Optimal Climate Finance

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June 4, 2024

Abstract

We analyse the efficiency and effectiveness of climate finance using the standard microeconomic theory/framework traditionally used to assess other externality reducing policies. We model climate finance as a capital (or capital cost) intervention aimed at reducing emissions, which can be voluntary or coordinated through regulation. Because of high information requirements and investment costs, these interventions will often be imperfectly targetted to emissions (but rather at firms, sectors or even, commonly, green/brown aggregates), and not directly incentivizing emissions reductions. Climate finance is thus an indirect emissions-reducing instrument. We describe implications of its imperfect grip, highlighting the difficulty of simulatanesouly exploiting between-sector/firm and within-sector/firms reduction possibilities, which severely limit its potential effectiveness and efficiency. Yet, we derive rules for optimal targetting (taxonomy design), and derive the (second-best) optimal capital cost subsidy/taxation schemes which balance within and between-group reductions. We describe effectivnesss, efficiency and distributional implications of common strategies including taxonomies, green bonds, ESG investing and divestment, both in absolute terms and relative to the (first-best) carbon pricing.

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Introduction

The economics literature concerned with addressing climate change has mostly endorsed carbon pricing policies due to their cost-efficiency. Yet, despite its theoretical attractiveness, the implementation of this direct approach has encountered substantial political resistance, with the effective price of carbon lagging behind its social cost. "climate finance"—encompassing various initiatives to reallocate capital with the objective of reducing greenhouse gases—has received considerably less attention by the environmental economics profession. This is despite investors already managing trillions of dollars of climate-friendly assets and governments increasingly adopting this approach (including through the design of "green taxonomies"). We provide, to our knowledge, the first theoretical framework in which to evaluate the effectiveness, efficiency, and distributional consequences of climate finance, similar to the large literature doing the same for carbon pricing.

Methods

We have developed a model focussed on investment across technologies, firms and sectors. The core assumption is that capital[1] and emissions—from fossil fuel combustion or industrial processes—are complementary at the activity (or technology) level, yet at least partially substitutable at the firm or sector level[2]. Our approach involves modeling substitution possibilities using general functional forms, constant elasticity of substitution production functions (to develop intuition) and a technology-based microfoundation (to map to data). We examine a coordinated financial industry that is concerned with social surplus (including the external cost of carbon). Our theoretical results are primarily resolved in general equilibrium with sectoral interactions, but we also present accessible partial equilibrium approximations.

Results

We examine conditions under which climate finance[3], through investing/divesting in firms, sectors, or "green" aggregates (or, equivalently, tilting capital costs), achieves the same first-best capital allocation and emission reductions as carbon pricing. We argue that these conditions are unlikely to hold in practice. The first requires directly incentivizing firms to lower capital costs by reducing emissions. Feasible in some cases, it entails crafting contracts linking capital costs to emissions, impossible to most investors. Theoret-

[1] Physical capital or the financial capital required to invest in physical capital.

[2] Imagine a firm choosing between investing in a less capital-intensive (cheaper) but more emissions-intensive technology or a more capital-intensive (expensive) technology that is associated with less emissions (e.g. an electricity producer having to invest in a new plant with a scrubber versus a new plant without.

[3] Whether voluntary interventions on the part of concerned investors or coordinated through regulation.

ically, climate finance can also be first-best optimal if "perfectly targeted" to investments where emissions are directly controllable (technically speaking, where emissions and capital always enter the production in fixed proportions). Again, while sometimes feasible (f.ex. 'project-level' climate finance), broad application would entail unreasonably large information requirements. Thus, we argue that a significant part of climate finance is in practice targeted at the firm or sector level, often even through simple green/brown categories (as sometimes defined through taxonomies). Under these conditions, capital has an "imperfect grip" on emissions, with significant implications which we explore.

Consider the example of a cement-producing firm. Based on its high CO_2-intensity, investors might decide to increase its capital costs to discourage production. We define this as a "between-firm" emissions reduction. However, because of imperfect grip, doing so might discourage investment in emission-reducing technologies, increasing emissions through "within-firm" substitution between emissions and capital.

Results

This section presents a non-exhaustive sample of results.

- We describe formulas describing the (in)effectiveness and (in)efficiency of (imperfectly targeted) capital cost interventions, including a decomposition into between and within effects. For example:

  $$\frac{dE}{d\lambda} = \underbrace{\sum_g \frac{Y_g}{p_g r_g} e_g^2 \sigma_g}_{Within>0} - \underbrace{VAR^{\frac{Y_g}{p_g r_g}\eta_g}(e_g)}_{Between<0} \gtreqless 0$$

  .. describes the effect of a capital cost intervention λ on total emissions E, in which the capital costs of firms (or sectors) g are increased according to the average emissions intensity of their capital, a commonly used investment rule.

  Between firm/sector re-allocation always reduces emissions, with reductions proportional to the variance in emissions intensity e_g. This reduction is mitigated by within sector subsitution between emissions and capital, proportionally to the average elasticity of subsitution between factors, weighted by the square of emissions intensity.

  This trade-off, linked to imperfect grip, has recent empirical backing from Hartzmark and Shue (2023 working paper), who offer the first substantial evidence that diverting capital from "brown" firms may paradoxically increase emissions. Our framework provides a theoretical framework to understand this investment decision

Similar formulas are proposed for various climate finance "targeting" strategies, as well as for cost-efficiency defined as the welfare cost per ton of emission reduced. Most of the expressions are derived as sufficient statistics and can be quantified using readily available data. For example, effectiveness is proportional to the covariance between the within effect and between effect, i.e. stronger (weaker) if CO_2-intensive firms/sectors are less (more) prone to within-sector substitution than average, once appropriately weighted.

- The "optimal" (second-best) capital cost interventions δ_j to be applied to each firm/sector j:

$$\delta_j^* = \frac{dEj}{dK_j}\omega \gtreqless 0$$

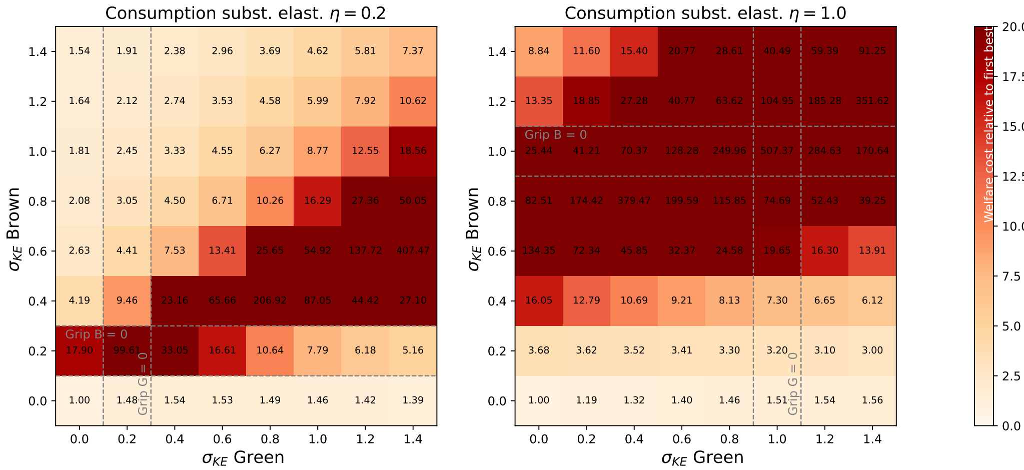
.. are a function of the grip of capital on emissions $\frac{dEj}{dK_j}$ and the social cost of emissions ω. These interventions can be positive or negative, i.e. "taxes" or "subsidies" to capital costs, depending on a firm/sector's relative contribution to between-sector reallocation relative to within-substitution. We propose formulas allowing to estimate this grip based on a limited number of observable or estimable parameters. Extensions describe how to include a firm/sector's grip on emissions in other parts of the economy through demand and input-output linkages, suggesting f.ex. ways to identify which parts of the supply chain should be targeted.

- While optimal climate finance reduces within-sector substitution and is thus found to unambiguously reduce emissions, (welfare) costs of emissions reductions are significantly higher than under first best carbon pricing: reductions are concentrated in (well-defined) sectors with high grip, leading to higher distortions to capital allocation.

- Numerical simulations: In a two-sector example, the following figure illustrates the (welfare) cost to society of reducing emissions using climate finance relative to carbon pricing, for various combinations of factor substitution possibilities in the green (x-axis, increasing from left to right) and brown sectors (y-axis, increasing from bottom to top) as well as levels of substitutability in consumption (low on the left, high on the right).[4].

While inefficiency relative to first best-carbon pricing is expected, the (parameter) space in which climate finance remains cost-efficient is limited. This has clear implications for investors or for policy-makers designing taxonomies: interventions must

[4]These numbers are the result of simple general equilibrium simulations in which capital costs are adjusted in each sector according to the optimal δ_j's above. The aggregate capital is stock is fixed, but energy is elastically supplied, and household/investor/government budgets are fixed, allowing a fair comparison of carbon pricing and climate finance.



remain limited to groups of technologies, firms or sectors with strong grip. This requires very low substitutability between emissions and capital, particularly in the more emissions-intensive "Brown" sectors.

- Guidelines for governments or regulators (for example by creating taxonomies that limit information requirements and limit within-group imperfect grip).

- Distributional impacts also differ from carbon pricing, both through the income channel (how climate finance deferentially affects households based on their dependency on capital versus labor income), and through the consumption channel (it deferentially affects the price of goods households consume).

We are currently actively working on bringing our theoretical model and simulation framework to the data. While we will not be able to quantify the cost of better "targeting" , we will be able to quantify the benefits of defining sector- firm- or even technology-specific capital costs.
We estimate capital-energy substitution at each level, allowing us to provide numerical estimates of the spreads in capital costs implied by optimal externality-correcting investment, as well as aggregate efficiency costs.

Data

Numerical calibrations may rely on the following data sources (among others). At the firm level: emissions data from SP Global Trucost; ESG ratings data from MSCI ESG Ratings; at the sector-level: production and consumption data from GTAP or WIOD, capital and energy intensity data from various sources, such as the Manufacturing Energy Use Survey.

Conclusions

The financial economics literature on sustainable investing is extensive, with Landier and Lovo (2022 working paper) providing a comprehensive overview. However, this body of work overlooks technological substitution possibilities between capital and energy, thus bypassing issues of grip. To our knowledge, no other article has attempted to estimate the aggregate welfare effects of climate finance.

Our paper also contributes to the economic literature on indirect regulation, particularly studies on imperfect, second-best policy responses to environmental externalities e.g., Diamond (1973), Knittel and Sandler (2018); and Jacobsen, Knittel, Sallee, and van Benthem (2020).

Overall, our findings deepen understanding of how financial markets can aid in combating climate change and brings us closer to defining "optimal climate finance". Beyond academic interest, our results will profit investors concerned about the environmental impact of their investments as well as governments aiming to regulate markets and design interventions and taxonomies.