy strategy like *X* in at least two ways. The first type of assessment evaluates strategy *X* from a proper *social* cost-*benefit* perspective, i.e. compares the (social) cost *and* benefits of the policy "doubling RET in the EU". Such an evaluation typically includes the effects of some strategy *X* on all dimensions considered relevant, and then makes an assessment not only using (opportunity) cost, but also including benefits (preferably at the individual welfare level). Note that this type of evaluation should properly account for direct and indirect effects of the policy including their valuation. Thus one would like to estimate whether, for instance, the strategy *X* passes a Pareto test, i.e. whether the individuals really benefit from this policy taking all relevant welfare indicators (environmental, employment and income effects) into account. Thus one typically has to assess direct and indirect effects of RET, i.e. to what extent increasing RET reduces emissions given their effect on the overall energy system, crowds out non-RET and its associated employment, and may crowd out R&D in other sectors. Although such evaluations are theoretically preferable, one typically does not find such studies in practice. One is more likely to find evaluations of the partial type, including those that assess welfare effects of emission reduction through monetization.

The second type of assessment takes the strategy itself as given, and evaluates whether the policy passes a *cost-effectiveness* test. Here the question is whether a given policy *X* attains a specific policy aim, e.g. reducing climate change emissions, in a cost-effective way, i.e. in a way that no other policies are available to reach the same goal at lower cost. Such an analysis starts from the presumption that one has to introduce some policy to promote RET in order to obtain a goal like reducing climate change emissions through, say, doubling the share of RET in TEP within some given time period. Next the social cost of this policy are captured by looking at both private and opportunity cost involved (e.g. cost of the subsidies necessary to reach this penetration goal for the RET). Finally, one compares the cost of this policy with (some) likely alternative(s), and determines whether it passes a social cost-cost test, i.e. minimizes overall costs in the policy dimensions considered important. Note that the difference with the previous type of evaluation has nothing to do with the question as to how to account for direct and indirect effects, but only with their valuation.

Complexities are somewhat reduced by no longer focusing on individual benefits, but on cost assessments instead.

One example of the latter approach is Palmer and Burtraw (2005) who apply this idea to the choice of renewable electricity policies in the US. They just look at a portfolio of RET options, assess the private cost differences of this particular RET compared to its alternative(s), compute how much tax payers should pay to bridge the private cost gap in terms of the higher expenses involved for these more costly energy generating technologies, and determine whether this policy passes alternative options to promote a less carbon-intensive economy. Given their general-equilibrium setting they also account for indirect effects of the subsidies involved to lower electricity price of renewables and its adverse effect (more demand for electricity), and they find that an alternative policy, in particular a cap-and-trade policy seems to be more cost-effective in achieving carbon emission reductions.

A somewhat different, though related approach here tries to find whether some potential policies exist that actually satisfy the goals of the strategy X from the set of all possible policy options, i.e. find a particular subset of RET that might produce an outcome in the policy dimensions considered important (like environment, employment and growth). Note that such an approach may not have a solution if the subset turns out to be empty.

The assessment so far already illuminates how demanding the Lisbon strategy is. In fact, the policies to be selected should typically yield a triple dividend, which is even more demanding than the double dividends at the time of the potential introduction of an EU carbon tax (Bovenberg, 1999). At that time the introduction of a carbon tax was supposed not only to be beneficial for the environment (weak dividend), but also for the labor market because tax revenues from energy taxes could be used to reduce (marginal) taxes on labor with more jobs as a result. Now the idea is that promoting RET would even be beneficial in a third dimension, i.e. by fostering economic growth. Subsequently, I will discuss the likelihood of each of these potential dividends. Note that, in general, it would not be sufficient to just look at the effects on the RET sector, but one should also typically include the indirect effects of this policy, for instance shifts in the energy market (fewer non-RET), the labor market (depending on the labor-intensity of RET vis-à-vis its alternative), and technological change.

22.4 Environment

Let us look at the environmental effects first. Three issues are important if one would go as far as a multi-dimensional cost-benefit or cost-cost evaluation: i) drawing system boundaries for proper comparisons; ii) finding proper shadow prices; iii) substitutability constraints.

The first issue, drawing system boundaries, is inherently problematic, in particular because RET technologies may entail complicated substitutes for a gas-fired power plant, like biomass. PJD (2005) also pay a lot of attention to the need for detailed emission profiles of the RET technologies that are likely to be implemented in order to reach the policy goal. However, they argue on p.7 that the system boundary should found its comparison with non-RET using life-cycle emissions *as well as* interactions on power generation from other, usually conventional fossil fuel sources. Although I agree that life-cycle assessment is essential, I would think that the indirect effects on the power system as a whole is only appropriate if one applies this to all sources. For instance, gas turbines differ from coal power plants also because they tend to be much more flexible which is particular useful in off-peak periods. To include such additional features might complicate comparisons too much.

One particular example of how problematic comparisons between studies on the environmental effects of RET options are the results of a study by Nitsch et al. (2005) cited by PJD on page 430 on the net effects of RET compared to conventional energy systems. This study reports among other examples that biofuels save up to 45% of the environmental effects of a future diesel car. Apart from the question how this aggregated effect is computed, this result is considereable above performance estimates reported for reasonable applications of biofuels for French diesel cars (see Vollebergh, 1997). In fact, taking careful estimates compiled by the OECD (1994) of the upstream agricultural system (and their environmental impact) into account, I found remarkably small differences in overall emission savings between conventional cars and cars that use biofuels, while much depends on the type of biofuel produced. This is not to claim that one should only trust my own estimates and not those of others because, indeed, studies are likely to differ in drawing their boundaries and choosing between relevant figures. Therefore, in a summary report of the literature I would like to see an analysis that provides detailed explanations of the specific RET technologies reviewed and the range of environmental impacts

reported in the literature under review (preferably including a column that explains where the differences (may) come from) to facilitate robustness checks.

The second issue is that one might like to see a comparison of RET not only in terms of their physical impacts, but also using proper shadow prices for these impacts. Although evaluation without aggregation of emissions across different dimensions is also possible using multi-criteria analysis, it is sometimes useful to at least have an idea of the relative cost (and benefits) of the emissions profile of different technologies involved, as well as an indication of the relative importance of private and external cost involved. For instance, Vollebergh (1997) and Dijkgraaf and Vollebergh (2004) have shown that biomass investments through Waste-to-Energy (WTE) Plants is an extremely expensive option to reduce greenhouse gas emissions as soon as one properly accounts for the fact that WTE is a typical joint product. It is certainly optimal to produce electricity and heat from a given waste incineration plant, but investing in this type of plant is very costly from the social perspective because private cost are so high for incineration plants and have to be subsidized at high costs. More or less the same holds for biofuels. Even if biofuels are preferable to oil based fuels from an environmental perspective, their private costs are usually so high that they provide a very expensive alternative for their fossil fuel substitutes. Again this is not to say that increasing RET is not a proper strategy. These examples are clearly conditional on the type of technology assessed, in particular the type of agricultural feedstock and the potential technological improvements. However, they serve to warn against too optimistic assessments of RET in the first place even if several of these options appear to perform much better on environmental grounds. A double dividend may not simply be available because the RET themselves seem to yield only few emissions.

The third issue considers aggregation of overall emission reduction if one implements particular scenario's with RET. This analysis usually calculates potential aggregated savings for the whole economy compared to some Business as Usual scenario, like in the study of Palmer and Burtraw (2005) who also consider implementation of a RET portfolio potential (see also Neuhoff, 2005). The evaluation of PJD takes stock of these kinds of studies, but their analysis does not make explicit for the studies they discuss what modelling assumptions are made and, in particular, which are the driving forces ('mechanisms') included in these models (see sections 21.5 and 21.6). Thus estimates may easily under- or overstate the potential of a particular RET scenario depending on, for instance,

whether or not technological change or international trade is included in particular models.

22.5 Jobs

The second important policy dimension is employment. Labor market effects typically come from at least four mechanisms: i) direct investment and maintenance of the RET themselves; ii) indirect effects from a reduced use of labor in the non-RET sector for which they substitute; iii) budgetary effects because of higher taxes necessary to pay for the higher investment cost in the RET sector[109]; iv) effects of international trade and cooperation in reducing climate change emissions (Kyoto).

The study by PJD cites several reports (although somewhat biased towards Germany), presenting current employment levels for the RET sector. Unfortunately, one does not have any reference as to whether these numbers are small or large relative to the non-RET energy sector or what type of RET is included or not. Furthermore, only a few estimates are used to discuss recent expansion. Thus the reader is left with estimates that typically aggregate the widely different labor and capital intensities in the sector for which it is impossible to make a useful comparison with existing non-RET options.[110] Similarly, I gain little insight in the studies mentioned by PJD that estimate the overall employment effects (i.e. also include reduction of the non-RET sector). It would be very interesting to see how substitution effects between both energy sectors are modeled, and how this affects the level of employment and capital in the studies mentioned. These effects are also likely to differ when different scenario's for the budgetary effects are taken into account. It would certainly seem to matter whether subsidies for the RET sector are financed out of the national budget or via carbon taxes as the previous literature on double dividend has shown (Bovenberg, 1999).

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[109] For instance, subsidies on outputs produced from RET or taxes on outputs produced from non-RET sources are necessary to increase investment in RET vis-à-vis their cheaper non-RET substitutes (see also Fisher and Newell, 2004).

[110] A typical windmill is capital intensive and requires few man-years of maintenance, whereas biomass is labor and land intensive.

The role of international trade and cooperation in reducing climate change emissions (Kyoto) is particularly important as PJD stress as well. Indeed, many studies are available that explicitly discuss the international macro-economic aspects of different Kyoto strategies. The particular role of the RET sector in this kind of scenario's is usually less clear, in particular its relative performance in terms of employment against alternative options that match Kyoto targets (see e.g. Bohringer, 2004). I think it would be particularly interesting to see what the applied climate change general equilibrium models have to tell us in this respect (see also below).

22.6 Technology and growth

The third dimension for evaluation is the effect on economic growth, which is, as I take it, mainly concerned with its effect on technological change (and thus on long run growth). PJD do not say much about this effect and concentrate on potential job losses due to relative differences in openness between RET and non-RET instead (see previous section). This is a pity because one might wonder to what extent this policy may affect changes in technology (see also Neuhoff, 2005). I distinguish three of such effects: i) (induced) innovation in the RET sector through learning by research (R&D); ii) (induced) learning-by-doing (LbD) including scale effects; iii) crowding out of R&D investment in other sectors, including potential improvements in non-RET technologies (in particular carbon-abatement technologies).

Recently, both top-down and bottom-up approaches have started to incorporate the ideas of induced technological change.[111] For instance, applied models, such as MERGE (Manne and Richels, 1999) and MIT-EPPA (Jacoby and Wing, 1999), now typically include induced technological change through a so-called autonomous energy efficiency improvement factor. Recent versions of MERGE also include endogenous representations of technological change through learning-by-doing (Manne and Baretto, 2004). Similarly, energy system models, such as MESSAGE (Grübler and Messner, 1998) as well as new versions of POLES (Kouvaritakis et al., 2000) and MARKAL (Barreto and Kypreos, 2000),

[111] Two recent special issues in *Environmental and Resource Economics* and *Ecological Economics* pay attention to these developments. See, in particular, the editorial comments by Carraro, Gerlach and Van der Zwaan (2002) and Vollebergh and Kemfert (2005).

include learning-by-doing in special (energy) functions within their energy system framework.

A particularly interesting model in our context is Gerlagh and Lise (2005). They develop the partial equilibrium model DEMETER-2E for energy supply and demand with endogenous technological change represented through both R&D and learning-by-doing. The typical bottom-up characteristic of this model follows from the two competing technologies (energy sources) included, a carbon-based (say non-RET) and a non-carbon-based technology (say RET). Accordingly, the model allows for energy *source* substitution, but the model does not assume a priori that these technologies are gross complements (substitution elasticity below unity). The transition from one energy source to the other is endogenous in the model, with energy production cost functions being variable over time and dependent on the state of technology. The model also includes an R&D sector that requires costly investment, whereas learning-by-doing is – as usual – assumed to be a direct spillover effect of production. Policy is typically represented in the model through a carbon tax. In contrast to Goulder and Schneider (1999) and Nordhaus (2002), this study finds that induced technological change can substantially accelerate the substitution of carbon free energy for fossil fuel and reduces cumulative emissions over the period 2000-2100 by a factor 3 for given effort.

I would also mention the interesting empirical case study on wind energy by Klaassen, Miketa, Larsen and Sundqvist (2005). They focus on cost-reducing innovation in wind turbines in three countries – Germany, Denmark and the UK. The innovation and diffusion mechanism is studied here using the so-called two-factor learning curve (see Kouvaritakis et al., 2000), which is a typical bottom-up perspective on the development and spread of new technologies. According to this concept, cost reductions for particular technologies arise out of two kinds of learning. The first mechanism is called searching, and typically arises because of investment in the stock of R&D (and its lagged effect). The second mechanism is labelled “learning-by-doing”, but this concept is somewhat more general here because it allows not only for improvements in (on-the-spot) applications of such technologies and their uses, but also for the development of “new” technology. The typical empirical indicator is cumulative capacity, as it is assumed that this type of learning grows with the amount of technology applied. The findings of Klaassen et al. typically support this two-factor learning curve, showing a robust estimation of a common slope (i.e. simi-

lar learning curves for the different countries) as well as heterogeneous intercepts, which point to differences in local (economic or other) environments. Accordingly, this case study seems to provide evidence for the Porter hypothesis, although it remains unclear whether environmental policy is beneficial in this case beyond the environmental dividend itself. Moreover, a case study can never generate a general confirmation of any hypothesis, but this one does seem to give some indication that, at some specific place and time, environmental policy is able to lift the growth of some sectors.

Finally, we cannot exclude negative indirect effects from increased effort in R&D in the RET sector. Indeed, a typical economic question is whether environmental regulation might have drawbacks for productivity because of crowding-out effects on R&D (see Smulders and De Nooij, 2003). A given dollar of investment can be spent only once. When this dollar is spent on (research in) pollution reduction, other perhaps more productivity-enhancing options are no longer possible. Indeed, recent evidence from applied general equilibrium models suggests that models with "free" learning-by-doing (as a costless device) report much larger potential gains from technological improvement (see also special issue in Ecological Economics).

22.7 Conclusion

From this small survey on potential triple dividends it seems unlikely that such dividends exist. Investing in windmills might be good for the environment, but also requires more capital than current large scale combustion plants. Moreover, this investment is also more expensive. Therefore such investments are likely to lower employment both directly through its higher capital intensity, and indirectly through the higher marginal taxes or subsidies necessary to stimulate their (initial) penetration. With respect to its potential positive impacts on overall economic growth the balance might seem more favorable, although again some trade-off might be inevitable here.

Nevertheless increasing investments in the RET sector might still be justified, in particular if the social benefit weighs up against the additional cost at the margin. This effect, however, is unlikely to be similar across all RET options and choices have to be made. For some options (wind?) the balance might certainly be positive, for others (particular biomass options?) doubts seem to be justi-

fied, in particular because cheap carbon abatement technologies are available as well (Anderson and Newell, 2003).

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23 Opponent note no. 6b: Renewable energies – environmental benefits, economic growth and job creation[112]

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23.1 Introduction

The recent climate summit in Montreal (COP/MOP1) on greenhouse gas (GHG) issues brought new hopes of continued and increased efforts of the Kyoto-process for combating climate change. Not only was it agreed by the parties that the Kyoto commitments were to be extended after 2012 with new requirements for GHG-reductions, but also a dialog-forum was formed to discuss with those countries that currently not active in the process. The European Union was among those taking the lead for an enforced development of the Kyoto-commitments and also GHG-issues are to an increasing extent at the core of the energy and environmental policies of the European Union and its Member States. Looking back at the Kyoto protocol, the European Union has agreed on a common GHG-reduction of 8% during the period 2008-2012 relative to 1990. According to the agreed burden sharing within the EU, a number of countries are required to reduce their GHG-emissions considerably; for example, the reduction figure for both Denmark and Germany is 21 % in the above-mentioned period of time.

In the implementation of these GHG-targets, the development of renewable energy sources (RES) is expected to play an important role. In its White Paper on a strategy for developing renewable energy, the EU-Commission has launched a goal of covering by renewable energy supplies, 12 % of the European Union's gross inland energy consumption by 2010 (European Commission, 1997). In line with this is the European Commission Directive on the promotion of renew-

[112] This note is a comment and a supplement to the paper written by Wolfgang Pfaffenberger: Renewable energies – environmental benefits, economic growth and job creation. Thus the intentions are not to treat renewables in details – which basically is excellent done in Pfaffenbergers paper – but to highlight a few additional and important issues for the development of renewables and the impact on economic growth and employment.

able energy technologies (European Parliament and Council 2001) which includes a proposal on the share of renewables in the electricity fuel mix in the individual Member States in 2010. Although not binding, these targets are in general accepted by the EU Member States.

Currently, the renewable energy market in Europe is relatively protected and non-harmonised among the Member States. In the future, due to evolution of important EU energy-related policies, such as the EU Directive on Renewables or the fulfilment of the Kyoto target in combination with the liberalisation of the electricity market, the structure of the European electricity market, in general, and the conditions for RES-E, in particular, will be fundamentally reshaped. Recently an evaluation of the promotion policies in the Member States was carried out (European Commission, 2005). The main outcome of this was that the EU Commission encourages the Member States to increase their collaboration and co-ordination of support to RES, but that it at present is premature to go for an actual harmonisation of the support policies within the EU.

Although being an obvious and important option for achieving GHG-reductions is a main characteristic of RES-technologies, other important issues characterise RES as well. On the benefit side these include the normal ones as:

- Environmental benefits of global, regional and local nature.
- Increased security of supply.
- Local employment and fostering the strength of European industries.

But other benefits normally not accounted for accrue from RES-technologies, including:

- Impact on power prices at the spot market, the low marginal cost of RES-technologies as photovoltaics and wind power lowering the general spot power price.
- RES-technologies are not depending on fossil fuels and therefore are not exposed by the risk of fossil fuel price volatility. This may lead to an overall strategic benefit of RES, e.g. power companies adding RES-options to their portfolios to minimise their overall risk.

Though also negative impacts are to be mentioned for RES, including:

- Intermittency in relation to technologies as wind power and photovoltaics.
- Visual impacts.

In the following the most important of the abovementioned issues will be addressed in more details.

23.2 Most important issues

23.2.1 Environmental impacts and benefits – externalities

When discussing the environmental benefits and costs of renewable energy tecnologies the concept of externalities cannot be disregarded. For power production, externalities are associated with those benefits/damages not accounted for in the price of electricity. In order to make up a fair comparison between different power generation technologies all costs and benefits to society need to be taken into account in the power price, both direct production costs and indirect external costs.

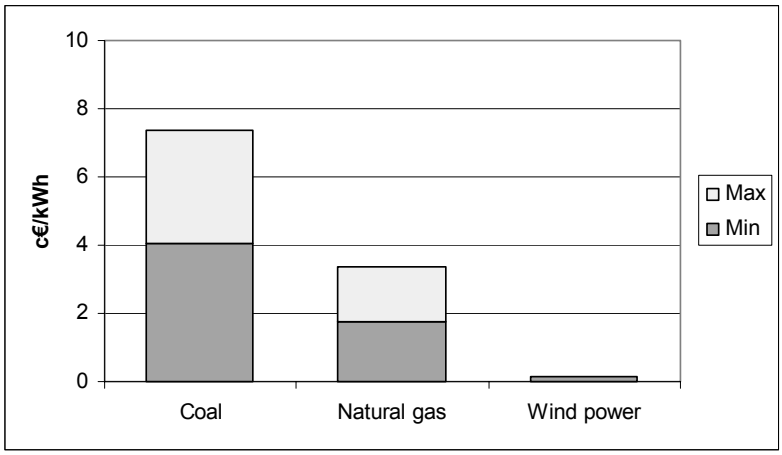
A classification of externalities include (EWEA, 2004):

- Human health (accidents, disease)
- Occupational health (accidents, stress, physical health)
- Amenity impacts (noise, visual impacts, odor)
- Security and reliability of supply
- Ecological impacts (acidification, eutrophication, soil quality)
- Climate change (temperature rise, sea level rise, precipitation changes, storms)

In the EU Externe-E project much work and many resources were devoted to calculating the externalities within the energy sector (European Commission, 1994). Figure 1 shows the externalities of coal and natural gas in comparison with externalities for wind power. In general the external costs are low for most renewable technologies as photovoltaics, wind power and wave/tidal power, the only exception being biomass/biogas where externalities are higher owing to emissions of SO_2 and NO_x (see Pfaffenberger for more details).

It was found in the ExternE study that external costs amounted to 1-2% of the GDP in the EU area; that is between 85 and 170 billion €, not including the costs of global warming and climate change (European Commission, 1994). Large uncertainties are associated with estimating externalities, especially in relation to climate change, handled in the ExternE-project by setting up a number of different scenarios/assumptions for global warming.

Figure 1: Externalities associated with coal, natural gas and wind power for Danish conditions. Maximum and minimum levels depend on two scenarios/assumptions on global warming, minimum 21€/ton CO_2 and maximum 52€/ton CO_2. Source: ExternE (European Commission, 1994).



In general externalities associated with renewable technologies are fairly low in comparison with conventional fossil fuel technologies. If externalities were included in the price of power, in many cases the costs of renewable power production would be lower than that of conventional power plants.

23.2.2 Job creation and economic growth

According to (EWEA, 2004) almost 70.000 full-time workers are employed in the wind power industry at present and approximately 200.000 in total within the renewable field as mentioned by Pfaffenberger. For wind power alone this could increase to almost 200.000 in 2020, if the trend in wind power installation continues (EWEA, 2004). Of this amount approximately ¾ is related to manufacturing and therefore the result depends almost entirely on the scenario of where the wind turbines are manufactured and if the European manufacturers will continue to be competitive on a global scale. Undoubtedly a similar picture is to be found for other RES-technologies.

The development of a strong RES-industry in Europe has gone hand in hand with a strong demand for RES-technologies. This is particularly seen in countries as Denmark, Germany and Spain, where strong home markets for wind power have implied the development of strong wind turbine manufacturing industries. In Germany a similar picture is seen for photovoltaics, as is also the case for biomass in countries as Austria, Sweden and Finland. Thus if European manufacturers are going to continue this development it will require a continued strong

demand for RES-technologies in Europe alongside increased efforts for strengthening research and development within the RES-field. This will require a pro-active involvement of the European Commission as well as the National Governments including a long-term vision for the use of research programmes and the shaping of organisational and legal entities to facilitate the development of these new technologies.

Whether the development of a new industry as the renewable industry will create additional employment and higher economic growth or mainly will substitute employment and growth elsewhere, is always a highly disputable matter. Will employment be crowding-out? Will there be a higher productivity and profitability in the RES-industry compared to alternative industrial developments? A Danish analysis from 2003 argues that this is not the case for the development of the Danish wind power industry that employment and economic growth would have been just as well off not developing wind power in Denmark (Det Økonomiske Råd, 2002). Nevertheless, some arguments suggest that RES-industries indeed do increase employment and economic growth:

- Most RES-industries employ both highly skilled workers in research and development and blue-collar workers in manufacturing. Due to the possibilities of hiring workers research departments are often situated close to metropoles, while manufacturing departments often are situated in areas with unemployment above the average. Thus, especially for blue-collar workers the RES-industry could improve local employment.
- At the start of the development the wind power industry utilised standard components developed for other purposes: Gear-boxes, ball-bearings and transformers were all being used in other constructions and just taken over by the wind turbines. Turbines growing much larger now have totally changed the situation. By now the wind power industry is driving the development of new components as very large ball-bearing and new designed gear-boxes. Today innovations are created in the RES-industry and spin-off to other industries.
- A strong demand for wind turbines and well-designed wind research programmes associated with a stable support from the Danish Government created the Danish wind power industry. By now the home market for wind power in Denmark is a tiny share of total wind turbine production and not driving the wind power development any more.

Therefore wind power manufacturing is being flagged out of Denmark and situated where the main markets are developing. But most of research and development is still being carried out in Denmark, mainly owing to well-established research environments. And not only the established companies are doing research in Denmark, but also foreign manufacturers have been attracted placing new research departments in Denmark, making Denmark the hub of wind power research.

23.2.3 The problem of intermittency

Wind power and photovoltaics are characterised by being intermittent sources to power production. Thus the amount of power produced is changing rapidly in accordance with the intermittent resources of solar and wind and this puts severe constraints on the conventional part of the power system in terms of regulation capabilities. Again and again intermittency is found to be one of the most important barriers to solve if sources as solar and wind are going to constitute significant shares of the power system.

In Denmark we have a high share of wind power in the power system and quite a number of experiences are gained with wind power. In the following, wind power will therefore be used as an example of the problems encountered with regard to intermittency and the remedies available. In two ways wind power interacts with the power system in different manners than conventional power plants:

Firstly, wind power will in many occasions not fulfil expectation to power production. Although the wind is blowing and turbines producing power, we might not be able to forecast the exact amount produced. Thus wind power cannot fulfil the bids given to the power market, which means that other expectedly conventional power producers have to step in to fill the gap left over from wind power. If wind power was forecasted to produce more than realised, other producers have to increase their production to equalise power demand and supply at the market place – and correspondingly reduce their power production if the wind turbines produce more than forecasted. This of course gives rise to additional costs in the power system, which wind power expectedly should cover.

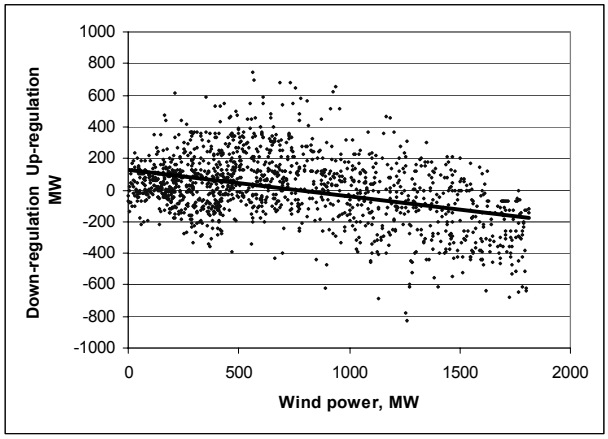
Secondly, if wind power covers a substantial share of the power system, the turbines producing at full load adds a substantial production capacity to the total capacity balance of the system. But if there is no wind and therefore no power production from the turbines, the conventional part of the power system

has to supply the needed electricity without any help from wind power. Thus in principle the conventional system always has to have enough capacity to supply the needed power, because you never know when the wind is not blowing.

The abovementioned two characteristics of wind power intermittency pose different challenges to the integration of wind power into the power system: Short term intermittency (within hours) wind power not delivering the expected amount of power to the market and long term intermittency (within days or even weeks) wind power not being able to deliver any capacity to the market.

We will first look at the problem of *short term intermittency*. Figure 2 shows the capacities at the Western Danish power market related to all regulation in the area, i.e. not only to regulation in connection with wind power failing to produce at the forecasted production level[113]. Nevertheless, although not very significant, there is a clear tendency that the more wind power is produced, the higher is the need for down-regulation. Correspondingly, the less wind power is produced, the higher is the need for up-regulation. Note that Figure 2 shows that forecasts for wind power production tend to be too low, when large amounts of wind power are produced, and they tend to be too high, when only small amounts of wind-generated power are fed into the system.

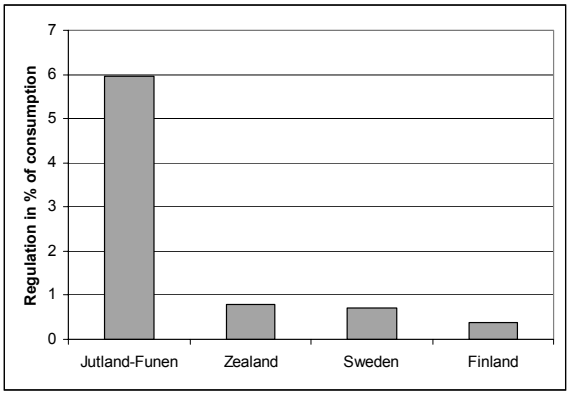
Figure 2: Regression analysis of down or up-regulation against the amount of wind power for the Jutland/Funen area. Hourly basis for January-February 2002.



[113] The Western Danish power area is chosen as an example in this section because of the high share of wind power produced in this area of more than 20%. From the available data, it is not possible to discern the specific cases when wind power failed to produce according to the forecasts.

Figure 3 compares power areas with different capacities of wind power and shows that wind power strongly increases the need for regulation. Note that at the Nordic power market the bidding for the spot market is carried out 12-36 hours in advance, which is one of the reasons why wind power often requires balancing power.

Figure 3: The need for balancing depending on the amount of wind power in the power system.



Sweden and Finland comprise large areas and have very little wind power capacity. Zealand (the Eastern part of Denmark) has approximately 10% of wind-generated power in relation to total domestic power consumption, while Jutland-Funen (Western part of Denmark), as mentioned, has a coverage of more than 20% of total power consumption. Figure 3 clearly illustrates the consequences for the regulation of power. In the Western Denmark area, regulation as a percentage of consumption is more than 6 times higher than in the other areas.

In general, more wind power in the power system should be expected to increase the need for regulation. However, the closer the time of gate closure is to the actual time of dispatch, the smaller should be the divergence between actual wind power production and the submitted production bids

In the Nordic power market, a wind turbine owner that produces more than his initial production forecast will receive the spot price for all his production. However, he will have to pay a premium because other power plants have to regulate down due to that his production exceeds the forecast. If he produces less than his bid, he will correspondingly have to pay a premium for the part that other generators have to produce in up-regulation.

Figure 4: The cost of regulation, calculated as monthly averages for the year 2002 for the Jutland/Funen area.

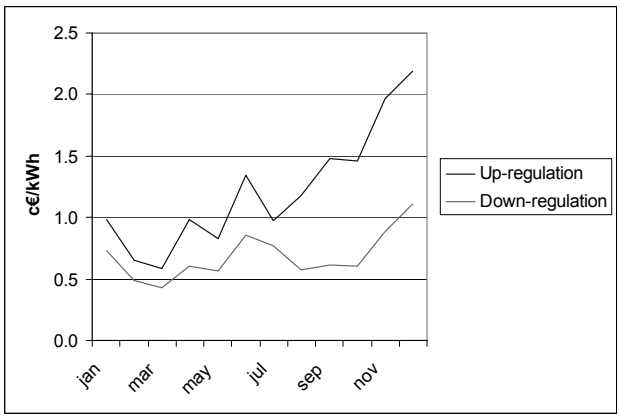


Figure 4 shows the regulation costs for 2002, calculated as monthly averages. As the figure shows, the cost of up-regulation is constantly above the cost of down-regulation, expectedly because the marginal cost of up-regulation is higher than for power producers regulating down. Moreover, as expected, the cost of regulation – especially up-regulation – increases with the general level of the spot price, which increases substantially towards the end of 2002[114]. In 2002, the average up-regulation cost reached 1.2 c€/kWh regulated, while the cost of down-regulation amounted to 0.7 c€/kWh regulated.

As mentioned the regulated quantities do not only relate to wind power, but to the total system, including non-fulfilment of bids from demand and conventional power producers as well. The estimate constitutes the upper limit, therefore Figure 5 relates the 2002 monthly regulation costs for the Western part of Denmark to wind power only. Finally, Figure 5 gives the corresponding costs related to the total power supply.

[114] At the end of 2002, there was a draught in Norway and Sweden and the power System prices reached extremely high levels.

Figure 5: Regulation costs calculated as monthly averages for the Jutland/Funen area for 2002, costs either incurred by wind power only or related to the total power supply.

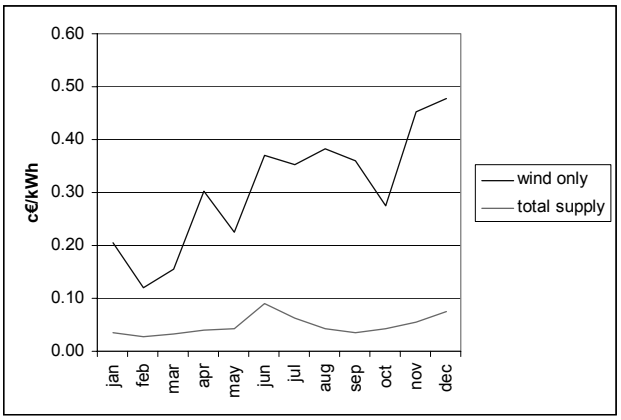


Figure 5 shows that regulation costs per kWh borne by wind power only are lowest during periods with plenty of wind-generated power, i.e. during Winter/Spring 2002, and higher during the summer, when less wind power is produced. However, the high spot prices of Autumn/Winter 2002 are an exception. For the year 2002, the average regulation cost if borne by wind power only amounts to 0.3 c€/kWh115. As mentioned above, these estimates constitute an upper limit of the regulation costs for wind energy, because the regulated quantities do not only relate to wind power. If the regulation costs are distributed across the total power supply, the cost per kWh is, of course, much lower, and if calculated as an average for 2002, the cost amounts to 0.05 c€/kWh.

In summary, short term intermittency is possible to cope with if 1) we are satisfactorily clever to forecast the wind leaving only small deviations to the rest of the power system, 2) we have enough capacity reserves at the balancing market to generate the needed power at a fairly low price. Thus short term intermittency is in most cases a problem of requiring a low volume of balancing capacity and that this balancing capacity can be delivered from other power plants at a low cost. Especially hydro power is capable with a short notice to absorb short term intermittency from wind power, but also regular power plants as natural gas-fired combined cycle have fast regulating capabilities. Finally, also short term demand regulations might be possible as a measure to absorb short term

[115] The year of 2002 is a fairly representative year for regulating costs in the Danish power system.

intermittencies in wind power, e.g. to reduce resistant heating load for a few hours at some consumers might be possible without causing any discomfort. The cost of balancing wind power in Denmark of 0.3 c€/kWh on average[116] is only adding approximately 7-9% to the cost of wind power (less if we look at the tariff paid for wind power) and is therefore not seen as a major barrier towards the development. But at the same time it is important to mention, that within the Nordic power market Denmark is at present the only country with a high share of intermittent power. If all Nordic countries were to expand their intermittent power production, the cost of balancing might increase considerably.

The problem of long term intermittency might be much more difficult to cope with. If the wind is not blowing a week, where we are close to the annual peak capacity power, this might lead to a very tight capacity balance of the power system, implying at least high prices if not technical problems. And if no capacity is left in the system, only investments in new capacity or lower demand for power can be remedies. Thus a lack of capacity might be a severe problem to solve. It might require the need for investments in new gas-turbines or similar plants, which are cheap in terms of investments but expensive in terms of variable costs, especially fuel costs. Another possibility is to utilise energy storage facilities, e.g. batteries for direct power storage although today it is quite expensive. Eventually hot water heating storages could be used as buffers for power demand in an optimised heat and power system. Using demand options to lower demand for power in specific situations with lack of capacity may also be possible, but interruptions of power demand for several hours up to days might show up to be difficult if not to cause too much discomfort at the power consumers. But investments in new capacity or long term options of flexible power demand are not only to be used in situations of wind power shortage, but could be a general part of the power system. Thus the problem of long term intermittency interacts closely with the long term development of the power system, including solutions that may benefit not only intermittent RES but the operation of the total system.

[116] Figure estimated using 2002 data.

23.2.4 Renewable technologies impacting the spot power price

In a number of countries wind power has an increasing share of the power production. This goes especially for countries as Denmark, Germany and Spain, where the share of wind of total power supply is 18%, 9% and 6% respectively. In such cases wind power can significantly influence the price determination at the power market. In the following, the impacts of wind power in Denmark on the power exchange in Scandinavia, Nord Pool's Elspot that comprises Denmark, Norway, Sweden and Finland, are discussed in more detail.

Wind power is expected to influence the prices at the power market in two ways:

1. Wind power has normally a low marginal cost and, therefore, enters close to the bottom of the supply curve. This, in turn, shifts the supply curve to the right, resulting in a lower system power price, depending on the price elasticity of the power demand. If there is no congestion in the transmission of power, the system price of power is expected to be lower during periods with high winds compared to periods of low winds.
2. During periods with high wind power generation, congestions in power transmission might arise. Thus, if the available transmission capacity cannot cope with the required power export, the supply area is separated from the rest of the power market and constitutes its own pricing area. With an excess supply of power in this area, conventional power plants have to reduce their production, because wind power normally will not limit its power production. In most cases, this will lead to a lower power price in this sub-market.

Figure 6: The impact of wind power on the spot power system price.

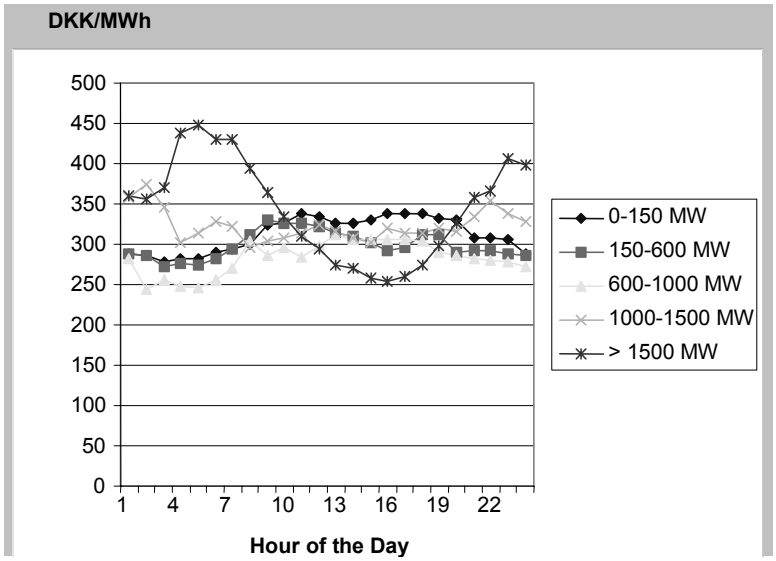


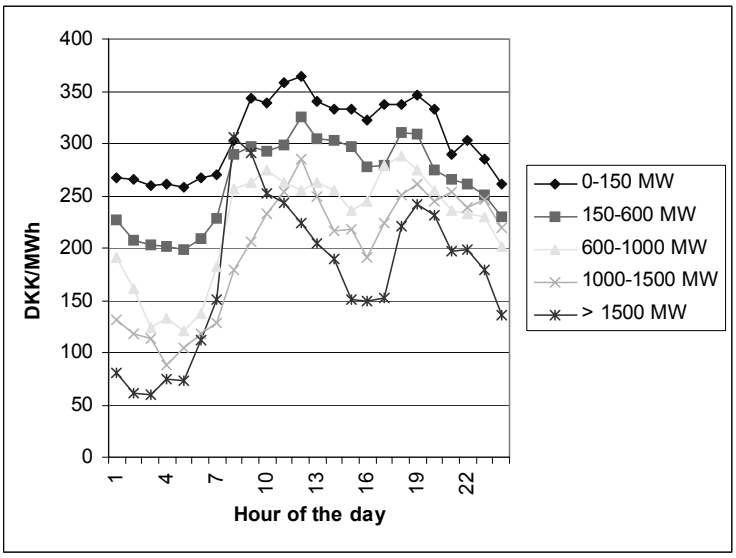
Figure 6 shows how the large capacity of wind power in the Western Denmark area affects the power system price. Five levels of wind power production and the corresponding system power prices are depicted for each hour of the day during periods without any congestion of transmission lines. As shown, the more the wind power production, the lower the system power price. At very high levels of wind power production, the system price is reduced significantly at daytime whilst increased at night-time, though. This phenomenon is difficult to explain. It could be a consequence of spot market bidders expecting high nocturnal levels of wind power. Nevertheless, there is a significant impact on the system price, which might increase in the long term if even larger shares of wind power are fed into the system.

The second of the above mentioned hypotheses is concerning power prices in cases where transmission line capacity is completely utilised. In the Western Danish power area wind power has a very high share and in cases with a high wind power production transmission lines are often totally utilised. Especially during December 2002 the share of wind-generated electricity in relation to total power consumption for the Jutland/Funen area were close to 100% at certain points in time. That means that at that time all power consumption could be supplied by wind power in this area. If the prioritised production from decentralised CHP plants is added on top of wind power production, there are several periods with an excess supply of power. Part of this excess supply might be exported. However, when transmission lines are completely utilised, we have a

congestion problem. In that case, equilibrium between demand and supply has to be reached within the specific power area, requiring conventional producers to reduce their production, if possible. The consequence to the market is illustrated in Figure 7 below.

Again, five levels of wind power production and the corresponding power prices for the area are depicted for each hour of the day during periods with congestion of transmission lines to neighbouring power areas. As shown, there is a significant correlation between wind production and power price. Thus, the more the wind power production, the lower the power price in the area.

Figure 7: The impact of wind power on the spot power price of Western Denmark, when there are congestions in the power system between countries.



How large the impact of wind power on the power price at the spot market is will heavily depend on the amount of wind power produced and the size and interconnections of the power market. Experience in Denmark shows that:

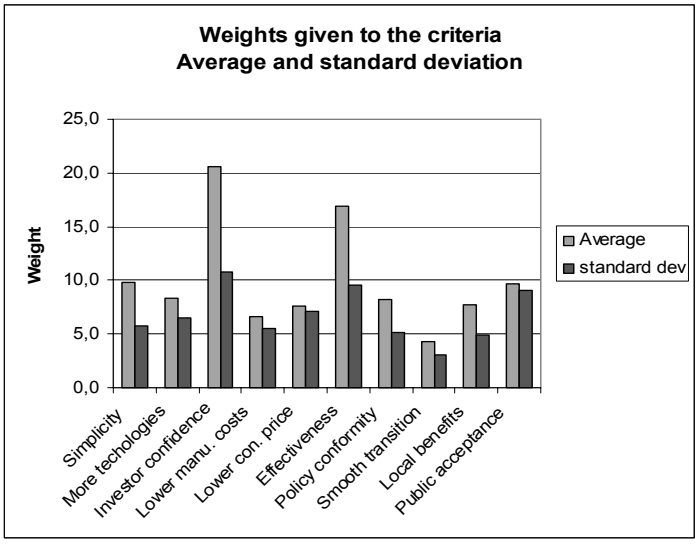
- Even within the large Nordic power system, wind power has a small, but significant negative impact on the power price. The more wind power is supplied the lower becomes the power System price.
- When Western Denmark is economically separated from the rest of the power market due to congestions of transmission lines, wind power has a strong and clearly negative impact on power prices, both during daytime and night-time.

- Ceteris paribus this implies that renewable technologies with high capital investments upfront and correspondingly low marginal costs (e.g. wind power and photovoltaics) will have a tendency of decreasing power prices at the spot market, which in turn makes the power consumers better off. This might to a certain extent moderate the higher costs incurred by power consumers owing to payment of high tariffs to renewable technologies.

23.2.5 Policy instruments and measures

In the EU-project Re-Xpansion (EWEA, 2005) support schemes were evaluated as part of the background information made available for the EU-evaluation of national support systems undertaken in the autumn of 2005. In Re-Xpansion ten evaluation criteria were defined and the importance of these was investigated in a questionnaire, results shown in Figure 8.

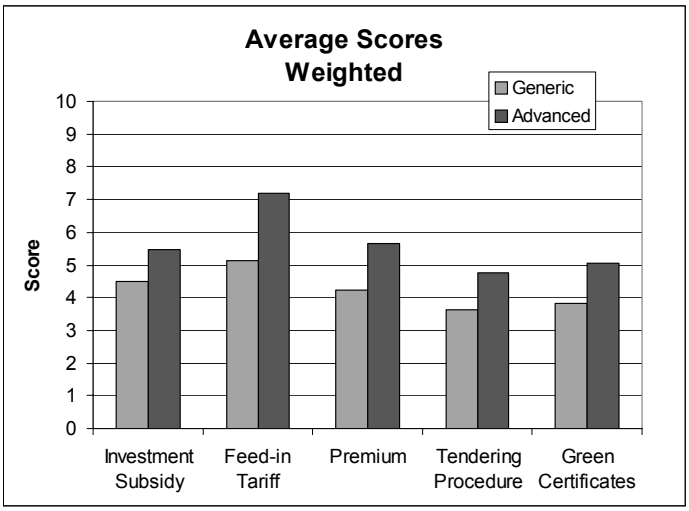
Figure 8. Importance of evaluation criteria for support schemes. Average and standard deviation of weights.



As shown in the figure two criteria stand out as the most important ones: Investor confidence and effectiveness, where the last-mentioned one defines how effective an instrument is in deployment of a renewable technology. Investor confidence is found to be more than twice as important as the thirdly chosen criterion of simplicity.

Subsequently another questionnaire was carried out with the specific task of identifying the best of five support schemes, defined in a generic and an advanced version. The results are shown in Figure 9 below.

Figure 9: Average weighted scores for each of five support schemes in a generic and an advanced version.



As shown the outcome points to the feed-in tariff as the preferred support scheme, followed by premium and investment schemes, leaving green certificates and tendering as the least preferred systems. Looking into details the feed-in tariff comes out very strong, especially with regard to investor confidence and effectiveness. The green certificate system scores significantly lower for both these criteria, indicating that the inherent uncertainties in the green certificate scheme make investors require a higher risk premium implying a lower deployment of RES. In the EU-communication on evaluation of support schemes the following conclusions on wind power are stated (Citation from European Commission, 2005):

"The green certificate systems present currently a significantly higher support level than the feed-in tariffs. This could be explained by the higher risk premium demanded by investors, the administrative costs as well as a still immature green certificate market. The question is how the price level will develop at the medium and long term." and "The most effective systems for wind energy are currently the feed-in tariff systems in Germany, Spain and Denmark." Finally, "Regarding profit, the feed-in systems investigated are effective with a relatively low producer profit. On the other hand, green certificates at present have

high profit margins. It should be emphasised that these green certificate systems are rather new instruments. The situation observed might therefore still be characterised by significant transition costs."

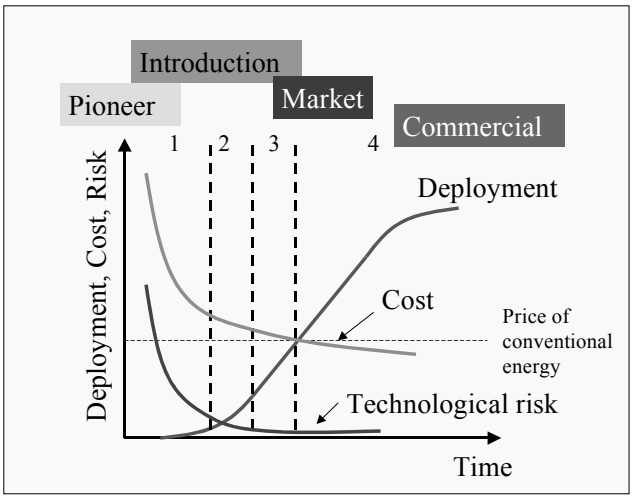
Thus, based on wind power experiences it seems that the picture is quite clear at present: The feed-in tariffs are performing better than the Green certificate systems, but of course things might change in the future.

For biomass it is pointed out, that the systems in Denmark (feed-in tariff) and Finland (hybrid system based on tax relief and investment support) "clearly show the best performance" (Citation from European Commission, 2005). But the analysis for biomass is more complex, other factors having a considerable influence.

In general it is concluded in the paper, that the specific design of the support systems is decisive for the performance. Thus, a well designed green certificate system might perform better than a badly designed feed-in tariff. And conditions outside the support system with regard to spatial planning and grid access might hamper the development of RES no matter how ideal the support scheme is by itself.

A final comment is directed towards the timing of different policy instruments. Because one instrument cannot facilitate the development of a new technology all the way;

Figure 10: The four phases of developing a renewable technology.



The development of RES-technologies can be split into four phases as illustrated by Figure 10:

1) The pioneer phase, where the new technology is started up, though still risky and technological unreliable.

2) The introductory phase, where the technology start to be marketed and where the costs and the technological risks are lowered significantly.

3) The market phase, where the costs are still above the price of conventional energy, but the technology is reliable and a strong deployment is driven by support schemes, and, finally,

4) The commercial phase, where the technology is on its own competing with other technologies on an equal footing (Skytte, 2004).

Each of these phases requires a specific support scheme to be efficient. In the pioneering phase the needs are mostly to bring down the risks and therefore measures as investment subsidies, grants, perhaps a simple feed-in tariff and certainly support of research and demonstration are well-suited for this period. In the introductory phase deployment should take off but we are still facing some technological risks and the costs are still pretty much above the price of conventional energy. Therefore a financial low risk support scheme as feed-in tariffs (eventually using benchmarking) with high confidence for investors could do the job. The closer we get to the commercial phase the more is needed a support scheme, that can facilitate the transition into a full competitive environment. In the market phase a differentiated feed-in tariff gradually changed into a premium system (eventually a well-designed green certificate system) could make the support scheme increasingly more market compatible.

Thus, there is a need, not only for well-designed support systems, but also for a well-timed utilisation of support systems according to the development pace and needs of the new technology.

23.2.6 Conclusions

Basically the Pfaffenberger paper describes the development of new renewable technologies in an excellent manner. Therefore this note has to be seen as a comment and a supplement to this paper and intentionally only a few important issues are treated. The main conclusions of this paper are:

- If we monetize externalities associated with both RES-technologies and conventional ones, the costs of renewable energy production would in many cases be (considerable) lower than conventional power production.
- RES-manufacturing (especially wind power) is moving from utilising standard components to be driving the development of new components. Product innovations spread from the RES-industry to other industries.
- Renewable technologies may facilitate the development of highly skilled research fields (e.g. wind power hub in Denmark), but may also increase working opportunities in areas with high unemployment placing manufacturing facilities in these areas.
- Intermittency might be the strongest barrier towards a high share of deployment of technologies as wind power and photovoltaics. Danish experiences with wind power show that short term intermittencies (within hours) can be coped with without excessive costs. Long term intermittencies (within days or weeks) is much more troublesome to handle and will require a long term development of the total energy system facilitating the introduction of these intermittent technologies.
- Though technologies as wind power and photovoltaics are expensive for power consumers because of high costs (high feed-in tariffs), these costs might be moderated somewhat through the impact on spot power prices, the low marginal costs of wind and PV decreasing the spot price on the power market.
- Concerning policy instruments for supporting RES the most important task is to make a well-designed support scheme. Based on experiences gained until now feed-in tariffs are in general found to be better performing in supporting the development of renewables, imposing a lower risk on investors. Nevertheless green certificate systems are still immature and better designed systems may improve the performance of theses schemes in the future.
- When new renewable technologies are developed the need for supporting these technologies will change over time. Therefore it is immensely important that the support systems are changed according to the development pace and needs of the new technology.

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Annex 1: Original programme[117]

Original programme from the Green Roads to Growth Forum in Eigtveds Pakhus, Copenhagen 1-2 March 2006.

[117] The original programme was in colour

green
roads to
growth

Programme

Green Roads to Growth Forum
Eigtveds Pakhus, Copenhagen
1 - 2 March 2006

Expert Forum
1 March 2006

Programme

8.00 **Registration with coffee**

8.30 Welcome and opening of Expert Forum
Peter Calow, Director, Danish Environmental Assessment Institute

8.40 What are the Linkages between Environmental Policy, Economic Growth and Job Creation?
Karsten Stæhr, Senior Economist, Danish Environmental Assessment Institute

9.00 Facilitation of Expert Forum Discussions
Nils Axel Braathen, Principal Adm., National Policies Division, Env. Directorate, OECD

9.10 **Session 1 – The Knowledge Based Economy**
Case Study Paper #1: "Innovation, technology and the global knowledge economy: Challenges for future growth", Prof. Jan Fagerberg, University of Oslo
Opponent #1A, Prof. Mario Pianta, University of Urbino
Opponent #1B, Jørgen Rosted, Director, FORA, Denmark

10.00 **Coffee break**

10.25 **Session 2 – Environment and Knowledge Based Growth**
Case Study Paper #2: "What Trade-off between Knowledge Based Growth and the Environment?", Hesham Morten Gabr, PhD, FORA
Opponent #2A, Uffe Nielsen, PhD, Danish Environmental Assessment Institute
Opponent #2B, Prof. Niels Kærgård, Institute of Food and Resource Economics, Denmark

11.15 **Session 3 – Eco Innovation**
Case Study Paper #3: "Environmental innovations and economic success of firms", Dr. Klaus Rennings, Senior Researcher, CEER, Germany
Opponent #3A, Prof. Fred Steward, Brunel University West London
Opponent #3B, Dr. Rene Kemp, Senior Research Fellow, Erasmus University Rotterdam

12.05 **Lunch**

13.05 **Session 4 – Green Taxation**
Case Study Paper #4: "Green taxation", Prof. Anil Markandya, University of Bath
Opponent #4A, Prof. Christoph Böhringer, CEER, Germany
Opponent #4B, Prof. Stephen Smith, University College London

13.55 **Session 5 – Agriculture**
Case Study Paper #5: "Support to organic farming and bio-energy as rural development drivers", Alex Dubgaard, Head of Environmental Economics and Rural Dev. Division, Institute of Food and Resource Economics, Denmark
Opponent #5A, Prof. Jukka Kola, University of Helsinki
Opponent #5B, Dr. Stijn Reinhard, Wageningen UR, The Netherlands

14.45 **Coffee break**

15.10 **Session 6 – Renewable Energy**
Case Study Paper #6: "Renewable energies – environmental benefits, economic growth and job creation", Prof. Wolfgang Pfaffenberger, International University Bremen
Opponent #6A, Dr. Herman Vollebergh, Erasmus University Rotterdam
Opponent #6B, Poul Erik Morthorst, Senior Researcher, Risø, Denmark

16.00 – 17.00 Policy Recommendations from the Expert Meeting
Nils Axel Braathen, Principal Adm., National Policies Division, Env. Directorate, OECD

Each of the six Sessions consists of a 15 min. Case Study Paper presentation and short Opponent Note presentations followed by discussion and questions from audience.

The Expert Forum explores the linkages between environmental policies, economic growth, and job creation, on the basis of theory and empirical evidence. Based on academic discussions 21 international experts will compile a list of Policy Recommendations. The list will be presented at the Policy Maker Forum on 2 March.

Policy Maker Forum

2 March 2006

Programme

8.30 **Registration with coffee**

9.00 Welcome and opening of Policy Maker Forum
Peter Calow, Director, Danish Environmental Assessment Institute

9.10 **Policy recommendations from the Expert Forum**
Nils Axel Braathen, Principal Adm., National Policies Division, Env. Directorate, OECD

9.30 Keynote, The European Perspective on Green Roads to Growth
Poul Nyrup Rasmussen, MEP (S), President of the Party of European Socialists, and former Prime Minister, Denmark

9.55 **Coffee break**

10.10 Keynote, The Danish Perspective on Green Roads to Growth
Connie Hedegaard, Danish Minister for the Environment (K)

10.30 Keynote, The Copenhagen Perspective on Green Roads to Growth
Ritt Bjerregaard, Mayor of Copenhagen (S), and former EU Commissioner for Environment

10.45 **Policy Maker Forum**
Round table discussion between high-level Policy Makers and key experts

- Connie Hedegaard, Danish Minister for the Environment (K) (tbc)
- Ritt Bjerregaard, Mayor of Copenhagen (S), and former EU Commissioner for Environment
- Dan Jørgensen, Member of the European Parliament (S)
- Eyvind Vesselbo, Member of the Danish Parliament (V)
- Steen Gade, Member of the Danish Parliament (SF)
- Robin Meige, EU Commission, Directorate General Environment
- Michel Catinat, EU Commission, Directorate General Enterprise and Industry
- Elisabeth Kasal, Austrian EU Presidency
- Jacqueline McGlade, Executive Director, European Environment Agency, Copenhagen
- John Hontelez, Secretary General of the European Environmental Bureau
- Lars Aagaard, UNICE (Union des Industries de la Communauté européenne)
- Nils Axel Braathen, Principal Adm., National Policies Division, Env. Directorate, OECD
- Associate Professor Arik Levinson, Economics Department of Georgetown University
- Professor Niels Kærgård, Institute of Food and Resource Economics, Denmark
- Professor Anil Markandya, University of Bath
- Professor Stephen Smith, University College London
- Professor Jan Fagerberg, University of Oslo
- Anders Hoffmann, Creative Director, FORA
- Dr. Klaus Rennings, Senior Researcher, CEER, Germany
- Alex Dubgaard, Head of Env. Economics and Rural Dev. Division, FOI, Denmark
- Professor Wolfgang Pfaffenberger, International University Bremen

- Chair: Kim Bildsøe Lassen, Journalist, DR

12.45 Closing of Green Roads to Growth Forum with personal reflections
Peter Calow, Director, Danish Environmental Assessment Institute

13.00 – 15.00 **Reception with refreshments**

At the Policy Maker Forum the Policy Recommendations from the Expert Forum are presented followed by a round-table discussion among 11 high-level policy makers and 10 key experts. A summary of policy contradictions and consensus will emerge from the Policy Maker Forum.

The purpose of the Policy Maker Forum is to inform Danish and EU Policy Makers on the linkages between environmental policies, economic growth and job creation on the basis of the framework of theory, empirical evidence and discussions between international experts and high-level policy makers.

Green Roads to Growth Forum

1-2 March 2006, Eigtveds Pakhus, Copenhagen

To which extent can environmental policies underpin the EU goals of improving economic growth, environmental quality and employment – all at the same time?

This is the main question to be discussed at the Green Roads to Growth Forum. The purpose is to inform Danish and EU policy makers on the linkages between environmental policies, economic growth, and job creation on the basis of theory, empirical evidence and round table discussions between leading experts and policy makers. The Green Roads to Growth Forum is an Expert Forum on 1 March and a Policy Maker Forum on 2 March.

Expert Forum 1 March

21 International Experts will present Case Study Papers and Opponent Notes at 6 Case Study Sessions. Based on academic discussions, the Expert Forum will produce a set of Policy Recommendations, which will be presented at the Policy Maker Forum on 2 March.

Policy Maker Forum 2 March

11 high-level Policy Makers including Danish Minister for the Environment, Connie Hedegaard (tbc), members of the Danish and European Parliament, Environmental NGOs, Industry Spokesperson and 10 key experts will participate in the Policy Maker Forum. They will engage in a round table discussion on the Policy Recommendations from the Expert Forum. The Policy Maker Forum will produce a Policy Discussion Paper summarizing the Round Table discussions.

Input to Green Roads to Growth Forum

19 scientific papers are specifically prepared for the Green Roads to Growth Forum:

- 1 Theoretical Framework Paper
- 6 Case Studies providing the evidence
- 12 Opponent Notes (two for each Case Study).

Output of Green Roads to Growth Forum

The Expert and Policy Maker Forums will respectively produce:

- An Expert Recommendation Paper
- A Policy Discussion Paper.

Green Roads to Growth Forum is open to the public.

Viscom as

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Rich, Jeppe Husted & Nielsen, Otto Anker (DTU).

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Saxe, Henrik; Busk, Rico & Petersen, Mads Lyngby.

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Nielsen, Uffe; Lerche, Dorte Bjerregaard; Kjellingbro, Peter Marcus & Jeppesen, Lykke Mulvad.

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Saxe, Henrik.

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ABOUT THE REPORT

"Green Roads to Growth" describes a programme of work carried out by the Danish Environmental Assessment Institute to explore the possible linkages between environmental policy and economic progress. The emphasis is on the EU but the principles apply broadly. This report constitutes the proceedings from Expert and Policymaker Forums that took place in March 2006.

The report opens with an Introduction, and a summary of the first day's discussions (Expert's Forum), and a summary of the second day's discussions (Policy Forum). The substance of the report follows a framework paper setting the scene. Six commissioned case study papers prepared by six independent groups of authors provided a basis for discussions. Each paper was reviewed by two independent experts, and both case study papers and opponent notes were made available to the Forums.

About IMV (Environmental Assessment Institute)

IMV is a policy analysis institute. The institute's approach is socio-economic analyses of environmental issues. Forming critical, independent views on the basis of existing knowledge and communicating these to policy makers and the public is the core objective of the Institute.

IMV was established in 2002. The Institute employs both environmental economists and natural scientists. In 2006 the Institute turns special focus on environment and growth, on EU-policy and on the applicability of socio-economic methods.

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