The role of technology development in international climate policy

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Properties of good global climate policies

- balance present costs against future benefits
- achieve climate goal at as low costs as possible (cost effectiveness)
- distribute costs “fairly” across countries

Examples of goals:

- Marginal costs of reducing emissions = marginal damage of emissions
- Atmospheric concentration of CO_2 should not exceed 450 ppm (Stern)
  - (or 500-550 ppm CO_2-equivalents)
- Temperature increase should not exceed 2 degrees (EU)
  - with 50% probability?
  - with 90% probability?

Cost effectiveness and the price of carbon

- correct carbon price with correct use gives cost effectiveness
  - allocation of emission reductions across sources
  - allocation of emission reductions across time
- carbon price as an emission tax or quota price
- carbon price as an input in cost-benefit analyses

The optimal carbon price

$$p(t) = \int_t^{\infty} e^{-(r+\delta)(s-t)} M(s) ds \qquad \text{(the Pigou level)}$$

$M(s)$ = marginal damages at time s

$p(t)$ will rise over time if $M(s)$ rises over time

$$0 \leq \frac{\dot{p}(t)}{p(t)} \leq r + \delta$$

- the level $p(t)$ will (usually) depend on the expected technology development
- the path of $p(t)$ should be revised over time as one obtains new information about technology and other variables

Example from DICE (Nordhaus, 2008):

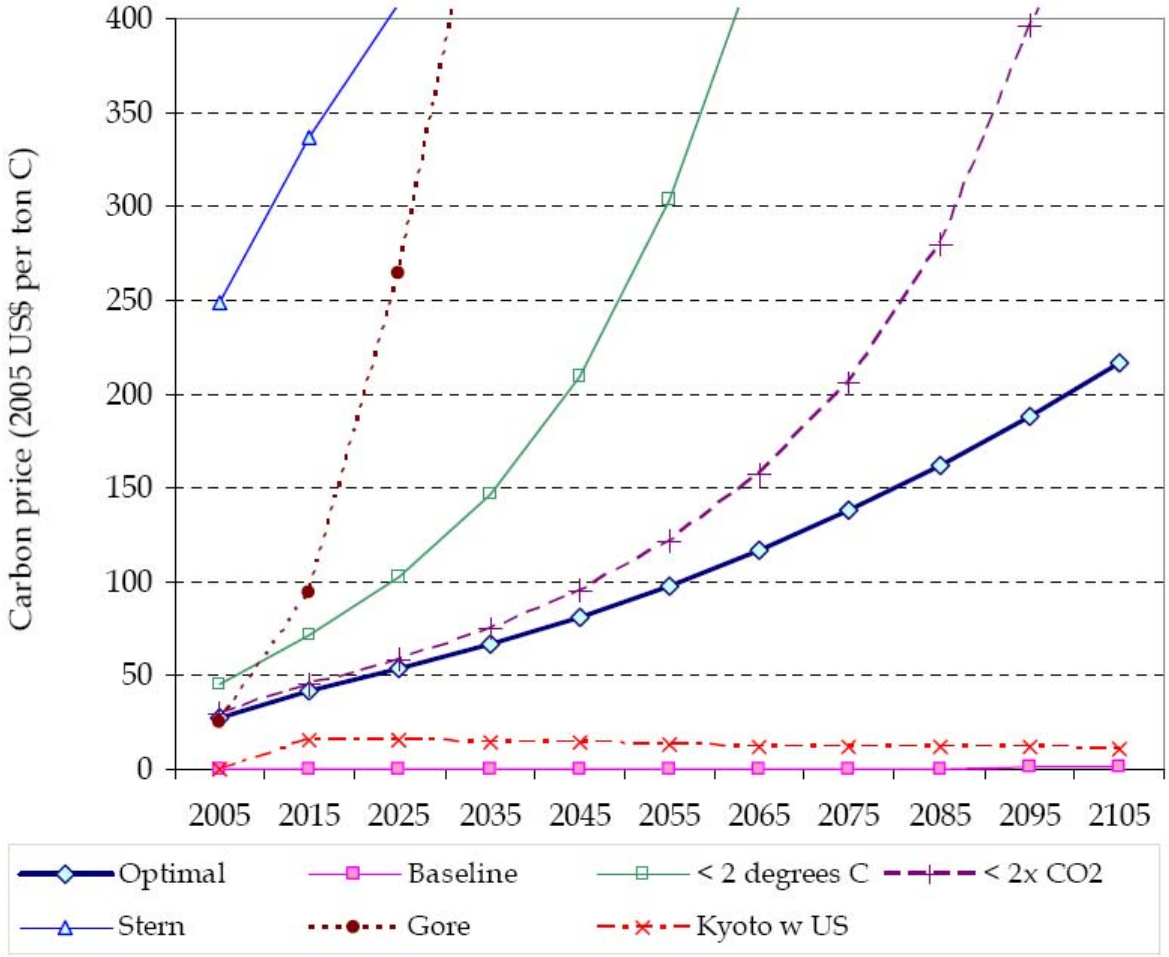

Figure V-4. Carbon prices for different strategies

Technology development

- uncertain
- depends on things we do
- R&D and LbD

Does a market outcome give optimal technology development?

- a correct carbon price is an important incentive for technology development
- but market failures
  - only part of benefit of new knowledge goes to creator of this knowledge
  - and other market failures
- different from other areas in the economy?

Literature on environmental policy with endogenous technology development

[for surveys see Löschel (2002), Jaffe et al. (2002), Requate (2005)]

- Comparison of different regulatory regimes
  - taxes
  - quotas
  - various forms of direct regulation
- Design of optimal environmental regulation
  - patent design
  - other instruments directed towards R&D
  - optimal emission tax rate (relative to Pigou level)

Climate policy and endogenous technology development

1) How is the optimal emission path affected?

2) How is the cost of achieving a stabilization target affected?

3) What does endogenous technological change imply for climate policies?

- patent design
- subsidies of R&D
- subsidies (and portfolio standards) of renewable energy and energy saving
- the optimal carbon price

[Some recent literature: Goulder and Schneider (1999), Goulder and Mathai (2000), Rosendahl (2004), Popp (2004, 2006a,b), Gerlagh and Zwaan (2006), Kverndokk and Rosendahl (2007), Gerlagh (2008), Gerlagh et. al (2008), Hart (2008), Fischer and Newell (2008)]

Subsidies to R&D?

- difficult in practise [Klette et al. (2000)]
- crowding out of other R&D [Popp (2004, 2006b)]

Subsidies to renewable energy and energy saving?

- difficult to justify unless there are technology externalities
- differentiated subsidies for different types of renewable energy and energy saving?

Can subsidies replace tax/quotas for CO2 emissions?

- No: Literature suggests this would increase mitigation costs dramatically

  [Gerlagh and Zwaan (2006), Fischer and Newell (2008)]

Carbon price development

The optimal carbon price is given by the Pigou rule if

- R&D can be satisfactorily influenced by other policy instruments
- no externalities from LbD

Otherwise the optimal carbon price path might be higher than the Pigou level

- but numerical models disagree on how strong this effect is

International climate agreements and endogenous technology development

[Some literature: Ploeg and de Zeeuw (1994), Xepapadeas (1995), Buchner and Carraro (2005), Barrett (2006), Golombek and Hoel (2004, 2005, 2006, 2008)]

1) Should an agreement contain elements related to technology development?
    - o interaction between technology elements and emission limits

2) Carbon leakage

3) Coalition stability

Carbon leakage

Reduced emissions in country A => increased emissions in country B due to

- increasing marginal environmental costs
- lower international prices of fossil fuels
- higher international prices of traded energy-intensive goods

Additional effect with endogenous technology*:*

- reduced emissions in country A => improved technology in country A and B
- improved technology in country B => reduced emissions in country B

Technology elements in an international climate agreement?

Yes in principle, due to

- technology spillovers across countries
- the carbon price implied by the agreement is too low (< Pigou level)

But likely to be difficult in practise

Second-best agreements (Golombek and Hoel)

a) covering only emissions

b) covering only technology

Agreement only on emissions

- the agreement should imply a carbon price above the Pigou level
- might want different carbon prices in different countries

Agreement only on technology

- not likely to achieve much

Technology development and the supply of fossil fuels

My own current research:

- no comprehensive climate agreement
- different countries (or groups of countries) have different WTP for reducing carbon emissions
- a perfect substitute for fossil fuels exists, but with a cost above the price of fossil fuels
- consequence of lower cost of substitute
  - emissions down if price of fossil fuels unchanged
  - but price of fossil fuels depends on present and future demand for fossil fuels
  - net result may be that emissions increase
  - social welfare may also decline

Summary

- The optimal carbon price, and thus the optimal mitigation efforts, in the near future depend on our expectations of future technology development
- Technology development depends on the carbon price and other policies
- Other policies should be *supplementary* to a sufficiently high carbon price
- International climate agreements should include elements related to technology development (if feasible)
- Cooperation on technology development should be *supplementary* to an agreement regulating emissions.

References:

Barrett, S. (2006), "Climate treaties and "breakthrough" technologies. *American Economic Review* 96 (2), pp. 22-25.

Buchner, B. and C. Carraro (2005): "Economic and environmental effectiveness of a technology-based climate protocol". *Climate Policy 4*, 229-248.

Fischer, C. and Newell, R.G. (2008), "Environmental and technology policies for climate mitigation", *Journal of Environmental Economics and Management* 55, 142-162.

Gerlagh, R. (2008), "A climate-change poicy induced shift from innovations in carbon-energy production to carbon-energy savings", *Energy Economics* 30, 425-448.

Gerlagh, R. and van der Zwaan, B:C:C: (2006), "Options and instruments for a deep cut in CO2 emissions: Carbon capture or renewables, taxes or subsidies?", *The Energy Journal* 27, 25-48.

Gerlagh, R., Kvedrndokk, S. and Rosendahl, K.E. (2008), "Linking environmental and Innovation policy", FEEM working paper 53.2008.

Golombek, R. and M. Hoel: "Unilateral Emission Reductions and Cross-Country Technology Spillovers", *Advances in Economic Analysis & Policy*: Vol. 4: No. 2, Article 3 (2004). (http://www.bepress.com/bejeap/advances/vol4/iss2/art3)

Golombek, R. and Hoel, M. (2005), "Climate policy with technological spillovers", *Environmental and resource economics* 31, pp. 201–227.

Golombek, R. and Hoel, M. (2006), 'Second-best climate agreements and technology policy', *Advances in Economic Analysis & Policy.* Vol. 6: No. 1, Article 1. http://www.bepress.com/bejeap/advances/vol6/iss1/art1.

Golombek, R. and Hoel, M. (2008), "Endogenous technology and tradable emission quotas", *Resource and Energy Economics* 30, 197-208.

Goulder, L.H. and S. Schneider (1999):"Induced technological change, crowding out, and the attractiveness of CO2 emissions abatement", *Resource and Environmental Economics* 21, 211-253.

Goulder, L.H. and Mathai, K. (2000), "Optimal CO2 abatement in the presence of induced technological change", *Journal of Environmental Economics and Management* 39, 1-38.

Hart, R. (2008), "The timing of taxes on CO2 emissions when technological change is endogenous", *Journal of Environmental Economics and Management*, 55, 194-212.

Kverndokk, S. and Rosendahl, K.E. (2007), Climate policies and learning by doing: Impacts and timing of technology subsidies", Resource and Energy Economics 29, 58-82.

Jaffe, B., G. Newell, R. Stavins (2002), "Environmental policy and technological change," *Environmental and Resource Economics* **22** (special issue), 41-69.

Klette, T.J., Møen, J. and Griliches, Z. (2000), "Do subsidies to commercial R&D reduce market failure?" Research Policy 29, 471-479.

Löschel, A. (2002), "Technological change in economic models of environmental policy: A survey," *Ecological Economics **43**, 105-126.*

Nordhaus, W.D. (2008), *A Question of Balance: Economic Modeling of Global Warming.* Yale University Press.

Requate, T. (2005), "Dynamic Incentives by Environmental Policy Instruments--A Survey", *Ecological Economics* 54, 175-95.

Rosendahl, K.E. (2004), "Cost-effective environmental policy: Implications of induced technological change", *Journal of Environmental Economics and Management* 48, 1099-1121.

Ploeg, F. and A. de Zeeuw (1994): Investment in Clean Technology and Transboundary Pollution control, in Carraro, C., *Trade, Innovation, Environment*. 229-240. Netherlands, Dordrecht: Kluwer Academic Publishers.

Popp, D. (2004), "ENTICE: Endogenous Technological Change in the DICE Model of Global Warming", *Journal of Environmental Economics and Management* 48(1), 742-768.

Popp, D. (2006a), "ENTICE-BR: The effects of backstop technology R&D on climate policy models", *Energy Economics* 28, 188-222.

Popp, D. (2006b), “Innovation in climate policy models: Implementing lessons from the economics of R&D”, *Energy Economics* 28, 596-609.

Xepapadeas, A. (1995), “Induced technical change and international agreements under greenhouse warming,” *Resource and Energy Economics* ***17***, 1-23.