Optimal Green Finance*

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Abstract

Green or sustainable finance seeks to reduce greenhouse gas emissions by reallocating capital from the most to the least emissions-intensive economic activities. We examine the effectiveness and efficiency of the financial approach to a production externality using the standard microeconomic analysis apparatus traditionally used to assess externality pricing. We model green finance as a capital (or capital cost) intervention, which can be voluntary or induced by public regulation. First-best optimal green finance requires either a specific intervention for each economic project or complex firm-level interventions contingent on each firm's actions, instead of a single carbon pricing instrument. In practice, green finance interventions are imperfect. They target capital in a group of activities, such as, firms, sectors, and, most often, green or brown aggregates, changing the group's cost of capital in a non-contingent fashion, thus, not directly incentivizing emissions reduction. Moreover, green finance is an indirect approach seeking to change emissions through capital or its cost. We examine the grip of capital over carbon emissions at various levels of intervention. Our analysis highlights the difficulty of simultaneously exploiting the "between-groups" reallocation effect of green finance, and its "within-group" effect on emissions intensity. This limits the potential effectiveness of green finance and has the potential of making green finance interventions counterproductive. Our formulas have implications for the design of an effective taxonomy maximizing impact. We also derive (second-best) optimal investment rules balancing, on the one hand, within- and between-groups effects on emissions and, on the other hand, the production inefficiency due to the reallocation of capital. Finally, we illustrate how sector-level costs of capital should be adjusted to align finance with decarbonization objectives and the deadweight-loss of green finance.

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I. Introduction

Green finance aims to provide funds for economic activities that have a lower climate impact. Over the past decades, the rise of green finance has been reflected in various investor actions: divestment from the most carbon-intensive sectors, specialized equity funds financing corporations with lower carbon footprints, and green bonds financing certified climate-friendly projects.

Besides investors, policy-makers embrace the financial approach to the climate challenge as is reflected by the implementation or discussion of various measures: the design of green finance standards—e.g., EU's recent taxonomy, second pillar of its climate action, among many other similar initiatives—governments' support to green bonds, financial regulators' targeted long-term refinancing operations, and lawmakers' discussions over instruments to promote banks' investment in greener activities.

Now more than ever, it is hoped that the financial approach to the climate challenge will help economies cut their emissions of greenhouse gases. As green finance advocates put it, echoing French President Emmanuel Macron's call for dual interest rates, these initiatives should translate in different interest rates for "green" and for "brown" activities, reducing the relative cost of capital in favor of green and away from polluting assets.[1]

The financial approach to emissions' reduction strikingly differs from economists' traditional prescription to price carbon emissions directly, rather than penalizing polluting activities through their cost of capital. Yet the obvious political resistance to carbon pricing accounts for the low proportion of emissions priced and for large carbon pricing gap even in developed economies. As Pedersen (2024) notices in a pioneering paper comparing the carbon pricing approach to its financial counterpart—see other related in our literature review further below—the prevalence of green finance worldwide seems large in comparison with the coverage of emissions by carbon pricing; yet little is known about the indirect effectiveness of the provision of capital at reducing carbon emissions in a cost-effective manner.

In this paper, we examine whether a production externality can be addressed indirectly through the allocation of capital and, if so, how it should be. We use static economic theory, a model calibrated based on empirical estimates, and its numerical simulation. Let a sector be a set of productive activities that combine capital and emissions-generating inputs. We obtain formulas indicating how the provision of capital to one sector (or its cost of capital) impacts this sector's and others' emissions, and we derive their implications for the welfare-maximizing provision of capital to each sector, or the optimal green penalty to be applied on capital. We illustrate optimal green finance and compare its social cost with respect to first-best carbon pricing.

Our analysis highlights that the effectiveness and the efficiency of the green finance approach at reducing emissions depend both on the level of intervention (divestment/investment or incentives) and on the technical relation between capital and emissions at this level.

Since green finance is an indirect approach, aiming to affect emissions through capital rather than directly, it imperfectly resolves the carbon externality, in general. We say "in general" because there are two exceptions to the imperfect nature of the green finance approach.

1. See, for example, `https://www.sustainableviews.com/ecb-urged-to-introduce-green-and-brown-interest-rat`

First, at the microeconomic level of Leontief type of technologies in which capital and other inputs are used in fixed proportions, capital is then strongly linked to other inputs, so that its allocation has the potential to implement the first-best resolution of the externality. In practice, however, to administer this solution is much more demanding than to price carbon because the former calls for examining every microeconomic project including its relation between capital and emissions. In reality, green finance interventions are made at a more aggregate level, selecting firms (e.g., green equity funds), subsets of firms' projects (e.g., green bonds), entire sectors (e.g., oil divestment, sin stocks), or some technologies used in various sectors (e.g., green finance taxonomies). The level of green finance interventions raises the question of the technical relation between capital provision and emissions.

To address the issue of the technical impact of capital provision on emissions, we define and characterize formally the "grip of capital," a metric that is specific to each green finance decision and that, perhaps interesting, differs from commonly-used emissions intensity measures according to substitution possibilities within each targeted group of activities.

Second, we show that if investors make a firm's cost of capital contingent on its emissions intensity, they could provide it with adequate incentives, in line with Pedersen's formulas.

In practice, capital provision to greener businesses lowers the cost of capital for these businesses in a way that is not contingent to their production decisions.[2] Given the current practice, it seems unrealistic that concerned investors or regulators will coordinate to design and enforce firm-level contracts based on firms' decisions.

More generally, green finance could be prohibitively difficult to manage if it calls for setting a specific cost of capital for each project, firm, or technology used. This is reflected by the archetypal green finance practice of treating capital use in a binary fashion, mainly discriminating green from other brown assets.[3]

At the level of one polluting sector or firm, we show that the effect of a lower provision of capital—equivalently, an augmented cost of capital—is limited by the internal substitution of emissions for capital, increasing the emissions intensity. This effect is in line with HS' recent empirical finding that polluting firms increase their carbon intensity when facing an augmented cost of capital. We characterize the net effect of capital interventions on emissions by the "grip of capital," a new theory-based, calculable metric that is specific to each firm or sector. The grip differs from often-used emissions intensity measures according both to the specific degree of substitutability between emissions-generating inputs and capital and to the output demand response.

Green finance interventions (through the provision of capital or its cost) permit to reduce the emissions

2. One seeming exception is sustainability-linked bonds, but the link between the cost of financing and the firm's performance is designed by the issuer itself, not its investors.

3. Exceptions rely on more categories but remain discrete. For example, CICERO certifier offers grades that are "shades of green" and the EU taxonomy includes a "transition" category.

externality but at the price of a distortion in the provision of capital: For a given reduction in emissions, the amount of capital is reduced more than it would be under first-best direct emissions pricing. The green finance distortion is inversely proportional to our grip measure. Properties of the grip have implications for the activities that should be targeted in priority by investors, i.e., for the design of effective and efficient taxonomies.

Then, we examine reallocation effects induced by green finance interventions. Capital may be reallocated across sectors, orienting capital used in more emissions-intensive sectors towards sectors that are less so. Demand may be reallocated across technologies within a sector. In both cases, by contrast with carbon pricing, the effectiveness of green finance is limited by the tension between the two margins of emissions reductions: the "between-reductions"—decreasing the relative size of brown sectors/firms—and the "within-reductions"—reducing the emissions intensity of each sector/firm.

Finally, we use a calibrated model in which two groups of activities, green and brown, compete for capital and demand. Simulations compare the effect of optimum green finance to carbon pricing. They show that the parameter space for cost-efficient green finance is narrow and that the social cost of emissions reductions through green finance is in most cases several times greater than the minimum cost obtained through carbon pricing.

II. Related literature and contribution

The finance literature has examined the effects of investors' environmental screening. Chava (2014) finds that investors require significantly higher returns on investment in excluded companies, increasing significantly the cost of capital (equity or debt) of affected firms. In the case of divestment from the coal sector, Green and Vallee (2022) find that bank exit policies negatively affect both the financing and operation of coal assets. Substitution to other sources and providers of capital appears to be limited. Duchin et al. (2024) study the asset market for pollutive plants and suggest that effective capital penalties requires that investors be coordinated. Berk and van Binsbergen (2025) establish the factors determining the impact of exclusion on the cost of capital and suggest that the largest social fund are still likely to have a limited impact. Hartzmark and Shue (2024) suggest that the effect os capital penalties are limited by technological change within targeted firms, making them more emissions intensive. All these papers exploit the binary dimension of green finance interventions, divesting from excluded firms or investing in their green counterparts.

Pedersen's (2025) pioneering paper is the first to consider the potential of an augmented cost of capital to address an externality. He focuses on capital penalties that mimic carbon pricing, suggesting that both their theoretical structure and orders of magnitude are unrealistic. His analysis leaves unexplored situations in which green-finance induced changes in the cost of capital contribute to addressing the carbon externality in a second-best fashion.

Our paper is also related to the economic literature on indirect regulation, particularly studies on imper-

fect, second-best policy responses to environmental externalities, e.g., Diamond (1973), Knittel and Sandler (2018); and Jacobsen, Knittel, Sallee, and van Benthem (2020).

In general, the literature has overlooked both constraints that limit the structure of green finance interventions (e.g., with respect to carbon pricing) and the technological relation between capital and energy. To our knowledge, our article is the first to attempt to estimate the welfare effects of optimized green 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.

III. Capital provision to a single sector

In this section, we examine how capital provision can be changed to address a negative externality generated by a production sector. We define the sector as a firm or a group of firms producing a homogeneous good (e.g., cement manufacturing industry) and we consider it in isolation of the rest of the economy.

We purposely focus on a single sector to start with, for two main reasons: First, this simple case will be sufficient to examine the efficiency properties of green finance; second, it will be a useful benchmark in more complex frameworks including the allocation of capital across various sectors and/or various technologies within sectors (Section IV).

Production of the commodity can be achieved by combining capital and carbon-emitting inputs—called "emissions," for short—such as fossil fuels. In general, this combination takes place through various substitutable technologies, each characterized by specific input intensities. In this section, we adopt the usual and meaningful representation that the sector's technological possibilities are summarized by a representative firm's production function. We denote this function by $Y = F(K, E)$, where Y is output, K is capital and E is "emissions." We assume that function F is twice differentiable and strictly concave.[4]

Let $p > 0$ be the output price, established on the output competitive market. The representative firm's output is used by a representative consumer with a quasi-linear utility objective in which $U(Y)$ is the twice-differentiable, strictly concave utility derived from the output use. We will focus the analysis on situations in which $U'(0) > p$ so that some production is warranted. The first-order condition for the maximization of quasi-linear utility yields the standard independent demand: $P(Y) = U'(Y)$.

The unit private cost of emissions is $c > 0$ and their unit external cost (e.g., social cost of carbon) is $\omega > 0$, and both are fixed exogenously. The unit cost of capital is $r > 0$, taken as given by the sector and exogenous at this stage. In the next section, r will be endogenously determined by the allocation of capital across sectors.

4. In this section, regardless of our representation of technical possibilities within the sector, we will use sector, firm, or representative firm interchangeably.

Social optimum. We will characterize production plans, on the one hand, by the size of production and, on the other hand, by the input composition of this production. In Appendix A, we define the marginal social cost function $MSC(Y)$ of producing output Y and the marginal rate of technological substitution of capital for emissions $MRTS(K, E)$, which is the change in emissions that technically results from a marginal increase in capital, production $Y = F(K, E)$ held unchanged. We characterize the socially optimal production plan by, on the one hand, its output *size* Y^*, such that

$$P(Y^*) = MSC(Y^*), \tag{1}$$

and by, on the other hand, its input combination (K^*, E^*) such that

$$MRTS^*_{KE} \equiv MRTS(K^*, E^*) = \frac{r}{c+\omega}, \tag{2}$$

which determines the emissions-capital ratio, also called emissions-intensity of capital.

The optimal production plan is illustrated in Figure 1, as explained further below.

Decentralized equilibrium, policy instruments, and size vs. intensity. We now consider the decentralized equilibrium of the sector and examine the potential both of emissions pricing and of green finance to effectively reduce the externality and to implement the socially optimal production plan.

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Assume that emissions are taxed or priced at the unit rate $\tau > 0$, and that revenue proceeds are rebated to the consumer in a lump-sum fashion. Taking τ as given, the firm maximizes its profit.

In Appendix A, we characterize the marginal private cost function $MPC(Y; r, c+\tau)$ of producing output Y given input prices. The equilibrium size of the sector is determined by the equality between price and marginal cost:

$$P(Y) = MPC(Y; r, c+\tau), \tag{3}$$

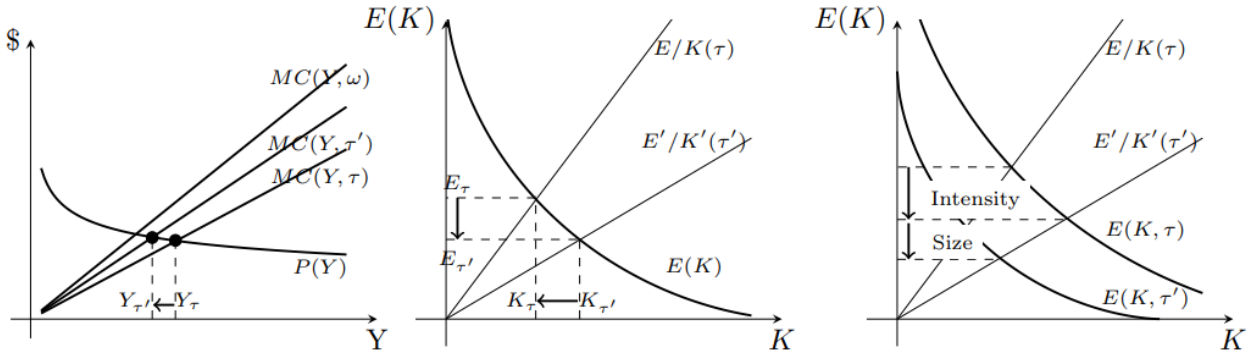
instead of (1) in the socially optimal plan. In Figure 1, (1) is represented in panel (a), and determined output Y corresponds to levels of isoquants in panels (b) and (c).

For a given size Y, the firm's emissions intensity is determined by the equality between the marginal rate of technical substitution of capital for emissions and the price ratio:

$$MRTS^e_{KE} \equiv MRTS(K, E) = \frac{r}{c+\tau}. \tag{4}$$

In Figure 1, a change in intensity follows from a change in the input composition along a given isoquant.

Example 1 (Iso-elasticity case). *Figures are based on the folloiwing case. Consider a constant-elasticity-of-substitution (CES) production function* $Y = A\left[\alpha K^\gamma + (1-\alpha)E^\gamma\right]^{\frac{\nu}{\gamma}}$*, where* ν *is a returns-to-scale parameter, and an iso-elastic demand* $P(Y) = Y^{-\epsilon}$*.*



(a) Size effect (b) Intensity effect (c) Both effects

Figure I: The effects of carbon pricing on one sector

We obtain the marginal cost function:

$$MPC(Y) = \frac{[(c+\tau)+r\beta]}{\nu \cdot A^{\frac{1}{\nu}} \cdot (\alpha\beta^{\gamma}+(1-\alpha))^{\frac{1}{\gamma}}} \cdot Y^{\frac{1}{\nu}-1}.$$

The equilibrium output size is:

$$Y^{e} = \left(\frac{\nu \cdot A^{\frac{1}{\nu}} \cdot (\alpha\beta^{\gamma}+(1-\alpha))^{\frac{1}{\gamma}}}{[(c+\tau)+r\beta]} \right)^{\frac{1}{c+\frac{1}{\nu}-1}},$$

where

$$\beta = \left(\frac{r}{c+\tau} \cdot \frac{1-\alpha}{\alpha} \right)^{\frac{1}{\gamma-1}}.$$

The equilibrium input ratio is:

$$\left(\frac{E}{K}\right)^{e} = \left[\frac{r}{c+\tau} \frac{1-\alpha}{\alpha} \right]^{\frac{1}{1-\gamma}}.$$

The homotheticity property of the CES production function implies that the above ratio is independent of the output size.

The welfare-maximizing counterparts of these equations, including MSC, are obtained by setting $\delta = 0$ *and* $\tau = \omega$.

III.A. First-best emissions pricing

The well-known Pigovian approach to resolving the emissions externality will be a useful benchmark to assess the potential of its financial counterpart.

Proposition 1 (Effectiveness and efficiency of Pigovian emissions pricing).

1. *An emissions price reduces both production size and emissions intensity, cutting emissions non-ambiguously;*

2. *The welfare benefit of cutting emissions by one marginal unit through emissions pricing is equal to the unpriced external effect, $\omega - \tau$;*

3. *If emissions are priced at their marginal external cost $\tau^* \equiv \omega$, then the sector's equilibrium plan is socially optimal.*

The property that emissions pricing is unambiguously effective because it reduces the sector's emissions both through the size margin, reducing production, and through the input composition margin, reducing the emissions intensity of production, is illustrated in Figure 1.

Throughout this paper, it will turn out to be useful to formally decompose the effect of policy instruments as per how they affect, on the one hand, the size of a sector's production, and, on the other hand, the contribution of emissions of this production. Denoting the sector's (endogenous) production intensity in emissions by $e = E/Y$, the change in the sector's total emissions may be written as

$$dE = \underbrace{Y\,de}_{intensity} + \underbrace{e\,dY}_{size}.$$

In our setting, the presence of other inputs of production in addition to capital and emissions are implicit in the production function. Assuming, for simplicity, that returns to capital and emissions were constant, as if there were no other inputs, we obtain the following formula, breaking the effect of the increase in emissions pricing on emissions ($d(eY)$) into its size margin (edY) and its intensity margin (Yde):

$$\frac{dE/E}{d\tau/\tau} = \underbrace{-\frac{\tau}{p}e\varepsilon}_{\text{size}} \underbrace{-\frac{\tau}{p}kMRTS_{KE}\sigma_{KE}}_{\text{intensity}}, \tag{5}$$

where $e \equiv E/Y$ and $k \equiv K/Y$ denote the (endogenous) emissions and capital intensity of output, $\varepsilon \equiv |p/YP'(Y)|$ is the sector's elasticity of demand (in absolute value), and $\sigma_{KE} \equiv d(K/E)/dMRTS_{KE} \times MRTS_{KE}/(K/E)$ is the elasticity of substitution between K and E.

Let us consider now the welfare impact of emissions pricing. Although the mechanism of environmental taxation is well known, it is interesting to recall it here for comparison purposes will be a Dividing the change in welfare induced by a marginal increase in the carbon price by the associated emissions reduction, we obtain

$$\frac{dW/d\tau}{-dE/d\tau} = \omega - \tau,$$

the social benefit of cutting emissions by a marginal unit through emissions pricing. It follows that welfare is maximum under Pigovian emissions pricing, at a rate equal to $\tau^* = \omega$. At this rate, equations (3) and (4) are equivalent to their social-optimum counterparts (1) and (2).

In the rest of the paper, we will mainly consider situations in which emissions pricing is restricted. Emissions may be priced but at a set level τ that is not controllable and that falls short of the external cost of emissions: $\tau < \omega$.

III.B. First-best green finance

We will now introduce green finance as an alternative approach to resolving the externality. When green finance is effective, it impacts the cost of capital of targeted activities. In this section, we model green finance as a change δ in the sector's cost of capital instead of its cost of emissions. This is formally equivalent to directly changing the amount of capital provided to the firm, as if, for example, concerned investors' divestment, reduced a sector's capital and raised its cost.

In our framework, Pigovian pricing does not call for any green finance intervention. Indeed, were emissions optimally priced, green finance would make the sector's plan socially suboptimal. It is the restriction that emissions pricing falls short of its Pigovian level that gives rise to the possibility that green finance plays a corrective role. Our analysis will formally validate this intuition shortly below.

Our analysis of green finance parallels our previous study of carbon pricing. In particular, it focuses on the allocative properties of both instruments. We do not need to consider whether changes in the sector's cost of capital δ stem from a coordinated action of investors or from a governmental intervention—see the introduction for examples of both. We assume that if green finance generates tax proceeds, these revenues are rebated to the consumer in a lump-sum fashion. We assume similarly that if it requires public subsidies, these can be financed through non-distortionary levies.

In theory, green finance can mimic emissions pricing and implement the socially optimal production plan in two main cases, summarized by the following result. We will discuss the conditions that they require thereafter.

Proposition 2 (First-best green finance). *Green finance would implement the social optimum in the following cases:*

1. ***(Emissions-contingent green finance)*** *If the capital cost instrument δ was the following linear function of the firm's realized emissions intensity E/K:*

$$\delta^* \left(\frac{E}{K} \right) = (\omega - \tau) \frac{E}{K}; \tag{6}$$

2. ***(Perfectly-targeted green finance)*** *If δ was determined at a micro level that does not feature substitution possibilities, where capital and emissions are perfect complements, and its rate was:*

$$\delta^* = (\omega - \tau) \frac{\hat{e}}{\hat{k}}, \tag{7}$$

where $\hat{e}$ and $\hat{k}$ are the technology-specific emissions and capital intensities of output respectively.[5]

First, according to formulas (6) and (7), the externality calls for effectively changing the cost of capital by $\delta^* \neq 0$ only absent Pigovian emissions pricing, i.e., when $\tau \neq \omega$. This validates our intuition that green finance is only justified when emissions pricing is restricted. If first-best green finance was possible, however, it would be a perfect substitute to Pigovian externality pricing. Under this condition, therefore, the impossibility of Pigovian pricing would not be an issue theoretically since optimal green finance could restore the socially optimal production plan.

In general, Pedersen (2025) demonstrates that green finance can mimic emissions pricing when each firm's cost of capital becomes function of each firm's characteristics, including its emissions intensity.[6] In our model, the optimal capital penalty takes the simple and meaningful form expressed in (6), corresponding to the product of the emissions intensity of capital with the unpriced external cost $\omega - \tau$. In equilibrium, the firm is induced to choose the optimal combination (K^*, E^*) and its cost of capital is augmented to $r + (\omega - \tau)E^*/K^*$.

In reality, there exist green finance instruments allowing a firm's cost of capital to be linked to its environmental performance. Firms increasingly issue sustainability-linked bonds (SLBs, for short) that make coupon payments to bond holders contingent on environmental objectives. For example, the Italian energy company Enel, issued a bond in 2023 in which coupon payments are function of the carbon intensity on the electricity produced. Proposition 2's Condition 1 establishes that SLBs have the potential to provide adequate incentives to firms. Moreover, it suggests conditions under which this potential could be realized, with implications for the structure of SLBs. The first condition is that the entirety of the firm's capital should be financed through an SLB. The second one is that coupon payments should include a penalty proportional to the (unpriced) external effect generated by the firm $(\omega - \tau)E$ per unit of capital mobilized.

Similarly, there exist green finance instruments that allow the financing of a firm's specific project, such as green bonds. In the past few years, for example, Apple has issued green bonds to finance renewable energy projects (e.g., solar and wind farms) to decarbonize its supply chain. Proposition 2's Condition 2 establishes that green bonds have the potential to provide firms with adequate incentives to develop specific projects. The first condition for this potential to be realized is that green bonds finance projects at such a granular level that these projects feature no possibility of substitution between capital and emissions. For example, one green bond should finance a project involving a single renewable energy source (e.g., solar or wind) but not a variety of sources. The second condition is that the cost of capital for each project is set equal to the

5. The Leontief technology is a limit case of our framework although it is excluded by our assumption of strict convexity of the production set. For example, as is well known, this technology is the limit of strictly convex CES technologies when the elasticity of substitution tends to zero.

6. In our static model, in contrast with Pedersen's two-stage framework, the issue of firms' ability to commit does not arise because its cost of capital is determined at the same time as it makes decisions.

fixed emissions intensity of capital that characterizes the project.

In practice, SLBs and green bonds represent almost 10% of the global bond issuance.[7] Moreover, SLBs provide for coupon rates that, although linked to environmental performance, are functions proposed by issuers rather than imposed by investors, involving arbitrary measures of environmental performance (e.g., CO2 intensity of output) that have no theoretical foundation. Finally, green bonds only certify that financed projects are green instead of conventional, only allowing investors to discriminate green projects and conventional ones, making it impossible that investors generate a specific cost of capital for each project.

In light of the current practice, therefore, first-best green finance instruments described in Proposition 2 require a degree of information and of coordination that not only is without comparison with carbon pricing but also seems unrealistic.

III.C. Second-best green finance

We adhere to the constraints reflected by the practice of green finance. As our introductory examples illustrate, in general, green finance manages capital (penalizing or promoting it) at an aggregate level of activities that is either sectoral (e.g., fossil fuels, high-carbon emitting industries vs. other sectors) or categoric (e.g., green vs. brown firms or projects). Moreover, within these aggregates, green finance does not generate a cost of capital that depends on environmental performance.

The following assumption focuses our analysis accordingly.

Assumption 1 (Imperfectly targeted, non-contingent, green finance). *We assume that green finance is (1) imperfectly targeted, in the sense that it induces a change in the cost of capital that applies at some aggregate level (e.g., sector, green category), and (2) non contingent, in the sense that it does not induce a cost of capital that is function of environmental performance.*

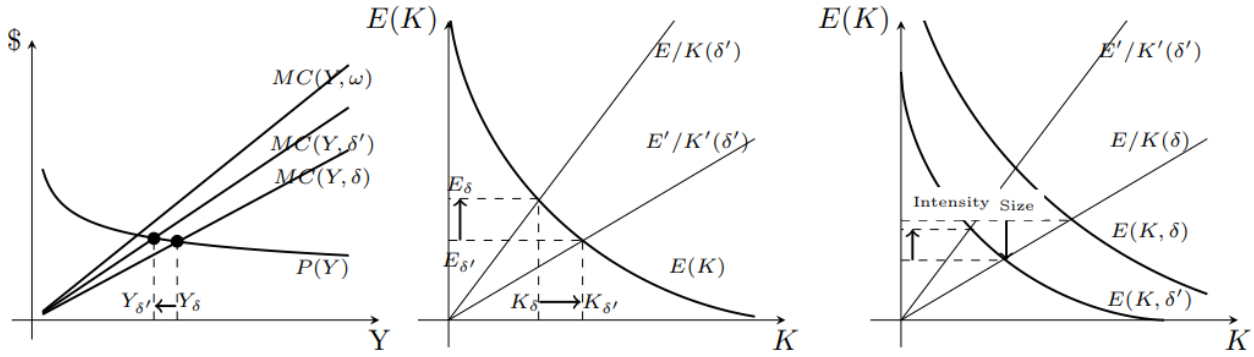
The assumption excludes the two cases of first-best green finance presented in Proposition 2, implying that green finance cannot mimic Pigovian emissions pricing. It focuses the analysis on more realistic situations in which green finance changes the cost of capital at the aggregate level of an entire sector or of a category of activities.

In this section, in line with Assumption 1, we consider that the change in the sector's cost of capital, δ, is not function of the firm's decisions. Including δ, the equilibrium production plan is characterized by equations:

$$P(Y) = MPC(Y; r + \delta, c + \tau), \tag{8}$$

$$MRTS^{e}_{KE} \equiv MRTS(K, E) = \frac{r + \delta}{c + \tau}. \tag{9}$$

7. See, e.g., `https://www.spglobal.com/esg/insights/featured/special-editorial/global-sustainable-bonds-2023-issuance-to-exceed-900-billion`.



(a) Size effect (b) Intensity effect (c) Both effects

Figure II: The effects of green finance on one sector

Analysis of this system immediately highlights the difference between green finance and carbon pricing. Unlike Proposition 1, green finance at the sector level cannot reduce both the sector's size and its emissions intensity.

Based on Examples 1 and 2's formulas, Figure 2 illustrates the effect of increasing the cost of capital, raised by δ to $\delta' > \delta$: The sector becomes smaller, but, unlike emissions pricing, it becomes more intensive in emissions.

Example 2 (Iso-elasticity case). *In this case, δ affects the sector's output and its input ratio as indicated by the following formulas:*

$$Y^e = \left(\frac{\nu \cdot A^{\frac{1}{\nu}} \cdot (\alpha\beta^\gamma + (1-\alpha))^{\frac{1}{\gamma}}}{[(c+\tau) + (r+\delta)\beta]} \right)^{\frac{1}{\epsilon + \frac{1}{\nu} - 1}},$$

where

$$\beta = \left(\frac{r}{c+\tau} \cdot \frac{1-\alpha}{\alpha} \right)^{\frac{1}{\gamma-1}};$$

$$\left(\frac{E}{K} \right)^e = \left[\frac{r+\delta}{c+\tau} \frac{1-\alpha}{\alpha} \right]^{\frac{1}{1-\gamma}}.$$

The following proposition summarizes our results.

Proposition 3 ((In)effectiveness of green finance). *By contrast with emissions pricing, green finance cannot reduce both the sector's size and its emissions intensity, potentially making green finance counterproductive.*

In the graphical example of Figure 2, the augmented cost of capital leads to a decrease in emissions. One could easily simulate an example in which the sector's emissions are induced to increase. In this case, the

intensity effect increasing the contribution of emissions is not compensated by the size effect. This simple case substantiates the possibility that green finance be counterproductive, unlike carbon pricing.

Recent empirical evidence supports the theoretical effect of green finance on the emissions intensity: Hartzmark and Shue (2024) find that an increase in financing costs for emitting firms leads these firms to become more emissions intensive on average, suggesting that divestment from a polluting sector could be counter-productive if this sector's size were unchanged. Our analysis, however, demonstrates that the effect of green finance on carbon emissions is not only to impact carbon intensity within the targeted sector but also to impact this sector's size. Taking into account the size effect of green finance, overlooked by Hartzmark and Shue (2024), on top of its intensity effect, the total effect of green finance on emissions is ambiguous.

The following formula decomposes the effect a change in the cost of capital δ on the sector's emissions into, on the hand, a size component, and, on the other hand, a composition component—see the proof in Appendix A.

$$\frac{dE/d\delta}{E} = \frac{1}{\alpha_{KE}} \frac{1}{p} \frac{K'(Y)}{\frac{1}{\varepsilon_D} - \frac{1}{\varepsilon_S}} + \frac{\alpha_K}{\alpha_{KE}} \frac{1}{r+\delta} \sigma_{KE}, \tag{10}$$

where terms $\alpha_K \equiv (r+\delta)K/(pY)$, $\alpha KE \equiv [(r+\delta)K+(c+\tau)E]/(pY)$ are income shares, $\varepsilon_D \equiv p/(YP'(Y)) < 0$ is the price elasticity of demand, $\varepsilon_S \equiv MPC(Y)/(YMPC'(Y) > 0$ is the price elasticity of supply—the inverse of the elasticity of marginal cost—$K'(Y)$ is the derivative of the conditional demand for capital with respect to the output level, and σ_{KE} is the elasticity of substitution between capital and emissions.

The first term on the right-hand side of (10) captures the size effect of δ. It is negative provided the demand for capital is increasing in output; in that case, an augmented cost of capital reduces the sector's emissions because it reduces the sector's size. It is lower in absolute value in a lower elasticity sector.

The second term captures the composition effect of δ. It is nonnegative and proportional to the elasticity of substitution σ_{KE}; an augmented cost of capital induces the sector to substitute emissions for capital. The extent of this substitution is indicated by $\sigma_{KE} \in (0, 1)$.

Overall, Formula (10) indicates how effective an increase in the cost of capital is at reducing emissions, as a weighted sum of the output elasticity and the elasticity of input substitution. It tells that, in a relatively inelastic sector in which technological possibilities allow firms to use capital to cut emissions, an increase in the cost of capital may be counterproductive.

We obtain a symmetric formula for the effect of δ on K. It implies an expression for $(dE/d\delta)/((dK/d\delta))$, the ratio that we coin "the grip of capital over emissions," which will play a crucial role in the efficiency of green finance:

$$\frac{dE/d\delta}{dK/d\delta} = \frac{E}{K} \frac{\frac{K'(Y)}{\frac{1}{\varepsilon_D} - \frac{1}{\varepsilon_S}} + \alpha_K \frac{p}{r+\delta} \sigma_{KE}}{\frac{K'(Y)}{\frac{1}{\varepsilon_D} - \frac{1}{\varepsilon_S}} - \alpha_E \frac{p}{r+\delta} \sigma_{KE}} \leq \frac{E}{K}. \tag{11}$$

Consider two polar cases in which δ affects emissions either through the size effect or through the

composition effect. In the absence of substitution possibilities ($\sigma_{KE} = 0$), $dE/dK = E/K > 0$, in line with the perfect complements limit case examined earlier. In the absence of size effect, for example when $\varepsilon_D = 0$, $dE/dK = -(r+\delta)/(c+\tau) = -MRTS_{KE} < 0$.

In general, the formula reflects that the grip of capital over emissions is maximum in the perfect complements case, validating an introductory intuition. Indeed, substitution possibilities ($\sigma_{KE} > 0$) make the equilibrium relation between capital and emissions softer. This result can be obtained more directly from the definition of the elasticity. When the input substitution occurs as a result from a change in the cost of capital, this definition implies:

$$\frac{dE}{dK} = \frac{E}{K} + \frac{E\sigma_{KE}}{r+\delta}\frac{1}{dK/d\delta}, \tag{12}$$

where the law of supply implies $dK/d\delta \leq$ so that the the second term on the right is non positive.

We will see further below that attenuation of the grip due to substitution possibilities will have dramatic consequences for the efficiency of the green finance approach to carbon reduction.

Example 2 (Iso-elasticity case). *In this case, the grip of capital over emissions is given by:*

$$\frac{\frac{dE}{d\delta}}{\frac{dK}{d\delta}} = \frac{E}{K}\cdot\frac{\frac{\beta}{\frac{A(\alpha\beta^\gamma+(1-\alpha))^{\frac{1}{\gamma}}}{\frac{1}{\epsilon_D}-\frac{1}{\epsilon_S}}} + \frac{\alpha K^\gamma}{\alpha K^\gamma+(1-\alpha)E^\gamma}\cdot\frac{p}{r+\delta}\cdot\frac{1}{1-\gamma}}{\frac{\beta}{\frac{A(\alpha\beta^\gamma+(1-\alpha))^{\frac{1}{\gamma}}}{\frac{1}{\epsilon_D}-\frac{1}{\epsilon_S}}} - \frac{(1-\alpha)E^\gamma}{\alpha K^\gamma+(1-\alpha)E^\gamma}\cdot\frac{p}{r+\delta}\cdot\frac{1}{1-\gamma}} \leq \frac{E}{K}.$$

In the case of constant returns to scale, the role of the size and intensity effects are captured by the demand elasticity ε and the elasticity of input substitution σ_{KE} respectively. The following formula shows that it is their difference that determines the sign and magnitude of the grip:

$$\frac{dE}{dK} = \frac{(\varepsilon - \sigma_{KE})}{(\frac{\theta_E}{\theta_K}\sigma_{KE} + \varepsilon)}\frac{e}{k} \leq \frac{e}{k}, \tag{13}$$

where the size effect is $e\frac{dY}{d\delta} = -\frac{Y}{p}\,e\,k\,\eta < 0$, proportional to the demand response, and the intensity effect is $Y\frac{de}{d\delta} = \frac{Y}{p}\,e\,k\,\sigma_{KE} > 0$), proportional to the elasticity of substitution between capital and emissions. This case brings up a simple and meaningful insight: Green finance is effective at reducing emissions if and only is $\eta > \sigma_{KE}$; otherwise, it is counterproductive. In this case, one can verify that the effect of a capital penalty on emissions has the same sign as the grip:

$$\frac{dE/E}{d\delta/\delta} = \frac{\delta}{p}k(\sigma_{KE} - \eta). \tag{14}$$

In line with our interpretation of Formula **??**, its expression in (13) indicates that the grip is perfect when capital and emissions are perfect complements ($\sigma_{KE} = 0$), equal to the emissions' instensity as in the Leontief limit case: $dE/dK = e/k$. It also shows that, absent any size effect ($\varepsilon = 0$), the grip is negative. It also shows that, under constant returns to scale, the grip of capital on emissions is systematically softer because of substitution possibilities: $dE/dK > e/k$ if and only if $\sigma_{KE} > 0$.

- If $\sigma_{KE} = 0$ (no within-sector change in intensity), $\frac{dE}{dK} = \frac{e}{k}$
- If $\eta = 0$ (no size effect), $\frac{dE}{dK} = -\frac{r}{c}$ (with two factors only)

At the (micro) level of activities/technologies for which capital and emissions are perfect complements, the grip of capital over emissions is at its maximum, i.e., equals the emission intensity of capital e/k. In this case, there is no within-sector substitution, thus no trade-off with optimal size, and we are back to the first-best plan.

With a strictly convex technology, however, the grip is weaker. The grip (like the effectiveness of green finance) is determined both by the curvature of the production function as well as the sensitivity of the demand to price.

While the strength of the grip (a function of $\eta - \sigma_{KE}$) is ultimately an empirical question, there is nothing to prevent it from being negative, a situation in which less capital results in less output but the sector's increased emissions intensity more than compensates, resulting in more emissions.

The softer relation between capital and emissions has implications for the (in)efficiency of green finance. Suppose a strictly convex sector with a positive grip $dE/dK > 0$, for simplicity. Reducing the sector's emissions calls for penalizing capital through $\delta > 0$. From a social welfare perspective, it means allocating less capital to this sector than under first-best emissions pricing, therefore causing a production inefficiency in the allocation of capital in order to resolve the original emissions inefficiency.

The welfare impact of the green finance approach is illustrated in Figure 2 in the case of a positive grip. Consider a profit-maximizing allocation of capital and emissions in which emissions are taxed at rate τ and capital is penalized at rate δ. The latter implies $MP_K \equiv P\left(F(K,E)\right) F_K(K,E) = r + \delta$, a departure from the optimal allocation rule $MP_K = r$, meaning that a marginal increase in δ reduces capital at a welfare cost equal to δ. Yet, this marginal decrease in capital translates into an emissions reduction given by the grip. This emissions reduction, in turn, translates in a welfare improvement equal to $(\omega - \tau)$, the non-internalized external cost of emissions.

Formally, the welfare contribution of a marginal increase in the capital penalty is

$$\frac{dW}{d\delta} = -(\omega - \tau)\frac{dE}{d\delta} + \delta\frac{dK}{d\delta},$$

where a positive grip implies that the first term is positive, capturing that a green finance capital penalty reduces excessive emissions, and that the second term is negative, reflecting that the penalty is suboptimal for the allocation of capital. It follows that the effect of avoiding a marginal unit of emissions through green finance is

$$-\frac{dW/d\delta}{dE/d\delta} = (\omega - \tau) - \frac{\delta}{dE/dK}. \tag{15}$$

In comparison, one can show that the welfare effect of reducing a marginal unit of emissions through

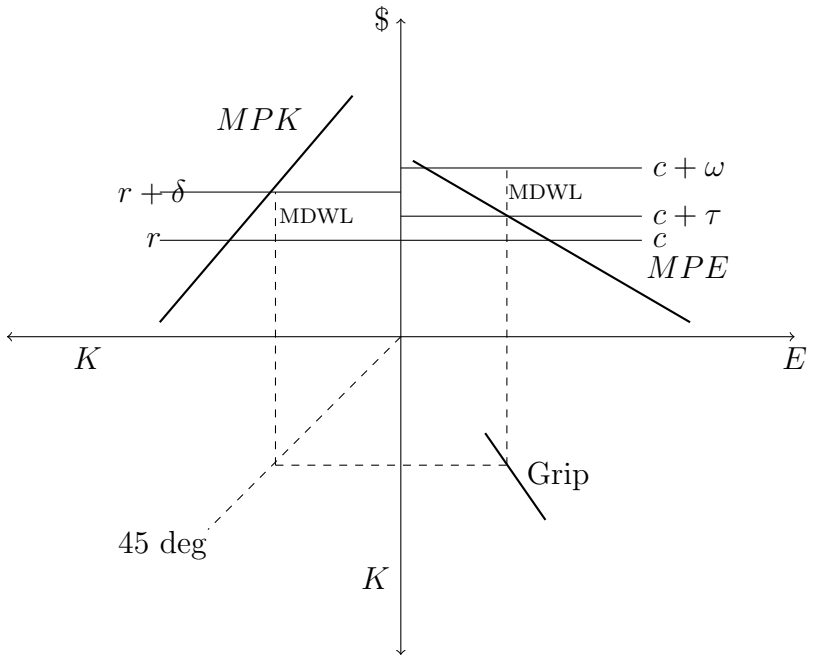


Figure III: The joint distortions in the use of capital and the generation of emissions

emissions pricing is $\frac{dW/d\tau}{-dE/d\tau} = \omega - \tau$.[8]

The comparison yields an insightful interpretation to (15): The parenthesis on its right-hand side captures the reduction of the environmental externality, the same welfare effect as under emissions pricing. The last term on the right, negative, reflects the inefficiency of departing from the optimal rule of capital allocation by introducing an additional cost of capital δ. This term shows that green finance is less efficient than carbon pricing at reducing emissions. It also shows that this distortion is inversely proportional to the grip. Symmetrically, if the grip is negative, the reduction of emissions would call for more rather than less capital, with the same welfare implications.

Welfare-maximizing green finance equalizes the marginal benefit in (15) to zero. It yields a second-best, green, optimal investment rule:

$$MP_K^{**} = r + \frac{dE}{dK}^{**} (\omega - \tau), \tag{16}$$

where $MP_K \equiv P\left(F(K,E)\right) F_K(K,E)$ and where the superscipt ** indicates that variables are evaluated at the (second-best) welfare maximum. The optimal green finance rule departs from the usual first-best rule $MP_K = r$ by adding a capital penalty $dE/dK \times (\omega - \tau)$ equal to the product of the grip with the unpriced

8. It follows from this expression that, welfare is maximum under Pigovian emissions pricing, at a rate equal to $\tau^* = \omega$.

externality. This optimal rule amounts to setting the optimal capital penalty

$$\delta^{**} = \frac{dE}{dK}(\omega - \tau). \tag{17}$$

If the sector's grip of capital over emissions is positive, optimal green finance calls for a capital penalty, $\delta^{**} > 0$. Vice versa, if it is negative, the green finance approach to the emissions externality calls for promoting capital allocated to the sector through $\delta^{**} < 0$.

Although (17) is reminiscent of **??**, the former is a second-best optimal policy, reducing emissions in a more costly manner than carbon pricing.

The following proposition summarizes our results on the efficiency of green finance under Assumption 1.

Proposition 4 ((In)efficiency of green finance).

1. *We define a sector's grip of capital over emissions as the ratio of the change in emissions over the change in capital provision induced by a change in the cost of capital;*
2. *A sector's grip is maximum in absence of substitution possibilities, equal to the sector's emissions intensity of capital;*
3. *Possibilities of substitution between capital and emissions attenuate the grip;*
4. *The economic distortion due to green finance is inversely proportional to the grip;*
5. *Optimized green finance commands to penalize (promote) capital in positive(negative)-grip sectors according to the product of the grip and of the marginal unpriced externality;*
6. *This (second-best) optimal policy depends not only on the targeted sector's emissions intensity of capital, but also on the response of the demand it faces and of the substitutability of capital and emissions, and is, therefore, sector specific, unlike uniform carbon pricing.*

IV. Reallocation of capital

In the previous section, we have focused on a single sector in which the technology is captured by a production function featuring possibilities of substitution between capital and emissions. In this context, we have examined the effect of capital provision to this sector on its emissions and on the surplus that it generates. We have shown that the optimal (in general, second-best) rule of capital provision depends on the sector's grip of capital over emissions.

In this section, we seek to examine two types of more realistic green finance interventions. The first one consists in reallocating capital across sectors, orienting capital used in more emissions-intensive sectors towards sectors that are less so. The second one is to make a distinction between technologies within a sector and to promote (discourage) capital provision to the least (most) emissions-intensive technologies.

We explore these two common approaches to green finance, building on the results previously established, in a very stylized way stressing the indirect effect of green finance that they involve.

IV.A. Reallocation of capital across sectors

Divestment is a common practice of green finance that commits investors to not financing certain sectors (e.g., fossil fuel extraction, conventional energy generation etc). More generaly, Chava (2014) shows that investors' demand is lower for stocks excluded by environmental screens (e.g., hazardous chemical, climate change concerns).

Suppose that the economy can be divided into two sectors, each with the same qualitative properties as the single sector presented in Section 2. Suppose that one sector is less emissions intensive (green, for short); variables related to this sector will be denotes by a G subscript. The more emissions-intensive sector (brown) will be denoted by a B subscript.

We assume a fixed amount of capital is allocated across the green and brown sectors through a competitive market. By contrast with the previous section, the cost of capital r is endogenously established by the balance between (fixed) supply and the demand of both sectors.

Moreover, we assume, for simplicity, that each sector's output meets an independent demand function of its own price only. That is, this stylized model of capital reallocation across sectors purposely focuses the analysis on the allocation of capital as the unique interaction between the two sectors.[9]

It follows that a change in one sector's capital provision goes hand in hand with an opposite change in the other sector's provision: $dK^B = -dK^G$. In turn, the economy-level grip of capital in one sector can be expressed as the difference between the two sectors' grips. For example, an increase $dK^G > 0$ or a decrease $dK^B < 0$ in the capital allocated to the green or brown sectors has the following impact the economy emissions:

$$\frac{d(E^B + E^G)}{dK^G} = -\frac{d(E^B + E^G)}{dK^B} = \frac{dE^G}{dK^G} - \frac{dE^B}{dK^B}.$$

Once the grip of one sector's capital over economy-level emissions is adjusted to take the reallocation of capital across sectors into account, the analysis of the previous section unfolds unchanged. We obtain the following results.

Proposition 5 (Reallocation of capital across two groups).

- *With two groups competing for a fixed supply of capital, a single instrument is sufficient to implement optimal green finance;*
- *The grip of capital in one group over the economy's emissions is the difference between group-level grips;*

9. In the next section, we will examine optimal green finance quantitatively in a model in which sectors are also linked by the demand for their output.

- *Green finance should target negatively groups with high grips (augmenting their cost of capital) and/or target positively groups with low grips (reducing their cost of capital);*
- *Green finance would mimic first-best carbon pricing in the limit case in which each of the two groups has a Leontief technology with perfect grip; otherwise, it generates a production inefficiency that is inversely proportional to the difference between the groups' grips of capital.*

IV.B. Capital provision to substitutable technologies within a sector

Another green finance approach is to target, instead of entire sectors, the least emissions-intensive technologies within a sector. For example, the EU sustainable finance taxonomy makes the distinction between types of cement-making technologies that should be promoted and others, which should not.[10]

In this subsection, we examine this approach in a stylized model of a sector or firm focusing on a brown or conventional (B) and a green (G) production technologies both combining inputs K and E to produce substititutable outputs Y_B and Y_G respectively. Outputs Y_B and Y_G are combined through a production function $Y = F(Y_B, Y_G)$, assumed globally concave, to produce the sector output Y, meeting an independent demand, like in Section III. Each technology combines E and K in fixed proportions e_G and k_G, and e_B and k_B, respectively. Unlike the previous subsection, we assume that the cost of capital r is exogenous to the sector or firm, as if the capital allocated to sector's green and brown technologies was small at the economy level.

The equilibrium allocation of the sector can be characterized by its size Y and the relative contribution of technologies Y_B and Y_G. The rest of the allocation follows from the fact that K and E in each technology are fixed proportions of Y_B and Y_G.

Its size is characterized by

$$P(Y) = MPC(Y; r, c + \tau), \tag{18}$$

where Appendix A redefines MPC as resulting from the cost-minimizing balance between the use of the two technologies, unlike **??** in Section III.

For a given size Y, the firm's relative use of the green and brown technologies is given by:

$$MRTS^e_{BG} \equiv MRTS(B, G) = \frac{p_B}{p_G}, \tag{19}$$

where $p_B = k_B(r + \delta_B) + e_B(c + \tau)$ and $p_G = k_G(r + \delta_G) + e_G(c + \tau)$.

In this context, we show that the effect of a penalty to capital in the brown technology has a negative effect on emissions generated by this technology:

$$\frac{dE_B}{d\delta_B} = \frac{1}{\alpha_{BG}} \frac{k_B E_B}{p} \frac{Y'_B(Y)}{\frac{1}{\varepsilon_D} - \frac{1}{\varepsilon_S}} - \frac{\alpha_G}{\alpha_{BG}} k_B E_B \sigma_{BG}, \tag{20}$$

10. However, the taxonomy does not make the distinction between green technologies of various sectors, equally labeled "green."

where elasticities are price elasticities of the output demand and supply.

δ_B directly increases p_B, which reduces Y_B and Y and therefore reduces proportional emissions (even when the output price is established by the market rather than exogenous in the supply problem). The difference with the effect of δ in Section III's analysis with one sector is that in the latter, the effect on E is not indicated by the law of supply.

A comparable formula indicates the effect of δ_B on E_G. It will be added to the appendix. The overall effect of δ_B is both to reduce the size—of the sector's output Y (law of supply)—and to improve the composition of the sector—reducing Y_B/Y_G.

The total effect of the capital penalty δ_B is given by the following formula:

$$\frac{dE}{d\delta_B} = \frac{1}{\alpha_{BG}} \frac{k_B E}{p} \frac{Y_B'(Y)}{\frac{1}{\varepsilon_D} - \frac{1}{\varepsilon_S}} - \frac{1}{\alpha_{BG}} k_B \sigma_{BG} \left[\alpha_B E_G - \alpha_G E_B\right]. \tag{21}$$

The formula predicts that the size effect reduces the sector's emissions, whereas the composition effect is only negative, decreasing the sector's emissions if the brown technology generates enough emissions ($E_B/E_G < \alpha_B/\alpha_G$). A priori, the case of counterproductive green finance is possible even when we penalize brown technologies within sectors.

When a penalty on the capital provided to the brown technology δ_B is effective at reducing emissions, its optimal level depends on the grip of brown capital over emissions, which we will determine now. Here, the optimal penalty is second-best optimal despite the fact that technologies have Leontief technologies. But if two penalties $\delta_B, \delta_G > 0$ were applied, I suppose that the first-best optimum could be implemented.

The grip of brown capital over the sector's emissions is:

$$\frac{dE}{dK_B} = \frac{d(E_B + E_G)/d\delta_B}{dK_B/d\delta_B} = \frac{e_B}{k_B}\left[1 + \frac{dE_G/d\delta_B}{dE_B/d\delta_B}\right].$$

Using the expressions previously derived, we obtain:

$$\frac{dE}{dK_B} = \frac{e_B}{e_G}\left[1 + \frac{E_G}{E_B} \frac{\frac{Y_B'(Y)}{1/\varepsilon_D - 1/\varepsilon_S} + \alpha_B p \sigma_{BG}}{\frac{Y_B'(Y)}{1/\varepsilon_D - 1/\varepsilon_S} - \alpha_G p \sigma_{BG}}\right]$$

Symmetric formulas indicate the effect of δ_G on emissions. A reduction in δ_G, promoting financing of the green technology has a positive size effect—increasing the sector's total output—and a negative composition effect—improving the relative contribution of the green technology therein. The overall effect of δ_G is ambiguous.

The following proposition summarizes our results.

Proposition 6 (Reallocation of capital across two technologies within a sector).

1. *The first-best optimal plan can be implemented by applying sector-technology-specific penalties to the capital provided both to the brown and to the green technology;*

2. *Interventions targeting (penalizing) brown technologies are more effective than interventions targeting (promoting) green technologies because the former are effective both through the size margin and through the sector composition margin;*

3. *Even though technologies have a perfect grip, their emissions intensity does not indicate their grips and, therefore, are inadequate guides to command how they should be penalized or promoted.*

V. Quantitative assessment of optimal green finance in two sector-model

In this section, we simulate the effect of carbon pricing and of optimal green finance to compare the effectiveness of the two approaches to reduce emissions, as well as their efficiency to cut emissions by a similar amount.

The model used in this section captures reallocation effects across sectors through demand (e.g., technology-level interventions) and through capital (e.g., sector-level interventions). We consider that the economy is divided into two groups of activities, green (G) and brown (B). Each group has a CES technology combining capital and emissions, with a specific elasticity of substitution σ^i_{KE}, $i = G, B$. Both groups compete for the fixed amount of capital and for demand. The representative consumer maximizes a CES utility objective, with elasticity of substitution denoted by η. The η parameter, therefore, is also the price elasticity of demand for the output of both sectors.

Unlike the previous part of the paper, the economy is considered at its general equilibrium. Moreover, in order to focus on the allocative properties of carbon pricing and green finance, we assume the revenue neutrality of each policy.

We simulate the equilibrium under both policies within the following parameter space. We consider two degrees of output price responsiveness and eight degrees of input substitutability in each group as indicated in the figures.

Figure IV illustrates the effect of Pigovian taxation of carbon $\tau = \omega$ on the economy's total emissions. In line with our previous analysis, carbon pricing systematically reduces emissions.

Let us now consider the effectiveness of green finance. Before examining optimum green finance, let us first examine the effect of capital penalties proportional to each sectors' emissions intensities. In Figure V, $\delta_g = \frac{e_g}{k_g}$, $g = G, B$. In line with our analysis, such penalties generate between-group reduction, but mistakenly ignore within-sector substitution.

These instruments have the potential to reduce emissions. However, they are counterproductive in some cases, in line with Hartzmark and Shue (2024), particularly if the brown sector has high degree of substitutability, hence a low grip.

In contrast, optimum green finance imposes penalties based on both sectors' grips—here, these grips are

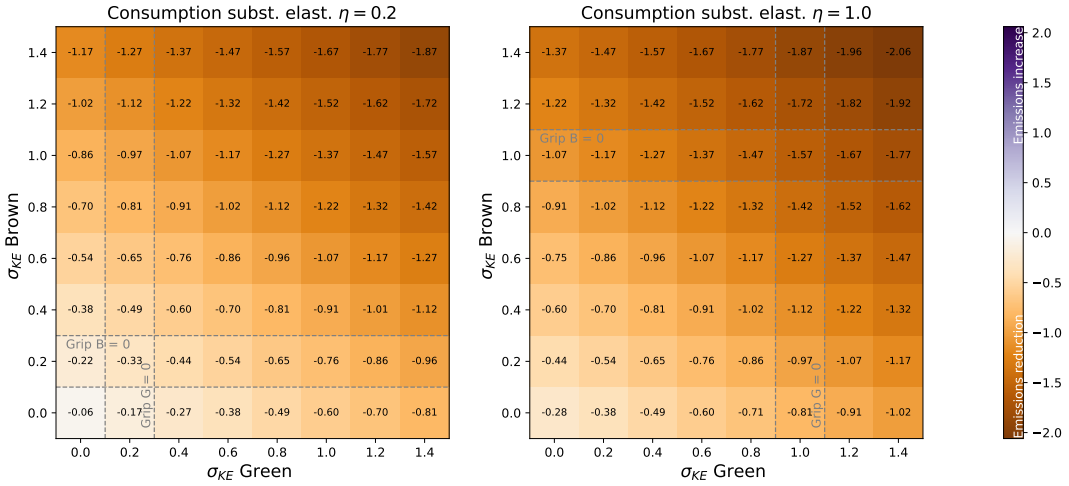


Figure IV: The effect of Pigovian taxation

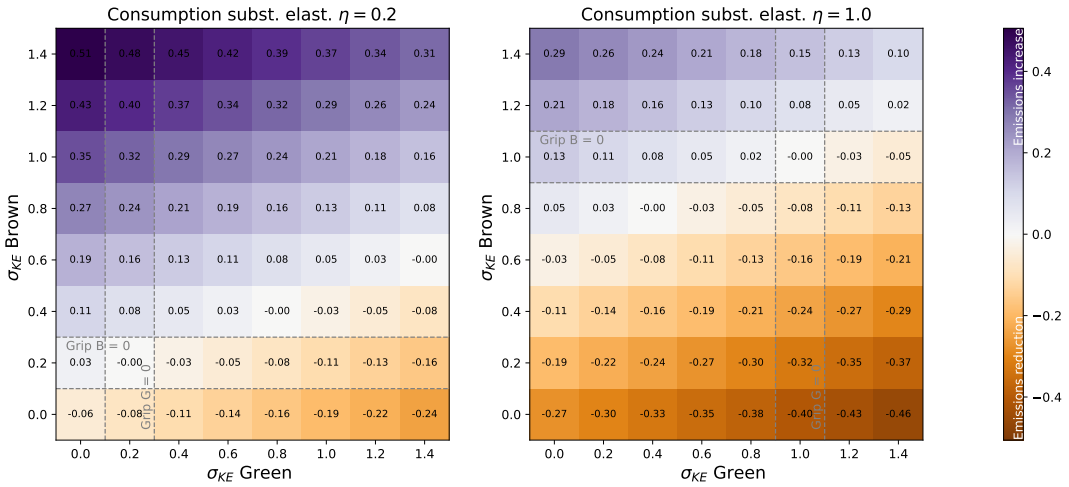


Figure V: The effect of naive green finance

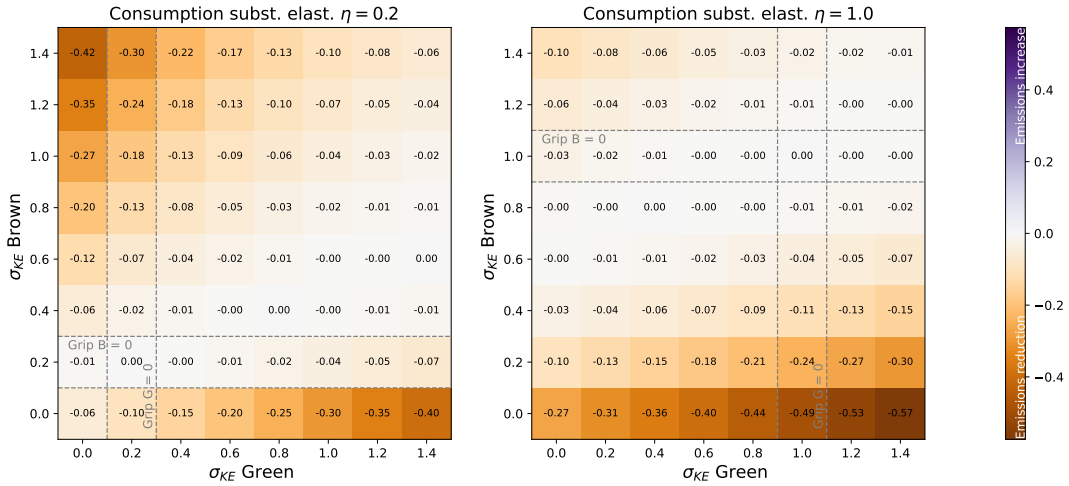


Figure VI: The effect of optimized green finance

calculated—resulting in systematic emissions reductions. These reductions are illustrated in Figure **??**.

Analysis of the obtained reductions shows that they are the largest in situations in which the grip of the brown sector is the strongest and the grip of the green sector is the lowest. This confirms that the design of a green finance taxonomy is more effective when it increase the difference between the categories' grips.

Finally, we compare the welfare contribution of carbon pricing and green finance by calculating the welfare cost of meeting a set emission cut through optimal green finance, relative to (first-best) carbon pricing. Figure VI shows the results.

The results indicate, consistent with theory, that green finance is systematically more socially costly than carbon pricing for a given externality reduction. More precisely, the parameter space for relatively cost-efficient green finance is small. The relative efficiency of green finance is limited to cases in which substitution possibilities are very low in the brown group. Otherwise, the social cost of green finance increases very rapidly.

VI. Conclusion

This paper provides a framework of analysis that permits to examine and assess the financial approach to the reduction of greenhouse gas emissions.

Besides qualitative differences between the effects of capital penalties and direct carbon penalties, we show that the scope for cost-effective emission reduction through is limited.

Our analysis reveals that commonly-used, emissions intensity measures do not indicate how finance should target various sectors, potentially inducing well-intentioned financial interventions to turn coun-

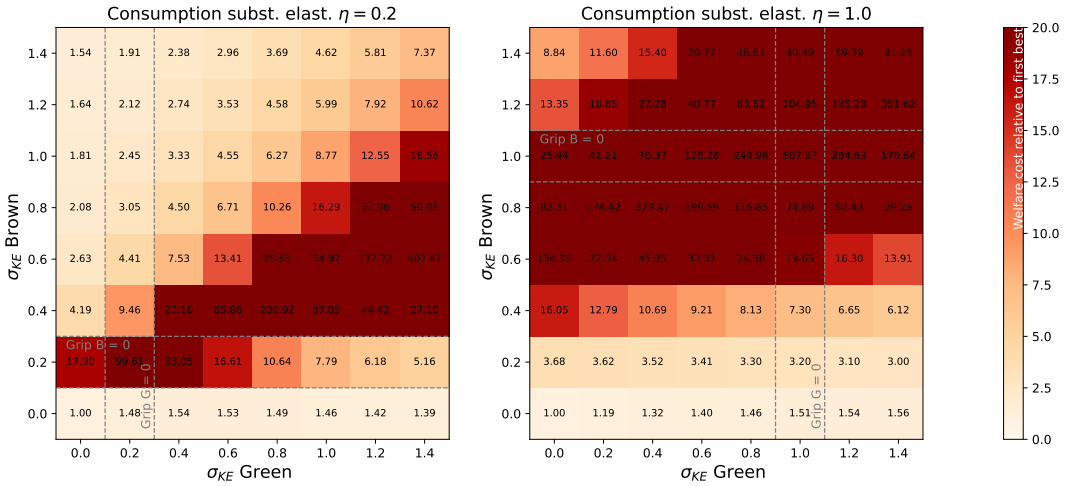


Figure VII: Welfare cost of emissions reduction under green finance relative to carbon pricing

terproductive. For investors, we provide heuristics to estimate grip and guide optimal intervention that balances the within-group and between-groups effect of green finance intervention. For policy-makers, we provide guidance for the design of an effective and efficient taxonomy.

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