# Intermediary Capital and Financing Sustainable Investment*

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**Abstract**

We present a theory of sustainable investment in which active engagement and low-cost capital provided by socially responsible intermediaries are keys to green transitions. A financing pecking order emerges: green entrepreneurs initially borrow from responsible investors before issuing sustainability-linked debt to purely profit-motivated investors. When responsible investors prioritize societal well-being, competition for limited social capital intensifies, eroding its funding advantage and crowding out green investments. Our model offers new perspectives on how financial constraints related to sustainable investments influence the return on social capital, the importance of its supply in reducing carbon emissions, and the need for welfare-improving regulatory measures to ease market competition.

**Keywords:** ESG, Sustainability, Impact Investing

**JEL classification:** G31, G32

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# 1 Introduction

Recent survey evidence indicates that investors tend to possess (pro-)social preferences, wherein they perceive non-pecuniary gains associated with contributing to social good, and likewise, losses associated with harm. These preferences are evident across various investment vehicles, spanning mutual funds (Riedl and Smeets (2017); Hartzmark and Sussman (2019)), venture capital funds (Barber et al. (2021)), and pension funds (Bauer et al. (2021)). Concurrently, the fast-growing empirical literature documents the significant impact of institutional investors on corporate social responsibility through active engagement with management (see, e.g., Dyck et al. (2019), Kim et al. (2019), Krueger et al. (2020), Azar et al. (2021), Naaraayanan et al. (2021), and Dimson et al. (2023)). Accompanying these phenomenal findings is the rapid growth of assets under management in socially responsible (hereafter SR) funds in recent years. Taken together, the evidence challenges Friedman (1970)'s separation argument and underscores the necessity for theoretical guidance on the real and financial effects of financial intermediaries on corporate social responsibility.

Since the seminal paper by Heinkel et al. (2001), the theoretical literature has suggested different mechanisms through which SR investors can improve corporate social responsibility.[1] Nevertheless, the influence of SR investors on the optimal financing mix and weighted average cost of capital (WACC) for sustainable firms remains unclear. The real and financial effects of SR funds are even more under-explored. Specifically, at the individual firm level, as SR funds become more pro-social, do financially constrained firms increasingly demand SR capital for funding sustainable investments? Moreover, at the aggregate level, how do SR funds' social preferences impact the share of sustainable firms and overall social welfare? How do environmental regulations impact the market for sustainable investment?

To address these questions, we study an economy featuring three distinct groups of agents: a continuum of entrepreneurs, purely for-profit financial investors with abundant capital, and SR investors who value both sustainability and financial returns but have a limited amount of capital. We introduce double moral hazard in sustainable investment into a workhorse model Ã  la Holmström and Tirole (1997). Within this framework, entrepreneurs make decisions regarding non-contractible effort levels (work or shirk) and sustainability policies (green, brown, or deep brown) upon securing funding from any investor. Meanwhile, SR investors lack the commitment to actively engage with

[1] The detailed discussion of the literature is provided later in the paper.

their portfolio firm's management.

Specifically, we model SR investors, referred to as SR funds, as financial intermediaries that have access to monitoring technology and are endowed with social preferences (e.g., perceiving "warm-glow" from funding green projects and "cold-prickle" from funding brown projects).[2] The active involvement of SR funds in monitoring serves to eliminate deep brown projects that cause significant social harm despite offering entrepreneurs the highest private benefits.[3] However, as monitoring is costly and non-contractible, SR funds must have sufficient skin in the game. We derive incentive-compatible contracts to ensure that entrepreneurs always work hard and that when SR funds provide funding to entrepreneurs, they always monitor and entrepreneurs implement the green project.

As a first step, we establish that entrepreneurs must invest in a deep brown project in the benchmark economy without SR funds. Entrepreneurs choosing a green project are subject to two disadvantages. First, they forgo the private benefit associated with the deep brown project. Second, due to the incentive cost of motivating green investment, the project has lower pledgeable income, potentially leading to smaller-scale investments.

Next, consider the economy with SR funds. We posit that SR funds play a dual role in influencing corporate social responsibility. They actively intervene with a firm's management to mitigate the incentive cost associated with green investments, while providing low-cost capital to green firms. In our model, the role of SR funds is capitalized as a funding advantage of social capital, a key concept we develop in this paper. This funding advantage has two key effects on green firms. Firstly, social capital eases the budget constraint by reducing the effective dollar cost of investment. Secondly, it complements financial capital by alleviating the firm's financial constraints, increasing pledgeable income, enabling the firm to leverage borrowing from financial investors, and consequently, expanding its investment scale. Moreover, in any market equilibrium where entrepreneurs break even between the green and deep brown projects, the funding advantage received by those investing in sustainability must be positive. Thus, our model predicts a financing pecking order: green firms exhaust the financing capacity from social capital before raising financial capital.

A notable result of our paper is that we provide a closed-form characterization of the return

[2]See Bénabou and Tirole (2011) for theoretical foundation.

[3]For simplicity, we refer to SR funds' action as "monitoring". It broadly represents other activists' behavior, including voice, voting, advising, strategic planning, and exercising control rights. Also, to stay focused on sustainable investment, we assume that monitoring does not affect the set of entrepreneur's effort choices.

(equivalently, the cost) on social capital in a market equilibrium where entrepreneurs compete for scarce social capital. The equilibrium return on social capital falls consistently below the return on financial capital, creating a cost-of-capital wedge. The wedge implies that SR funds are subject to financial losses as long as they possess social considerations. Importantly, we show that the wedge is driven by both the agency friction related to entrepreneurial decisions on sustainability policy and the incentive cost of SR funds' monitoring. Both factors contribute to the endogenous financial constraint faced by firms. Our result thus highlights agency frictions as a novel aspect of the cost-of-capital channel for sustainability investment, complementing the existing literature that primarily focuses on the risk and cash-flow channels.

We then explore the impact of SR funds' characteristics on market outcomes in equilibrium. Suppose SR funds have stronger social preferences, measured by their larger non-pecuniary benefit from transitioning to a greener economy.[4] This exogenous change relaxes the incentive-compatibility constraint for monitoring, as SR funds' social preferences and financial incentives are substitutes. It follows that entrepreneurs gain a larger funding advantage of social capital and have increased incentives to invest in green projects. As a result, the individual firm demand for social capital increases along the intensive margin, causing the equilibrium return on social capital to rise and the cost of capital wedge to decrease. Notably, the feedback effect from the equilibrium adjustment in the price of social capital offsets the effect of substituting away from the more expensive source of financial capital. This leads to novel predictions: both WACC and the optimal scale of investment are independent of SR funds' social preferences.

Ironically, an economy populated by investors with strong social awareness may not necessarily lead to improved sustainability outcomes. This is especially true when escalated social preferences are not accompanied by an increase in the supply of social capital. With a limited amount of social capital, competition along the intensive margin may result in a forceful crowding-out effect of sustainable firms along the extensive margin. Some entrepreneurs, initially supported by SR funds as both financiers and monitors may now struggle to maintain their sustainable investment policy as societal emphasis on social responsibility intensifies.

Our paper also sheds light on the optimal security design for sustainable firms. We show that effective incentive provision requires both entrepreneurs and SR funds to be rewarded or penalized

[4] SR funds' monitoring cost has opposite effects.

based on their firms' environmental and social (ES) performance. One way to implement the optimal contract is through the issuance of sustainability-linked debt to financial investors, thereby rendering entrepreneurs and SR funds residual claim holders and forcing them to bear higher interest costs in the event of poor ES performance. Entrepreneurs retain inside equity while SR funds hold outside equity along with control rights such as board representation and disproportionate voting rights.[5] In contrast, firms implementing the deep brown project exclusively rely on funding from financial investors.[6]

Finally, we use our model to draw policy implications. We examine the effects of carbon taxes and green investment subsidies on the market for social capital. We find that both environmental policies display a strong crowding-out effect that worsens the aggregate social impact (emissions) and reduces social welfare (financial profits and social cost of emissions). In particular, carbon taxes are levied on project cash-flows upon brown outcomes such that brown firms face a greater reduction in profitability. Entrepreneurs respond by switching to climate-friendly investment, creating a larger demand for social capital. Despite an increase in the number of green firms, all of them operate on a smaller scale. This happens because the increase in the equilibrium price of social capital and the decrease in pledgeable income (in the presence of taxes) tighten financial constraints. Hence, in this sense, the competition for social capital crowds out green investment along the intensive margin.

Green investment subsidies have similar adverse effects. We model investment subsidies as private benefits granted to entrepreneurs when they engage in green investment, which induces entrepreneurs to focus on sustainability. In contrast with carbon taxes, the subsidies reduce incentive costs for green investment, relaxing financial constraints so that green firms can operate on a larger scale. However, once again, the increased demand for SR funds' monitoring services and funding drives up the cost of social capital, crowding out green investment along the extensive margin.[7]

[5] As it becomes clear later, a simply linear sharing rule may not suffice for entrepreneurs and SR funds. Additional incentives are necessary to induce entrepreneurs to choose the green project. For example, in the event of good ES performance, they could receive extra stock grants or be allowed to exercise stock options at reduced strike prices.

[6] In our parsimonious model with only two cash-flow states, it is not possible to distinguish outside equity from debt for brown firms. However, our equilibrium does imply brown firms should be exclusively funded by market financing and green firms should use a mix of market and bank/intermediated financing.

[7] Gryglewicz et al. (2023) derive negative effects of carbon taxes and green subsidies in a dynamic model of green transition with activist entry and exit. Our model focuses on financial constraints as well as market demand for and supply of social capital. Bustamante and Zucchi (2023) argue that under carbon taxes, firms tilt towards transient abatement policies from long-term carbon reduction (green innovation). Bensoussan et al. (2024) argue that constraints on investor's and entrepreneurs' participation matter for optimal policies.

To bypass the crowding-out effects, we argue that perhaps government interventions should prioritize increasing the supply of social capital over further strengthening existing social investors' preferences for sustainability. For instance, relaxing financial intermediaries' capital requirements when funding sustainable investments or extending clean loans can enhance capital supply, facilitating transition and ultimately increasing welfare. These results complement analysis on green capital requirements and prudential regulations, as in Oehmke and Opp (2023). Moreover, we derive a sufficient condition for carbon taxation to impact sustainability. This condition highlights the importance of accompanying regulatory demands for transparent corporate sustainability disclosure.

**Related literature.** The theoretical literature has explored various channels through which investors' social preferences drive corporate sustainable investment. To create a price pressure, SR investors choose to divest from polluting firms (Heinkel et al. (2001)) or more broadly, tilt their portfolio weights towards clean firms and away from polluting firms (Pástor et al. (2021), Edmans et al. (2022), Hong et al. (2023), Dangl et al. (2023), and Favilukis et al. (2023)). Chowdhry and Waters (2018) show that SR investors' ownership stakes can dilute the share of profits for purely for-profit owners. Broccardo et al. (2022) and Jagannathan et al. (2022) evaluate the impact of divestment, boycott, and engagement strategies. Landier and Lovo (2022) and Gupta et al. (2022) focus on the effects of imposing capital market search frictions on polluting firms. Our contribution to the literature lies in emphasizing the dual role played by financial intermediaries, serving as both capital suppliers and monitors.

Our paper is closely related to Oehmke and Opp (2024). The authors show that SR funds induce corporate sustainable investment by increasing constrained firms' scale of production and that SR capital (supplied by SR funds) and financial capital (supplied by purely for-profit investors) are complements. Our work differs in several aspects. Firstly, we model SR funds' active engagement with firm management and non-contractible sustainable investment with stochastic social outcomes. Secondly, we characterize the optimal contract for both entrepreneurs and SR funds and the equilibrium cost of capital wedge. We use these results to evaluate the impact of SR funds in market equilibrium. Finally, we derive novel predictions regarding the WACC and investment scale for sustainable firms. Specifically, we show that the investment scale of sustainable firms may not always exceed that of irresponsible firms. This comparison depends on whether the private benefit of the deep brown project exceeds the incentive cost of the green project.

The security design aspect of our paper is related to Barbalau and Zeni (2022) who rationalize the co-existence of green bonds and sustainability-linked bonds. However, our approach differs in that the optimal financial contract is implemented by issuing sustainability-linked debt to passive financial investors without social preferences. Equity-like securities are held by SR funds, enabling them to actively engage with management. We further address the moral hazard problem for SR funds acting as monitors, emphasize the concept of the funding advantage, and derive the cost of capital wedge in market equilibrium.

# 2 The Setting

Our model builds on Holmström and Tirole (1997). To analyze the impact of intermediary capital on corporate social responsibility, we extend their framework of endogenous financial constraints in two key aspects. First, entrepreneurs multitask: they exert effort to improve the project's financial return and invest in sustainability that influences the firm's social impact. Second, in addition to financial investors, we introduce SR investors who fund and actively monitor corporate sustainable investment. We characterize the equilibrium return on social capital, i.e., capital supplied by SR investors. While the setting is stylized, it is sufficiently rich for studying the real and financial effects of SR investors.

## 2.1 Technology

There is a unit mass of entrepreneurs. Each of them is endowed with an ex-ante identical project and the same amount of initial net worth $A$. At date 0, each entrepreneur contracts with outside investors for external funding and invests a total of $I > A$ in the project. Subsequently, the entrepreneur establishes a firm and manages the project by choosing effort $e$ and sustainability policy $s$ right before date 1. Agency friction, a key market imperfection in our model, gives rise to endogenous financial constraints. Specifically, the entrepreneur's choice $(e, s)$ is unobservable to outside investors.

At date 1, conditional on the entrepreneur's sustainability policy $s$, the project generates two sets of verifiable and independently distributed outcomes. First, the project produces a financial cash flow of $RI$ with probability $p_e$, where $R > 0$, and 0 with probability $1 - p_e$. Effort provision increases the probability of cash-flow generation. Under high effort $e = h$, $p_h = p$; and under low effort $e = l$, $p_l = p - \Delta p$, where $\Delta p > 0$. However, the entrepreneur receives a private benefit of shirking $\lambda_R > 0$ per unit of investment $I$.

Second, the project delivers stochastic social outcomes. Per unit of investment, the amount of social impact is either $S = G$ (green) or $S = -B$ (brown). The probability of a green outcome is denoted by $q_s$. As an example, a prominent measure of a firm's social impact is its carbon emissions. For discussing environmental-related policies later, we follow a definition by the United Nations and normalize to zero the level of carbon emissions that can be absorbed and durably stored by nature.[8] In particular, we set $G > 0 > -B$ so that positive values of $B$ present excess carbon emissions, while positive values of $G$ denote spare carbon emissions.

The entrepreneur's choice of sustainability policy $s$ determines the distribution of social outcomes. There are three types of policies: green, brown, and deep brown. Under the green policy $s = g$, the green outcome realizes with a probability $q_g = q$ and the brown outcome realizes with a probability $1 - q$. Both the brown and the deep-brown policy generates the same distribution of social outcomes, and thus, we simply label them as $s = b$.[9] Whenever $s = b$, the green outcome occurs with a lower chance $q_b = q - \Delta q$, where $\Delta q > 0$. The expected *spare* carbon emissions under the green and brown project are

$$\begin{aligned}
\mathbb{E}_g(S) &= qG - (1-q)B, \\
\mathbb{E}_b(S) &= (q - \Delta q)G - (1 - q + \Delta q)B,
\end{aligned}$$

respectively. Throughout the paper, we assume

**Assumption 1.** $\mathbb{E}_g(S) > 0 > \mathbb{E}_b(S)$.

That is, the green project on average delivers social benefit by generating less carbon emissions than the target of zero. In contrast, any of the brown projects on average yield social harm since their carbon emissions exceed the target of zero. For simplicity, we assume that entrepreneurs do not value the social impact of the project.

The entrepreneur also obtains private benefits if she shirks on the social investment. For every

[8]See https://www.un.org/en/climatechange/net-zero-coalition.

[9]Throughout the paper, we use the lowercase $s = g, b$ for sustainability policies and the uppercase $S = G, B$ for social outcomes.

unit of investment $I$, the date-1 value of the private benefits are $\Lambda_S(1+r_F)$ under the deep-brown, $\lambda_S$ under the brown, and 0 under the green project with $\Lambda_S(1+r_F) > \lambda_S > 0$. Here, the parameter $\Lambda_S$ is a date-0 value and $r_F > 0$ is an exogenous discount rate of the entrepreneurs. The notations are chosen merely to simplify expressions. Importantly, the assumed ranking of private benefits guarantees that the entrepreneur will pick the worst social policy without interference of socially responsible investors. The following table summarizes the trade-off between social impact and the private benefit of sustainable investment.

| Type: $s$ | Green | Brown | Deep Brown |
|---|---|---|---|
| $Pr(S = G\|s) = q_s$ | $q$ | $q - \Delta q$ | $q - \Delta q$ |
| Private benefit | 0 | $\lambda_S$ | $\Lambda_S(1 + r_F)$ |

## 2.2 Financial and Social Investors

There are two types of outside investors. First, financial investors (F), who are purely profit-motivated and do not care about a firm's social impact at all. For simplicity, we suppose that financial investors are unlimited in number, so the aggregate supply of financial is perfectly elastic at the exogenous rate of financial return $r_F \geq 0$. Note that both entrepreneurs and financial investors discount cash flows at this rate.

Second, socially responsible funds (SR funds) value both financial cash flows and social impact. SR funds discount cash flows at rate $r_{SR}$ and derive a non-pecuniary benefit of $\gamma_{SR}SI$ at date 1 from a firm's social impact, where $\gamma_{SR} > 0$ measures the strength of social preferences. That is, SR funds receive a non-pecuniary benefit, $\gamma_{SR}GI > 0$, from the green outcome and loses a non-pecuniary value, $\gamma_{SR}BI > 0$, from the brown outcome. In sharp contrast with financial capital, SR funds are limited, and the aggregate supply of social capital is given by $K_{SR} > 0$.

A novel feature of our model is that SR funds are active investors. They have expertise in monitoring, advising, or actively intervening in a firm's sustainability investment decisions. In practice, these SR funds could correspond to socially responsible mutual funds or banks that commit capital to ESG investing. If SR funds work diligently on monitoring, then the deep brown project would be eliminated, leaving an entrepreneur with only the green and the brown. However, SR fund's monitoring is also subject to agency frictions, in that the decision is unobservable or non-verifiable to their outside investors. SR funds gain a private benefit $c > 0$ (e.g., saved time and resources that could otherwise generate benefits for SR funds) per unit of the firm's investment scale $I$ if they shirk on monitoring.

### 2.3 Financial Contracts and Payoffs

Next, we turn to financial contracting. Since social outcomes are verifiable, contractual transfers can be made contingent on their realizations at date 1. In particular, in the high cash-flow state, the entrepreneur receives $X_S$ and SR funds receive $Y_S$, for $S \in \{G, B\}$. Both investors and entrepreneurs are protected by limited liability, in that $X_S \geq 0$, $Y_S \geq 0$, and $R - X_S - Y_S \geq 0$.[10] Throughout the paper, we focus on contracts that implement high effort but allow brown investment. Let $I_F$ and $I_{SR}$ be the amount of capital provided by the financial investors and SR funds, respectively. The budget constraint requires that $I_s \leq I_F + I_{SR} + A$ for $s = g, b$, where $I_s$ denotes the total investment of a firm choosing sustainability policy $s$.

In anticipation of the green policy, an entrepreneur offers a contract to solve

$$U_E^g \equiv \max_{\{X_S, Y_S\}_{S\in\{G,B\}}, I_g} \frac{p}{1+r_F}\mathbb{E}_g(X_S)I_g - A, \tag{1}$$

subject to incentive-compatibility constraints (to be specified in the next sections), financial investor's participation constraint:[11]

$$\frac{p}{1+r_F}\left(R - \mathbb{E}_g(X_S) - \mathbb{E}_g(Y_S)\right) I_g \geq I_F; \tag{2}$$

and SR fund's pricing condition:

$$\frac{p}{1+r_{SR}}\mathbb{E}_g(Y_S)I_g \geq I_{SR}; \tag{3}$$

as well as SR fund's participation constraint:

$$(1 + r_{SR})I_{SR} + \gamma_{SR}\mathbb{E}_g(S)I_g \geq (1 + r_F)I_{SR} + cI_g. \tag{4}$$

[10] We abuse notation: as a subscript, $S$ denotes social outcomes rather the numerical values of those outcomes. Moreover, in the low cash flow state, everyone receives zero.

[11] To ease exposition, we ignore for now limited liability constraints $X_G \geq 0$, $X_B \geq 0$, $Y_G \geq 0$, $Y_B \geq 0$ and budget constraints $X_G + Y_G \leq R$, $X_B + Y_B \leq R$. After deriving the optimal financial contract (in subsection 3.4), we verify whether these constraints are satisfied and discuss both cases of interior and corner solutions.

The pricing condition (3) states that the maximum amount of capital provided by SR funds (the right-hand side) is determined by how the funds price the financial claim $Y_S$ (the left-hand side). In the condition, $r_{SR}$ reflects the rate of financial return of the claim. The participation constraint (4) requires that the SR fund's payoff of investing $I_{SR}$ in a green firm with scale $I_g$, which consists of the gross financial return $(1 + r_{SR})I_{SR}$ and the non-pecuniary benefit $\gamma_{SR}\mathbb{E}_g(S)I_g$, is greater than the payoff of the outside option. The outside option value is composed of (i) an investment return that SR funds earn from a diversified, ESG-neutral portfolio and (ii) their saved monitoring cost.[12] SR funds sign a contract with a green firm if and only if their social preferences are strong enough, in that

$$\gamma_{SR} \geq \gamma_{SR}^{PC} \equiv \frac{1}{\mathbb{E}_g(S)} \left( \frac{(r_F - r_{SR})I_{SR}}{I_g} + c \right). \tag{5}$$

The cutoff value $\gamma_{SR}^{PC}$ is essentially the minimum level of social preferences that offsets SR fund's financial loss due to funding a green firm, $(r_F - r_{SR})I_{SR}$, and monitoring cost, $cI_g$, scaled by the green firm's social impact $\mathbb{E}_g(S)I_g$.

## 2.4 Benchmark: Financial Investors Only

Our benchmark economy is populated by no SR funds. Since neither entrepreneurs nor financial investors value sustainability, it is suboptimal to implement the green project. In fact, to enforce the green policy, financial investors must incentivize the entrepreneur by leaving her with a rent to compensate for the loss in the private benefit of running a brown or deep brown project. However, this reduces the income pledgeable to financial investors, which in turn, limits the investment scale and reduces the entrepreneur's payoff. Indeed, an entrepreneur chooses the deep brown project as it provides the highest private benefit. The characterization of the optimal contract is then standard.

Without the need to incentivize sustainability, $X_G = X_B = X$, and the contract satisfies the incentive compatibility constraint for high effort

$$\Delta p X \geq \lambda_R, \tag{6}$$

[12] The participation constraint (4) implies that SR funds only value the social impact of the firm they are investing in. If they take the outside option, their payoff is independent of the level of sustainability in the whole economy. See Dangl et al. (2023) for a related discussion on (non)-consequentialist preferences and Oehmke and Opp (2024) for differential implications of narrow and impact mandates.

which requires that the marginal gain of exerting high effort outweighs the private benefit of shirking. Additionally, the contract satisfies the participation of financial investors: $p(R - X)I_b \geq (1+r_F)(I_b - A)$. Both constraints bind under the optimal contract, leading to the following result:

**Lemma 1** (Benchmark: financial investors only)**.** *With only financial investors in the market, each entrepreneur chooses the deep brown policy, the optimal contract stipulates $X = \frac{\lambda_R}{\Delta p}$, and the optimal investment scale is given by*

$$I_b = \frac{A}{\rho_R - \pi}, \tag{7}$$

*where $\pi \equiv \frac{pR}{1+r_F} - 1$ is the project NPV and $\rho_R \equiv \frac{p}{1+r_F}\frac{\lambda_R}{\Delta p}$ is the incentive cost for high effort.*

We make the following textbook (Tirole, 2006) assumptions:

**Assumption 2.** *(i) $\pi > 0$; (ii) $\frac{(p-\Delta p)R+\lambda_R}{1+r_F} - 1 < 0$; (iii) $\rho_R > \pi$.*

Parts (i) and (ii) state that the project is financially profitable to the entrepreneur if she exerts high effort and is otherwise not profitable, even including her private benefit of shirking. Part (iii) rules out an infinite investment scale.

The optimal investment scale (7) implies that each firm demands financial capital of $I_b - A = \frac{1-\rho_R+\pi}{\rho_R-\pi}A$. Since we normalize the mass of entrepreneurs to one, it is also the aggregate demand for financial capital. Moreover, the net payoff of each entrepreneur is

$$U_E^b \equiv \left(\frac{p}{1+r_F}\frac{\lambda_R}{\Delta p} + \Lambda_S\right) I_b - A = \frac{\pi + \Lambda_S}{\rho_R - \pi}A. \tag{8}$$

Different from the textbook case, non-sustainable policy leads to a private benefit of $\Lambda_S I_b$. As all firms are brown, the aggregate expected social impact is $\mathbb{E}_b(S)I_b = \frac{(q-\Delta q)G-(1-q+\Delta q)B}{\rho_R-\pi}A$. However, nobody worries about sustainability, implying that $U_E^b$ in (8) is the level of welfare in the benchmark.

## 3 The Optimal Contract with Socially Responsible Funds

In this section, we focus on a single firm and characterize the optimal contract that implements high effort, green investment, and monitoring while taking $r_{SR}$ as given.

### 3.1 Pledgeable Income

Let us provide some preliminaries. From (2), (3), and the budget constraint, the total amount of external funding cannot exceed the pledgeable income,

$$\underbrace{\left(\frac{p\left(R-\mathbb{E}_g(X_S)\right)}{1+r_F}+\frac{\left(r_F-r_{SR}\right)p\mathbb{E}_g(Y_S)}{(1+r_F)(1+r_{SR})}\right)}_{\text{pledgeable income}}I_g \geq \underbrace{I_g-A}_{\text{external funding}}. \tag{9}$$

The first term on the left-hand side depends on the firm's agency problem, which affects $\mathbb{E}_g(X_S)$, and the second term is related to SR fund's agency through $\mathbb{E}_g(Y_S)$ as well as the wedge between $r_F$ and $r_{SR}$.

Suppose that social capital is cheaper $r_F > r_{SR}$ (which will be established as an equilibrium result), then borrowing from SR funds relaxes the firm's financial constraints and expands its pledgeable income. We define the *funding advantage of social capital* as

$$\Delta_{SR}\left(r_{SR},\mathbb{E}_g(Y_S)\right) \equiv \frac{\left(r_F-r_{SR}\right)p\mathbb{E}_g(Y_S)}{(1+r_F)(1+r_{SR})}. \tag{10}$$

Under the maximum scale $I_g$ that binds (9), the entrepreneur's net payoff is

$$\begin{aligned} U_E^g &= \left(\pi+\Delta_{SR}\right)I_g\left(\Delta_{SR}\right) \\ &= \left(\pi+\Delta_{SR}\left(r_{SR},\mathbb{E}_g(Y_S)\right)\right)\cdot \underbrace{\frac{A}{\frac{p}{1+r_F}\mathbb{E}_g(X_S)-\pi-\Delta_{SR}\left(r_{SR},\mathbb{E}_g(Y_S)\right)}}_{\equiv I_g(\Delta_{SR})}. \end{aligned} \tag{11}$$

The funding advantage of social capital enters the payoff in two ways. In the numerator, $\Delta_{SR}$ comes from the budget constraint. By having access to external funding with a required return $r_{SR}$ lower than the discount rate $r_F$, the entrepreneur faces a lower effective cost of investment and extracts a surplus $\pi+\Delta_{SR}$ per unit of scale. In the denominator, $\Delta_{SR}$ affects the entrepreneur's payoff by affecting the total scale $I_g$. This effect is reflected in (9): borrowing from cheaper social capital releases financial capacity and allows the firm to borrow more from financial investors. Hence, a higher value of $\Delta_{SR}$ increases pledgeable income, investment scale, and the entrepreneur's payoff.

In the next two subsections, we derive the optimal contract $X_S$ and $Y_S$ that maximizes (11).

### 3.2 Entrepreneur's Incentives

We focus on contracts that implement SR fund's monitoring on the equilibrium path. With SR fund's active engagement, the deep brown project is eliminated from the entrepreneur's set of sustainability policies. However, the brown project remains present and appropriate incentives must be provided to the entrepreneur when implementing the green project. It is useful to consider $X_B$ as the entrepreneur's baseline compensation, received no matter what the social outcome is, and $X_G - X_B$ as the ES-linked pay spread, received only when $S = G$. Clearly, the pay spread serves as an incentive compensation for the green investment. To ensure the entrepreneur exerts high effort and implements the green project, $X_B$ and $X_G - X_B$ must satisfy the following incentive-compatibility constraints.

**1. Green investment $(\mathbf{h}, \mathbf{g}) \succeq (\mathbf{h}, \mathbf{b})$:** Given that the high effort is exerted, the entrepreneur must be incentivized to follow the green policy, i.e.,

$$p\Delta q \left(X_G - X_B\right) \geq \lambda_S. \tag{12}$$

Under the high effort, the project will succeed with probability $p$, and the green project increases the chance of receiving the ES-linked pay spread by $\Delta q$. Therefore, the left-hand side of (12) is the entrepreneur's marginal gain in choosing the green project. Its right-hand side is the private benefit $\lambda_S$ of deviating to the brown project. Note that, under SR fund's monitoring, the entrepreneur cannot choose the deep brown and capture $\Lambda_S(1 + r_F)$ upon deviation.

**2. High effort $(\mathbf{h}, \mathbf{g}) \succeq (\mathbf{l}, \mathbf{g})$:** Suppose the entrepreneur is engaging in green investment. Then incentives must be provided such that she does not shirk, i.e,

$$\Delta p \left(X_B + q(X_G - X_B)\right) \geq \lambda_R. \tag{13}$$

The left-hand side of (13) is simply the entrepreneur's marginal increase in the entrepreneur's expected compensation, which must be greater than her private benefit of shirking on the right-hand side. This is a standard incentive constraint for effort provision (see Holmström and Tirole (1997)) and is similar to (6) in the financial investors-only benchmark.

**3. Green investment and high effort $(\mathbf{h}, \mathbf{g}) \succeq (\mathbf{l}, \mathbf{b})$:** The last constraint requires that the entrepreneur prefers exerting effort and choosing the green project to shirk and implementing the brown policy. Specifically,

$$\Delta p X_B + (p\Delta q + (q - \Delta q)\Delta p)(X_G - X_B) \geq \lambda_R + \lambda_S. \tag{14}$$

The left-hand side of (14) consists of two terms. The first term, $\Delta p X_B$, represents the marginal effect of effort on the entrepreneur's baseline compensation. The second term reflects the marginal effect of exerting high effort and implementing the green policy on her ES-linked pay spread $X_G - X_B$. To see it, observe that the entrepreneur is rewarded the pay spread with probability $pq$ if she exerts high effort and implements the green policy and that probability is reduced to $(p-\Delta q)(q-\Delta q)$ if she does neither of the two.

Lemma 2 below characterizes the set of incentive compatible contracts that also maximize the pledgeable income and investment scale.

**Lemma 2** (Entrepreneur's contract)**.** *The incentive-compatible contract $X_S$ that implements high effort and the green project as well as maximizing the investment scale has the following properties:*

1. *The expected compensation to the entrepreneur must be $\mathbb{E}_g(X_S) = \frac{\lambda_R}{\Delta p}$.*
2. *The ES-linked pay spread must be bounded, i.e., $X_G - X_B \in \left[\frac{\lambda_S}{(p-\Delta p)\Delta q}, \frac{\lambda_R}{q\Delta p}\right]$.*

The first property describes the level of expected compensation to the entrepreneur. The idea is that the entrepreneur maximizes her net payoff (11) by maximizing the investment scale. To achieve this, it is optimal for the entrepreneur to pledge as much future cash flow as possible to outside investors, regardless of who the firm is borrowing from. This leaves the entrepreneur with $\mathbb{E}_g(X_S) = \frac{\lambda_R}{\Delta p}$, which is the lowest expected compensation compatible with effort provision. Indeed, the incentive compatibility constraint (13) for high effort must be binding in the optimal contract.

The second property states that the ES-linked pay spread $X_G - X_B$ must be sufficiently large to maximize the investment scale, as it is a more cost-effective incentive instrument than baseline compensation $X_B$. Let us ignore discounting $r_F$ and the probability of success $p$ in the pledgeable income (9), as they merely scale numbers in our argument. Then the intuition is as follows. By reducing a dollar of baseline compensation, the pledgeable income increases by a dollar. However, the same dollar-boost in the pledgeable income only requires a $\frac{1}{q}$-dollar reduction in the ES-linked pay, since $X_G - X_B$ occurs with probability $q$ given the project success. Therefore, in order to improve the firm's borrowing capacity, the minimization of the baseline compensation $X_B$ should be prioritized. Yet, $X_B$ being too low would destroy effort incentives and violate (13) and (14). In fact, the range of $X_G - X_B$ given in Lemma 2 results from the simultaneity of (13), (14), and the minimization of $\mathbb{E}_g(X_S)$.[13] Overall, ES-linked pay is a less costly incentive instrument, in that $X_G - X_B \geq \frac{\lambda_S}{(p-\Delta p)\Delta q}$ is a necessary condition for the optimal contract.

### 3.3 SR Funds' Incentives

Because monitoring is unobservable to financial investors, the contract $Y_S$ held by SR funds must satisfy the following incentive compatibility constraint

$$p\Delta q\,(Y_G - Y_B) + \gamma_{SR}\,(\mathbb{E}_g(S) - \mathbb{E}_b(S)) \geq c, \tag{15}$$

where $\mathbb{E}_g(S) - \mathbb{E}_b(S) = \Delta q\,(G + B) > 0$ is the increase in the expected social impact brought by the green policy. Altogether, the marginal gains in financial compensation and social benefit must outweigh the private benefit of shirking on monitoring. It is evident from (15) that the ES-linked pay spread to the SR funds must be sufficiently high to induce monitoring, given by

$$Y_G - Y_B \geq \frac{c - \gamma_{SR}\Delta q(G + B)}{p\Delta q}. \tag{16}$$

If the SR funds have stronger social preferences $\gamma_{SR}$, then they are more willing to subsidize the firm's sustainability investment and accept a lower spread $Y_G - Y_B$. This is so because non-pecuniary social motivation substitutes for financial incentives.[14]

### 3.4 The Optimal Financial Contract

Now, we can characterize the optimal financial contract and propose a way to implement the contract by common financial securities, such as debt and equity contracts.

[13]The incentive compatibility constraint (12) does not bind in the optimal contract. See Appendix 7 for proof and a graphical illustration.

[14]For SR funds to have a meaningful role, the private benefit of the deep brown project must be greater than the financial incentives for the green investment under the optimal contract. That is, $\Lambda_S(1 + r_F) > p\Delta q(X_G - X_B)$. Under this condition, the entrepreneur will deviate to the deep brown project on the off-equilibrium path without monitoring. Hence, the active role of SR funds is necessary for sustainable investment. In the optimal contract (17) below, the condition is equivalent to $\lambda_S < \left(1 - \frac{\Delta p}{p}\right)(1 + r_F)\Lambda_S$.

To fix ideas, we focus on parameter constellations such that the entrepreneur's compensation $X_G$ and $X_B$, given in equation (17) below, satisfying that $X_G \leq R$ and $X_B \geq 0$. We also assume for now and verify shortly that $Y_B > 0$ in a competitive market equilibrium.

**Proposition 1** (The optimal contract for the entrepreneur and SR funds)**.** *Given $r_{SR} < r_F$,*

1. *The entrepreneur receives*

$$X_G = \frac{\lambda_R}{\Delta p} + \frac{(1-q)\lambda_S}{(p-\Delta p)\Delta q} \text{ and } X_B = \frac{\lambda_R}{\Delta p} - \frac{q\lambda_S}{(p-\Delta p)\Delta q}. \tag{17}$$

2. *SR funds receive $Y_G = R - X_G$ and $Y_B = \min\left(R - X_G - \frac{c-\gamma_{SR}(G+B)\Delta q}{p\Delta q}, R - X_B\right)$. This implies*

$$\mathbb{E}_g(Y_S) = \min\left(R - \frac{\lambda_R}{\Delta p} - \frac{1-q}{\Delta q}\left(\frac{\lambda_S}{p-\Delta p} + \frac{c-\gamma_{SR}(G+B)\Delta q}{p}\right), R - \frac{\lambda_R}{\Delta p}\right). \tag{18}$$

The intuition for the optimal contract is as follows. Given $r_{SR} < r_F$, social capital offers a funding advantage relative to financial capital, and the firm would like to maximize the use of socially responsible funding to scale up investment. To raise capital $I_{SR}$ from SR funds, the pricing condition (3) requires the firm to promise a corresponding future cash flow $\mathbb{E}_g(Y_S)$ and to maximize its usage. The key question is how $Y_G$ and $Y_B$ should be allocated.

Starting with any incentive-compatible contract, the firm can increase $Y_G$ until the budget constraint in the green state becomes binding, i.e., $Y_G = R - X_G$. Evidently, any further increase in $Y_G$ can then be achieved by decreasing the entrepreneur's compensation $X_G$. Thus, it is optimal for the entrepreneur to minimize the ES-linked pay spread $X_G - X_B$. At the same time, the baseline pay $X_B$ must increase accordingly to satisfy effort incentive (13). By Lemma 2, $X_G - X_B = \frac{\lambda_S}{(p-\Delta p)\Delta q}$, and thus, the optimal contract (17) binds both the incentive constraints (13) and (14). Importantly, cash flows that can be allocated to SR funds in the green state $Y_G = R - X_G$ are maximized.

Given the maximal $Y_G$, it is also optimal to maximize $Y_B$ in the brown state. Yet, the choice is subject to the monitoring constraint (16), which depends on the value of $\gamma_{SR}$. If

$$\gamma_{SR} < \gamma_{SR}^M \equiv \frac{1}{G+B}\left(\frac{c}{\Delta q} + \frac{p\lambda_S}{(p-\Delta p)\Delta q}\right),$$

then the monitoring constraint is binding in the optimal contract: any further increase of $Y_B$ breaks the monitoring incentives. The firm exhausts its capacity of borrowing from SR funds by setting $Y_B = R - X_G - \frac{c-\gamma_{SR}(G+B)\Delta q}{p\Delta q}$ and fills the financing gap by raising financial capital. In this case, financial investors receive $R - X_B - Y_B > 0$ in the brown state and receive nothing in the green state.

If instead, $\gamma_{SR} \geq \gamma_{SR}^M$, SR funds strongly value social impacts and are willing to provide monitoring effort even with a low pay spread. In this case, the green entrepreneur borrows only from SR funds. That is, financial investors receive nothing in the brown state, in that $R - X_B - Y_B = 0$. Since the green firm pledges all its future income to SR funds, their expected compensation is

$$\mathbb{E}_g(Y_S) = R - \mathbb{E}_g(X_S) = R - \frac{\lambda_R}{\Delta p}.$$

In sum, SR funds' expected compensation, stated in equation (18), maximizes the funding advantage of social capital $\Delta_{SR}(r_{SR}, \mathbb{E}_g(Y_S))$, which in turn maximizes the entrepreneur's payoff (11).

### 3.4.1 Security Design

To implement the optimal contract with financial securities, we must note a number of key properties of the optimal contract design. First, in the zero cash-flow state, no one receives anything. Second, in the high cash-flow state, the entrepreneur receives a larger payment $X_G > X_B$ if the green outcome occurs. Similarly, SR funds receive $Y_G > Y_B$ in the green state as long as $\gamma_{SR} < \gamma_{SR}^M$. This implies that the payoffs of the entrepreneur and SR funds are equity-like: they are rewarded for enforcing the green policy through effort provision (the entrepreneur) and monitoring (SR funds). In this sense, their compensations are linked to sustainability outcomes.

In practice, entrepreneurs may be granted extra stocks or stock options with strike prices tied to a firm's ESG performance.[15] Importantly, outside equity held by SR funds grants these funds control rights, voting rights, and the power to intervene with the management. These features of equity are important for SR funds to be active and provide their monitoring or advising services.

[15] See, e.g., Hong et al. (2015), Flammer et al. (2019), and Cohen et al. (2023) for empirical evidence of CSR-linked executive compensation.

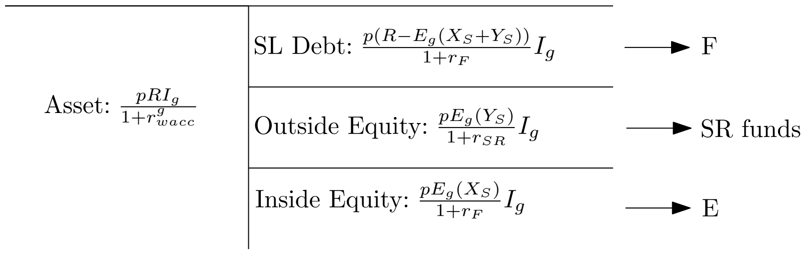


**Figure 1: Security Design.** Financial investors (F) hold sustainability-linked (SL) debt, SR funds hold outside equity, and the entrepreneur (E) holds inside equity. The firm's expected free cash flow $pRI_g$ is discounted at the weighted-average cost of capital $r^g_{wacc}$ to be determined endogenously in Section 4.2.3.

Nevertheless, financial investors receive no cash flows, $R - X_G - Y_G = 0$, in the green state and

$$\begin{aligned} R - X_B - Y_B =& \frac{\lambda_S}{(p-\Delta p)\Delta q} + \frac{c - \gamma_{SR}(G+B)\Delta q}{p\Delta q} \\ =& X_G - X_B + Y_G - Y_B \end{aligned}$$

in the brown state. This implies that the payoff of financial investors is inversely related to sustainability outcomes. We implement the contract held by financial investors as *sustainability-linked debt* (loans or bonds), for which the interest payment becomes lower if the issuer has better ESG performance. Figure 1 provides the market value balance sheet under our proposed security design.

Our model rationalizes sustainability-linked debt through the agency channel: if the entrepreneur and SR funds are able to successfully produce a green outcome, then they are rewarded by a reduction in interest repayment. The sustainability-linked interest is thus a useful way to deal with the limited ability of the entrepreneur and SR funds to commit to the green policy. In contrast, green debt, which has a flat interest rate, would not be able to address commitment frictions. Hence, it is not an efficient contract design for sustainable firms in the presence of potential agency problems.[16]

# 4 Market Equilibrium and Implications

In this section, we characterize the market equilibrium of the economy. Section 4.1 provides the definition of a market equilibrium. Section 4.2 and 4.3 derive implications on costs of capital,

[16] As is typical in financial contracting models, the implementation of the optimal contract is non-unique. We may also interpret SR investors as a bank that holds a loan. Importantly, our security design exercise suggests that a straight green loan may be suboptimal since it does not provide the appropriate incentives for banks to monitor a firm's sustainable investment. Our analysis highlights that bank loans should also be sustainability-linked.

investment scale, and the economy's overall level of green investment.

### 4.1 Market Equilibrium

We denote the mass of green firms ($s = g$) by $m_g$ and that of brown firms ($s = b$) by $1 - m_g$, and we focus only on interior equilibria, $m_g \in (0, 1)$, as they are the most interesting case. A *market equilibrium* is a pair $(r_{SR}^*, m_g^*)$ that satisfies the following two conditions.

1. Each entrepreneur maximizes her net payoff by choosing the sustainability policy, which then determines the optimal contract with investors. That is, each green firm offers the optimal contract as stated in Proposition 1 to both types of investors; and each brown firm only offers the optimal contract as stated in Lemma 1 to financial investors. For both green and brown firms to have a positive mass, it must be that entrepreneurs are indifferent between green and brown. Hence, the individual firm's optimization requires that

$$\underbrace{\frac{\pi + \Delta_{SR}(r_{SR}^*)}{\rho_R - \pi - \Delta_{SR}(r_{SR}^*)}}_{=U_E^g,\text{ green firms}} = \underbrace{\frac{\pi + \Lambda_S}{\rho_R - \pi}}_{=U_E^b,\text{ brown firms}}. \tag{19}$$

2. The market for social capital clears, i.e., the aggregate demand for social capital equals its aggregate supply. Since green firms are identical and each has an individual demand for social capital given by the pricing condition (3), the market-clearing condition is

$$\underbrace{m_g^* I_{SR}(r_{SR}^*)}_{\text{aggregate demand for social capital}} = \underbrace{K_{SR}}_{\text{aggregate supply of social capital}}. \tag{20}$$

We show that the market equilibrium exists and is unique in Appendix 7. Intuitively, we observe that the payoff of a green entrepreneur in the optimality condition (19) is continuous and monotonically decreasing in $r_{SR}$. Assumption 2 guarantees that the payoff becomes lower than that of a brown entrepreneur when social capital is more expensive than financial capital. Therefore, there is a unique $r_{SR}^*$ with which the payoffs of the green and brown policy are identical.

## 4.2 The Impacts of SR Funds

Our model offers insights into how SR funds can significantly influence a firm's sustainable investment practices. In an economy dominated solely by financial investors, green policies are not implementable (Lemma 1) simply because neither entrepreneurs nor financial investors value corporate social impacts. However, the introduction of SR funds into the market makes green investments feasible in equilibrium. This outcome is achieved because SR funds perform two important roles in inducing corporate sustainable investment. First, they are capable of eliminating the deep brown policy by actively engaging with entrepreneurs. This effectively reduces the agency costs associated with incentivizing green investment and thus, increases the project's pledgeable income. Furthermore, given their non-pecuniary valuation of social outcomes, SR funds are strongly motivated to contribute to society's well-being. Consequently, they are willing to provide capital to firms even without a matching financial return.

Indeed, SR funds must provide a funding advantage in the market equilibrium. As seen from the optimality condition (19), implementing the green policy negatively affects the entrepreneur's payoff in that she would otherwise enjoy the private benefit $\Lambda_S$ from running a brown firm and disengaging with SR funds. Therefore, the entrepreneur would never implement the green policy unless she is subsidized by SR funds, i.e., social capital must have a lower cost than financial capital in the market equilibrium.

### 4.2.1 The Cost of Capital Wedge

To develop further insights, we derive a simple analytical expression for the equilibrium cost of social capital. A significant implication of our model is that the cost of capital wedge, defined as the difference between the cost of social capital and the cost of financial capital, is fully characterized by SR funds' characteristics and agency frictions.

**Proposition 2.** *The equilibrium return on social capital is given by*

$$r^*_{SR} = r_F - \underbrace{\frac{\Delta^*_{SR}(1+r_F)^2}{p\mathbb{E}_g(Y_S) + \Delta^*_{SR}(1+r_F)}}_{=\text{cost of capital wedge}}, \tag{21}$$

*where the equilibrium funding advantage of social capital is*

$$\Delta^*_{SR} \equiv \Delta_{SR}(r^*_{SR}) = \frac{(\rho_R - \pi)\Lambda_S}{\rho_R + \Lambda_S} > 0. \tag{22}$$

Equation (21) immediately implies $r_F > r_{SR}$ since we show in Appendix 7 that the equilibrium funding advantage is $\Delta^*_{SR} > 0$. Moreover, the equilibrium funding advantage of social capital, stated in equation (22), does not depend on SR funds' social preferences. This is so because price-taking firms compete for the funding advantage until they become indifferent between the green and brown policies, as seen from condition (19). Thus, the proposition implies that the cost of capital wedge is driven by the firm's agency problems and the resulting financial constraints, because the primitive parameter capturing conflicts of interest, $\lambda_R$, determine the baseline pledgeable income through the term $\rho_R = \frac{p}{1+r_F}\frac{\lambda_R}{\Delta p}$. Put differently, absent firm's agency friction, i.e., $\Lambda_S = 0$, the cost of capital wedge vanishes. This *agency friction* channel is novel and differs fundamentally from existing mechanisms.

Panel A of Figure 2 shows the effect of social preferences on the equilibrium return on social capital.[17] The vertical dashed line on the left of the panel indicates the cutoff value for the SR fund's participation $\gamma^{PC}_{SR}$. For values of $\gamma_{SR}$ less than $\gamma^{PC}_{SR}$, SR funds do not engage with green firms since their social preferences are not strong enough to offset financial losses due to funding and monitoring green firms. Positive shocks to social preferences close the gap between $\gamma_{SR}$ and $\gamma^{PC}_{SR}$ and eventually induce SR funds to finance green projects.

When SR funds place an even stronger focus on sustainability (a further increase in $\gamma_{SR}$), the incentive constraint for monitoring (16) is relaxed. Entrepreneurs can then raise $Y_B$ to attract more social capital $I_{SR}$, bidding up the price of social capital $r^*_{SR}$ (the solid line). Consistent with equation (21), the return on social capital is always below $r_F$, shown as the horizontal dashed line. Further increases in $\gamma_{SR}$ continue to relax the monitoring constraint until the maximum amount $Y_B = R - X_B$ is pledged to SR funds in the brown state. This is evidenced by the vertical dashed line on the right of the panel, indicating the cutoff value $\gamma^M_{SR}$, beyond which the monitoring constraint is slack. Since $Y_B$ attains its maximum, so is the amount of social capital raised by each green firm. Therefore, any further increase in $\gamma_{SR}$, beyond this vertical dashed line, has no impact on

[17] Our model parameters are chosen only for illustrating qualitative results.

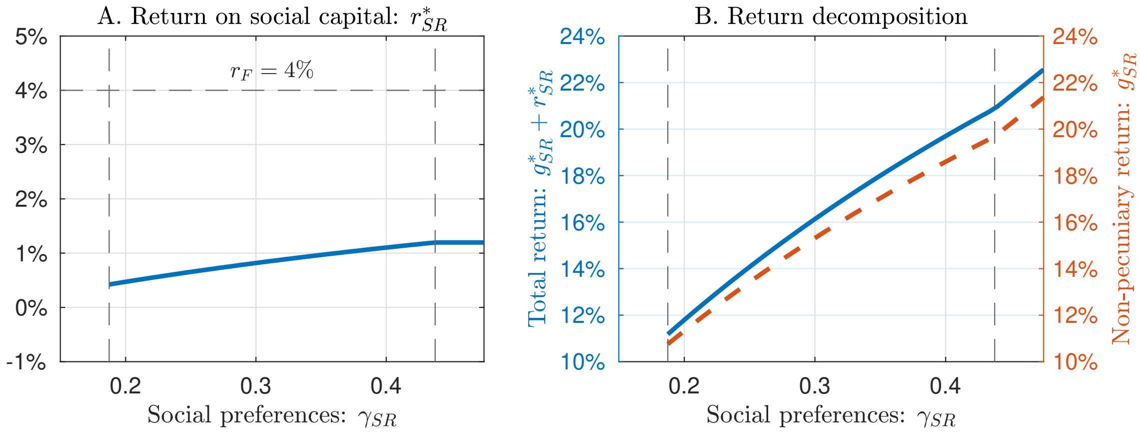


**Figure 2: Equilibrium return on social capital.** The solid line in Panel A is the equilibrium return on social capital $r^*_{SR}$. In Panel B, the dashed line is the non-pecuniary return $g^*_{SR} \equiv \frac{\gamma_{SR}\mathbb{E}_g(S)I_g}{I_{SR}}$ and the solid line is SR funds' total return $g^*_{SR} + r^*_{SR}$. The left vertical dashed line is $\gamma^{PC}_{SR}$ and the right vertical dashed line is $\gamma^{M}_{SR}$.

the equilibrium return $r^*_{SR}$.[18]

Proposition 2 also implies that SR funds are subject to financial losses, as their return is lower than what they would receive from an alternative ESG-neutral portfolio or as if they were financial investors. This highlights the sacrifice SR funds must make in order to deliver social impact. Nevertheless, financial losses do not mean that SR funds would refrain from participation since they also derive non-pecuniary benefits from making a social impact. As previously shown, SR funds find it optimal to fund a green project, provided that their social preferences are stronger than $\gamma^{PC}_{SR}$. In Panel B of Figure 2, we plot the non-pecuniary return, $g^*_{SR} \equiv \frac{\gamma_{SR}\mathbb{E}_g(S)I_g}{I_{SR}}$, per dollar invested; showing that the value of sustainable investment is the major driving force for SR funds' capital contributions.

### 4.2.2 Optimal Investment

What are the real effects of financing with social capital? To explore this, we compare the equilibrium investment scale of green firms to brown firms. As is common with constant-returns-to-scale models following Holmström and Tirole (1997), investment is determined by the endogenous finan-

[18] We place the same two vertical dashed lines in other figures, indicating the cutoff values $\gamma^{PC}_{SR}$ and $\gamma^{M}_{SR}$, respectively.

cial constraint. Brown firms' investment is given by the financial investors-only benchmark,

$$I_b = \frac{A}{\rho_R - \pi}. \tag{23}$$

Green firms' investment is obtained by setting (9) as an equality and evaluating the pledgeable income under the optimal contract. I.e.,

$$I_g = \frac{A}{\rho_R - \pi - \Delta_{SR}^*}. \tag{24}$$

Using the equilibrium funding advantage derived in Proposition 2, we show in the next proposition that green firms have a higher investment scale than brown firms.

**Proposition 3.** *Green firms invest more than brown firms,* $I_g = I_b\left(1 + \frac{\Lambda_S}{\rho_R}\right) > I_b$.

The intuition is simple. To induce the green policy, i.e., to offset the private benefit $\Lambda_S$, SR funds must compensate the entrepreneur with positive funding advantage, which increases the project's pledgeable income and investment scale so that entrepreneurs are indifferent between investing in green and brown projects.

#### 4.2.3 Weighted Average Cost of Capital

The capital structure implementation in Section 3.4.1 allows us to examine the model implications on the weighted average cost of capital (WACC). Since both financial investors and entrepreneurs discount at rate $r_F$, the WACC of brown firms is simply $r^b_{wacc} = r_F$. By Proposition 2, we expect that the WACC of green firms $r^g_{wacc}$ is lower than $r_F$. The following result characterizes $r^g_{wacc}$.

**Proposition 4.** *The weighted average cost of capital of a green firm is*

$$\begin{aligned} r^g_{wacc} =& \frac{pR}{\frac{pR}{1+r_F} + \Delta^*_{SR}} - 1 \\ =& \frac{pR}{\frac{pR}{1+r_F} + \frac{(\rho_R - \pi)\Lambda_S}{\rho_R + \Lambda_S}} - 1. \end{aligned} \tag{25}$$

According to a green firm's market-value-based balance sheet (Figure 1), the denominator on the right-hand side of (25) is the total value of securities, $\frac{pR}{1+r_F} + \Delta^*_{SR}$, per unit of investment scale $I_g$. $r^g_{wacc}$ is then the unique discount rate for the expected free cash flow, $pR$, per unit of investment

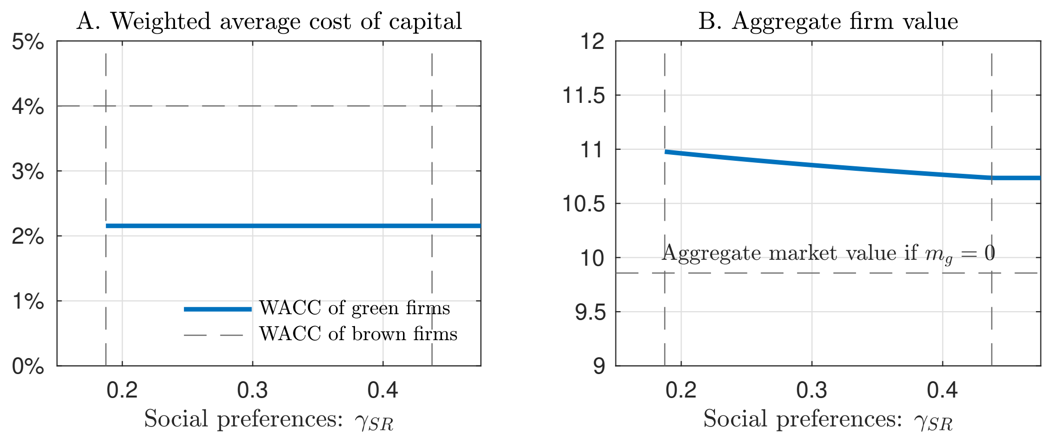


**Figure 3: Weighted average cost of capital and aggregate firm value.** In Panel A, the wacc is $r^g_{wacc}$ for green firms and $r_F$ for brown firms. In Panel B, we plot the aggregate firm value $m^*_g \frac{pR}{1+r^g_{wacc}} I_g + (1 - m^*_g) \frac{pR}{1+r_F} I_b$.

such that the asset value equals the total market value of the sustainability-linked debt and equity claims.[19]

Notably, Proposition 4 shows that the WACC of green firms $r^g_{wacc}$ is independent of the characteristics of SR funds, such as the strength of social preferences $\gamma_{SR}$ and monitoring cost $c$. Panel A of Figure 3 provides an illustration. The rationale behind this result lies in the fact that any changes in $\gamma_{SR}$ or $c$ that favor the use of social capital are accompanied by decreases in the required funding from the more expensive source of financial capital.[20] Hence, despite an increase in $r^*_{SR}$ with $\gamma_{SR}$, the effect on WACC is undone by adjustments in the composition of funding. This logic is reminiscent of Modigliani-Miller Proposition 2 for the weighted average cost of capital. In fact, (25) claims that $\Delta^*_{SR}$ is a sufficient statistic for $r^g_{wacc}$. Moreover, Proposition 2 highlights that the equilibrium funding advantage itself is driven by the private benefit $\Lambda_S$, the incentive cost $\rho_R$, and project-specific characteristics.

Panel B of Figure 3 plots the aggregate market value of the firm

$$m^*_g \frac{pR}{1 + r^g_{wacc}} I_g + (1 - m^*_g) \frac{pR}{1 + r_F} I_b,$$

[19]The WACC of green firms, by definition, is also a weighted average of $r_{SR}$ and $r_F$, with the weights given by the corresponding market value of securities relative to the total value of securities. Indeed, this accounting definition delivers expression (25).

[20]This is so because, in the brown state, the optimal financial contract determines $X_B$ and $Y_B$, thereby allocating the residual cash flow $R - X_B - Y_B$ to financial investors.

which is the average of the green firm value $\frac{pR}{1+r_{wacc}^{g}}I_g$ and brown firm value $\frac{pR}{1+r_F}I_b$, weighted by their respective fraction in the economy, $(m_g^*, 1-m_g^*)$. Since green firms have a lower cost of capital ($r_{wacc}^{g} < r_F$) and invest more ($I_g > I_b$) than brown firms, the market value of green firms is greater than that of brown firms. As a consequence, the aggregate firm value is higher in an economy with SR funds than in another with only financial investors. Moreover, the aggregate firm value is decreasing in $\gamma_{SR}$. The result requires us to understand how the characteristics of SR funds relate to the equilibrium mass of green firms $m_g^*$, which we discuss next.[21]

### 4.3 Green Investment and Competition for Social Capital

Now, we examine the market for social capital. As discussed in Section 4.2, increases in social preferences change firm behavior. Particularly, such increases ease the incentive constraint for monitoring (16) and therefore, allow entrepreneurs to increase $Y_B$ up to $R - X_B$ so that they can raise more social capital $I_{SR}$ ex ante. We analytically prove this results in the following proposition, which is illustrated in Figure 4.

**Proposition 5.** *In the market equilibrium and if $\gamma_{SR} < \gamma_{SR}^M$, the following results hold:*

1. *The individual firm's demand for social capital $I_{SR}$ increases with $\gamma_{SR}$ but decreases with $c$.*

2. *The equilibrium mass of green firms $m_g^*$ decreases with $\gamma_{SR}$ but increases with $c$.*

*If $\gamma_{SR} \geq \gamma_{SR}^M$, then both $I_{SR}$ and $m_g^*$ are independent of $\gamma_{SR}$ and $c$.*

The first part of the proposition implies that the financial structure of green firms is affected by SR funds' characteristics, including their social awareness and monitoring costs. Specifically, an increase in $\gamma_{SR}$ or decrease in $c$ relaxes the monitoring constraint and makes social capital more attractive, leading to a stronger demand for SR funding and shifting the financial structure towards social capital. In terms of our capital structure implementation, $I_F$ is raised through issuing sustainability-linked debt to financial investors and $I_{SR}$ is raised from SR funds by equity issuance. Moreover, the optimal investment (24) is independent of $\gamma_{SR}$. As a result, the proportion of debt financing decreases with the strength of social preferences. The first implication of the proposition is that the financial leverage of green firms will decrease with $\gamma_{SR}$.

[21] Note that the mass of green firms $m_g$ does not enter into the optimality condition (19), and thus, the condition alone determines the equilibrium return on social capital $r_{SR}^*$.

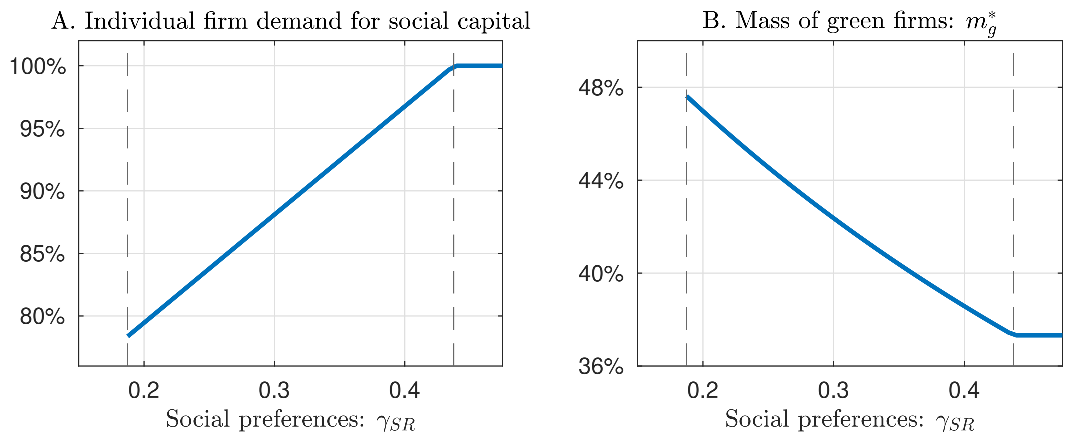


**Figure 4: Demand for social capital and the mass of green firms.** In Panel A, we plot the ratio of the individual firm's demand for social capital to its total external funding: $\frac{I_{SR}}{I_g - A}$. Panel B depicts the equilibrium mass of green firms $m_g^*$.

The proposition delivers another important message: competition for social capital crowds out green firms. As $\gamma_{SR}$ increases, first, the associated increase in $I_{SR}$ is an adjustment along the *intensive margin*. The market-clearing condition (20) also implies an adjustment along the *extensive margin*. Specifically, $m_g^* = K_{SR}/I_{SR}(r_{SR}^*)$ declines with $I_{SR}(r_{SR}^*)$. In other words, as firms that are already green post a larger demand from a fixed supply of social capital, some firms will be crowded out and become brown.

The competition effect presents a paradox: the transition to a greener economy occurs when SR funds place less emphasis on sustainability investments. This observation explains the shape of the aggregate firm value depicted in Panel B of Figure 3: the economy has fewer more valuable green firms as SR funds focus more on sustainability. Our model argues that such an ironic observation might arise in an economy with a limited amount of social capital.

Finally, our model implies that the impact of social preferences on green transition is non-monotonic. When social preferences are weak, i.e., $\gamma_{SR} < \gamma_{SR}^{PC}$, positive preference shocks help relax pro-social investors' participation constraint and promote positive impact. As long as $\gamma_{SR} \geq \gamma_{SR}^{PC}$, however, the mass of green firms starts decreasing in social preferences, due to the crowing-out effect. Further increases in social preferences result in $\gamma_{SR} > \gamma_{SR}^{m}$. As previously shown, each firm reaches its maximum financing capacity from social capital and thus, the mass of green firms becomes independent of social preferences.

# 5 Welfare Analysis and Policy Implications

In this section, we study our model's welfare and policy implications. We first derive model-implied welfare measures in Section 5.1. Then, we analyze welfare consequences of environmental-related policies including carbon taxes, green investment subsidies, and capital requirements in Section 5.2 to 5.4. Our analysis highlights nuanced effects of these environmental policies: while they help SR funds with weaker social preferences fund green firms, they may backfire, i.e., intensify competition for scarce social capital and crowd out green investments. Technical details for this section's results are provided in Appendix B.

## 5.1 Measuring Welfare

We define the welfare of the market economy using the utilitarian approach. That is, welfare is the sum of the net payoffs of all the agents in the economy. First, note that competitive financial investors break even. Second, entrepreneurs of both green and brown firms earn the same payoffs because of the indifference condition (19). Lastly, SR funds break even in the sense that their financial contribution $I_{SR}$ equals the value of outside equity $\frac{p\mathbb{E}_g(Y_S)I_g}{1+r^*_{SR}}$. However, SR funds also derive non-pecuniary benefits from sustainability investment. As a result, the social welfare is

$$W(r^*_{SR}, m^*_g) \equiv U^g_E + m^*_g \gamma_{SR} \frac{\mathbb{E}_g(S) I_g}{1 + r^*_{SR}}. \tag{26}$$

Note that SR funds do not invest in brown firms, and thus, do not internalize $\mathbb{E}_b(S)$ in (26).[22] In addition, we interpret SR funds as a representative agent of the intermediary sector. Hence, their private valuation of the social outcome is weighted by $m^*_g$. That is, SR funds are better off if more firms they invest in are engaging in sustainability investment.

In Figure 5, we first plot the welfare measure (26) in Panel A. It shows that (i) the presence of SR funds improve sustainability investment relative to the benchmark ($m_g = 0$), and thus, improves social welfare; and (ii) the overall social welfare of the economy with SR funds increases with $\gamma_{SR}$. However, these results must be interpreted with caution. As seen from equation (26), $\gamma_{SR}$ has a mechanical effect on the calculation of the social welfare. It is thus not surprising to see that the welfare increases with the preference parameter.

[22]See Broccardo et al. (2022), Oehmke and Opp (2024), and Dangl et al. (2023) for analyses involving investors who internalize the consequences of their funding decisions.

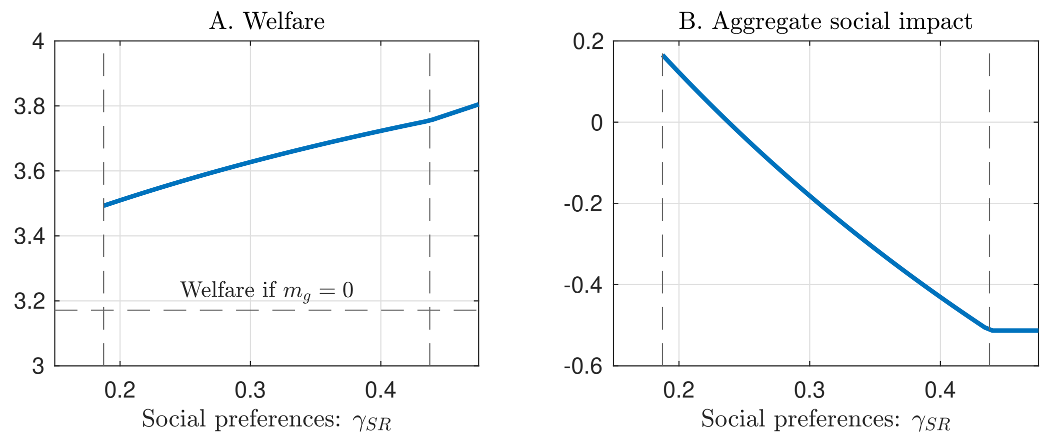


**Figure 5: Social impact and welfare.** In Panel A, we plot the social welfare $W(r^*_{SR}, m^*_g)$; and in Panel B, we plot the aggregate social impact $m^*_g \mathbb{E}_g(S) I_g + (1 - m^*_g)\mathbb{E}_b(S) I_b$.

While the entrepreneur sector does not internalize the aggregate social impact of the production economy, it is a critical determinant of a government's objective. In our model, we define it as

$$m^*_g \mathbb{E}_g(S) I_g + (1 - m^*_g)\mathbb{E}_b(S) I_b.$$

This measure is closely linked to the target of achieving net zero emissions, as positive (negative) values of social impact indicate that the economy exceeds (falls short of) this target. Similar to welfare, the economy with SR funds (solid line) always produces a higher social impact than the economy with only financial investors (dashed line). However, once we account for the effects of social preferences on $m^*_g$, strong social preferences result in the same competition effect that reduces the aggregate social impact.

## 5.2 Carbon Taxes

Consider a carbon tax levied on the carbon emissions made by producers. For simplicity, we assume that the government taxes cash flows at rate $\tau_C$ upon the brown outcome and normalize the carbon tax rate to zero upon the green outcome. Denote the project's after-tax NPV per unit of investment by $\pi_g(\tau_C) \equiv \frac{p(1-(1-q)\tau_C)R}{1+r_F} - 1$ under the green policy; and by $\pi_b(\tau_C) \equiv \frac{p(1-(1-q+\Delta q)\tau_C)R}{1+r_F} - 1$ under the brown policy.[23] Under the optimal investment scale, the incremental tax obligation associated

[23] In what follows, variables having 0 as an argument, e.g., $\Delta^*_{SR}(0)$, are derived in the baseline model with $\tau_C = 0$; and variables with $\tau_C$ as argument means $\tau_C > 0$. The same notation rule applies to the subsidies discussed in the next section.

with the brown project is

$$\frac{\tau_C pR}{1+r_F}\left((1-q+\Delta q)I_b(\tau_C)-(1-q)I_g(\tau_C)\right).$$

Hence, a brown firm's carbon tax liabilities are higher than that of a green firm if and only if

$$\frac{\Delta q}{1-q} > \frac{I_g(\tau_C)-I_b(\tau_C)}{I_b(\tau_C)} = \frac{\Lambda_S}{\rho_R}. \tag{27}$$

Intuitively, the condition requires that the brown outcome is sufficiently more likely to occur under the brown policy, i.e., the observable social outcome is informative about the unobservable investment in sustainability.[24] Let us state the main result of this section.

**Proposition 6.** *If condition (27) holds, then the carbon tax $\tau_C$ lowers the required funding advantage, in that $\Delta^*_{SR}(\tau_C) < \Delta^*_{SR}(0)$, reduces each green firm's demand for social capital $I_{SR}$, and its investment scale $I_g$.*[25] *However, it increases the equilibrium mass of green firms $m^*_g$. In addition, the carbon tax reduces $\gamma^{PC}_{SR}(\tau_C)$, thereby promoting the entrance of SR funds with weaker social preferences.*

The results can be understood as follows. The carbon tax that satisfies (27) reduce the net payoff of brown entrepreneurs relative to green entrepreneurs and thus, makes the green project comparatively more attractive to entrepreneurs. This increases the demand for green investment as well as SR funds' monitoring services, bidding up the equilibrium return on social capital. The price effect is verified in the top-left panel of Figure 6. As the cost of social capital increases, the funding advantage declines. The marginal entrepreneur committing to sustainability investment earn a lower advantage of

$$\Delta^*_{SR}(\tau_C) = \rho_R\left[\frac{\pi_b(\tau_C)+\Lambda_S}{\rho_R+\Lambda_S} - \frac{\pi_g(\tau_C)}{\rho_R}\right] < \Delta^*_{SR}(0). \tag{28}$$

Next, the carbon tax decreases each green firm's demand for social capital $I_{SR}$. There are two reasons. First, the price effect: as $r^*_{SR}$ increases with $\tau_C$, each dollar of social capital becomes less desirable to use. Second, the carbon tax directly tightens financial constraints. Specifically, firms

[24] The condition does not depend on which tax base is used. E.g., if firms are taxed based on their carbon emissions in the brown state, then replacing $pR$ with $B$ would lead to the same condition as (27).

[25] The carbon tax also decreases each brown firm's investment scale $I_b$.

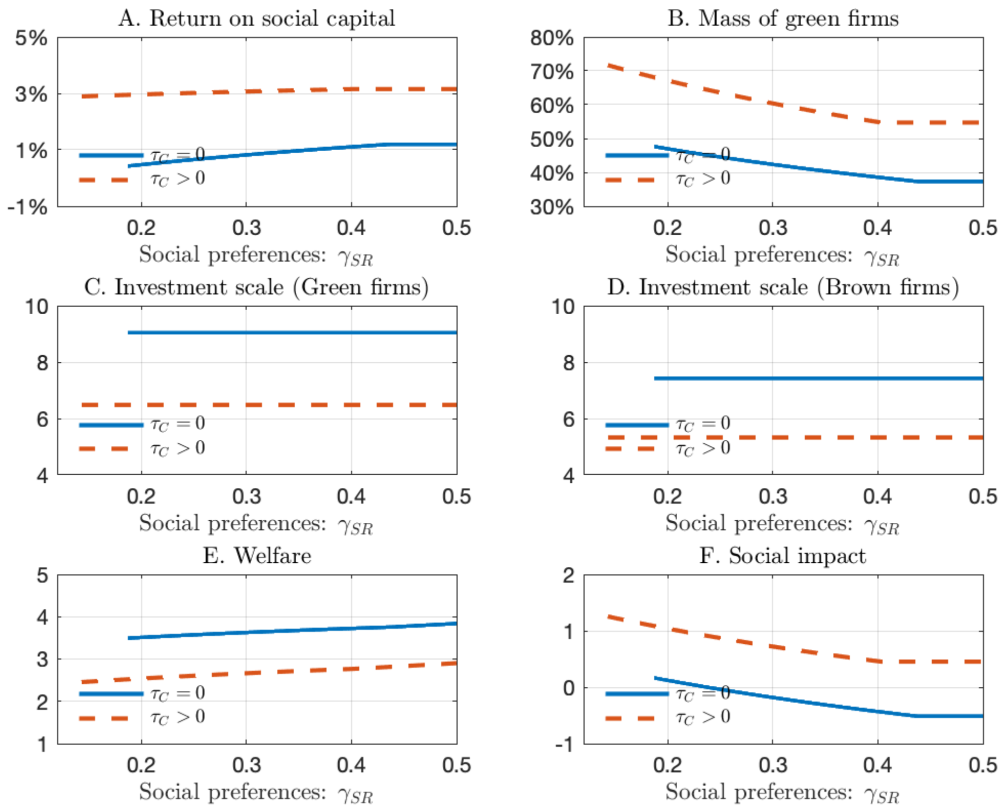


**Figure 6: The carbon tax.** In each panel, the solid line represents the base-case in which $\tau_C = 0$ and the dashed line represents the case in which $\tau_C > 0$.

in the brown state must pay the carbon tax, which reduces their pledgeable income.[26]

This effect on the intensive margin $I_{SR}$ has a profound implication: the carbon tax increases the equilibrium mass of green firms becomes larger (top-right panel of Figure 6), even though competition for the limited supply of social capital intensifies. Our analysis thus reveals a novel trade-off: the carbon tax promotes sustainability at the expense of reduced investment capacity. In addition, the carbon tax promotes sustainability also by relaxing the participation constraint of SR funds. The intuition is that a lower required funding advantage implies a smaller financial loss for SR funds, which then allows those funds with weaker social preferences to participate in

[26]When a green firm faces a binding monitoring constraint ($\gamma_{SR} \leq \gamma_{SR}^M(\tau_C)$) and borrows also from financial investors, a lower pledgeability implies a reduced investment scale $I_g(\tau_C > 0) < I_g(\tau_C = 0)$. When the monitoring constraint does not bind in the optimal contract ($\gamma_{SR} > \gamma_{SR}^M(\tau_C)$) and the green firm borrows solely from SR funds, reduced pledgeability implies $\mathbb{E}_g(Y_S; \tau_C > 0) < \mathbb{E}_g(Y_S; \tau_C = 0)$, and the difference is given by $(1-q)\tau_C R$. In this case, the investment scale of green firms is also reduced.

funding green projects.

The bottom-right panel of Figure 6 illustrates a case in which the aggregate social impact, $m_g^* \mathbb{E}_g(S) I_g + (1 - m_g^*) \mathbb{E}_b(S) I_b$, improves despite each green firm undertaking a smaller investment scale. This is so because the carbon tax increases the equilibrium mass of green firms.[27] However, the bottom-left panel of Figure 6 shows that the carbon tax reduces welfare in the utilitarian sense. This is driven by both the adverse effects of the tax on the price (discount rate) of social capital and pledgeability, which together erode the non-pecuniary value of sustainability to SR funds and the net payoff of entrepreneurs. Taken together, these results hint that there is a potential conflict between two common regulatory objectives: raw emissions (aggregate social impact) and utilitarian welfare (firm's value and social costs of emissions). This raises the question of what the appropriate objective is for analyzing optimal regulation.

### 5.3 Green Investment Subsidies

In 2022, the United States Congress passed *the Inflation Reduction Act*, which aims to accelerate the transition to a clean energy economy by offering renewable energy tax credits. In response, the European Commission proposes *the Green Deal Industrial Plan*, which includes expanded subsidies to clean-tech firms.[28] In this section, we consider a green investment subsidy that rewards firms pursuing green projects and evaluate its effects on several key equilibrium outcomes.

To fix ideas, we assume that the government can verify the firm's investment at the end of date 1. If an entrepreneur implements a green project, she will receive a payment $z$ per unit of scale from the government, which can then be consumed by her. The green subsidy becomes a private benefit for the entrepreneur when she does not choose any of the brown projects, and it effectively reduces the private benefit of a brown project from $\lambda_S$ to $\lambda_S^z \equiv \lambda_S - z$. We summarize our analytical results in the proposition below.

**Proposition 7.** *The green subsidy $z$ increases the equilibrium return on social capital $r_{SR}^*$ and decreases the investment scale of green firms $I_g$. In addition, the green subsidy reduces $\gamma_{SR}^{PC}(z)$ through reducing the equilibrium funding advantage $\Delta_{SR}^*(z)$.*

As with the carbon tax, the green subsidy generates the same price effect. It is immediate

[27]Note that the total emission is reduced partly because each brown firm operates at a smaller scale.

[28]See, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_510.

that the subsidy provides an extra incentive for entrepreneurs to go green. As shown below, the investment subsidy also (weakly) increases each green firm's demand for social capital. Thus, competition among entrepreneurs bids up the equilibrium return on social capital $r^*_{SR}$ (the top-left panel of Figure 7) and reduces the equilibrium funding advantage

$$\Delta^*_{SR}(z) = \Delta^*_{SR}(0) - \frac{z}{1+r_F}\frac{\rho_R - \pi}{\rho_R + \Lambda_S}, \tag{29}$$

for the marginal entrepreneur choosing the green project.

Proposition 7 also claims that the investment scale of green firms decreases with the subsidy (the middle-left panel of Figure 7). This is driven by the increased equilibrium return on social capital or equivalently, reduced equilibrium funding advantage (29).[29] In other words, the subsidy makes social capital more costly, reduces green firms' pledgeable income, and lowers their investment scale. Similar to the carbon tax, however, the investment subsidy mitigates SR fund's financial losses by increasing their return $r^*_{SR}$, thereby encourages participation, in that $\gamma^{PC}_{SR}(z)$ decreases with $z$.

However, the effects of the green subsidy on the equilibrium mass of green firms are subtle. It is evident that the green subsidy relaxes the entrepreneur's incentive compatibility for green investment, frees up resources for the firm to increase borrowing from SR funds. Each green firm then demands more capital from SR funds, in that $I_{SR}(z)$ increases with $z$. Consequently, a smaller number of firms are able to access social capital. In this sense, the green subsidy crowds out green firms. The top-right panel of Figure 7 provides an illustration of the crowding-out effect: $m^*_g(z)$ is generally lower than $m^*_g(0)$.

It is noteworthy that for each line, the kink happens when $\gamma_{SR} = \gamma^M_{SR}(z)$, beyond which SR funds face a slack monitoring constraint and thus, green firms are able to borrow exclusively from SR funds by setting $Y_G = R - X_G$ and $Y_B = R - X_B$. As a result, $\mathbb{E}_g(Y_S; z) = \mathbb{E}_g(Y_S; 0)$ no longer depends on $\gamma_{SR}$. For a market populated by SR funds with strong social preferences (high $\gamma_{SR}$), the green subsidy actually lowers $I_{SR}(z)$ through the price channel, in that the increased cost of capital reduces the amount of capital each green firm can raise from SR funds and thus, crowds in green firms.

[29] It is true that the subsidy erodes the private benefit of brown projects and the corresponding incentive costs for green investment. However, the policy reduces only the ES-linked pay spread to the entrepreneur while leaving the average compensation for effort unchanged, in that $\mathbb{E}_g(X_S; z) = \mathbb{E}_g(X_S; 0) = \frac{\lambda_R}{\Delta p}$. Thus, the effect of the subsidy on investment scales comes from the increased cost of capital.

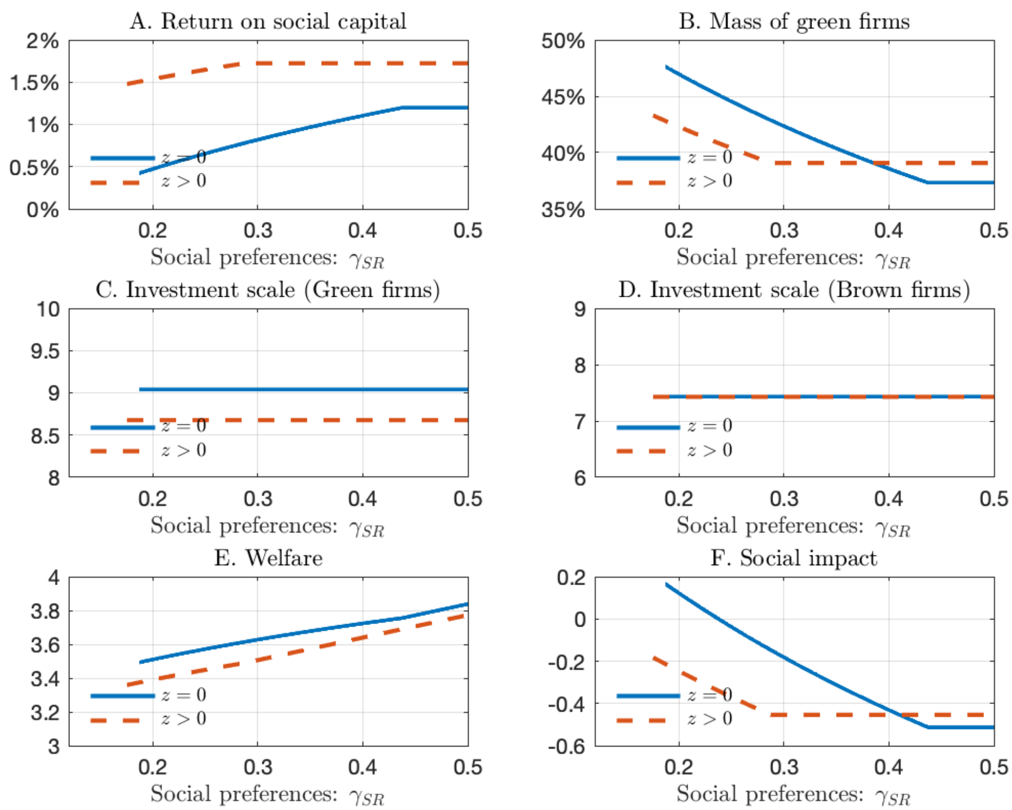


**Figure 7: Green investment subsidies.** In each panel, the solid line represents the base-case in which $z = 0$ and the dashed line represents the case in which $z > 0$.

Compared to the case of the carbon tax, the bottom panels of Figure 7 then illustrate a less ambiguous welfare implications of the green subsidy. Because of the tightened financial constraints and the crowding out effect, the aggregate social impact generally declines with the subsidy, and it increases only from the policy that crowds in green investment. Note that the green subsidy has no effect on the payoff of brown entrepreneurs, and hence, the green entrepreneurs receiving the subsidy attain the same payoff as the green entrepreneurs without it. Thus, the reduction in welfare (the bottom-left panel) is driven by the lower non-pecuniary value of social impact to SR funds.[30]

### 5.4 Capital Requirements

What could be a more efficient policy that improves an economy's sustainability and welfare? Our analyses so far have been confined to a fixed supply of social capital. However, commonly proposed policy tools, referred to as a green supporting factor, aim to reduce the credit risk weights assigned to green loans and climate-friendly investments.[31] This observation motivates us to conjecture that the supply side can be the key and that a green capital requirement might be welfare-improving.

As an example, we interpret SR funds as banks that lend to sustainable firms, which face less stringent capital requirements imposed by regulators. In terms of the model, this policy corresponds to an increase in the supply of social capital $K_{SR}$. Since the equilibrium return on social capital $r^*_{SR}$ is driven by the funding advantage $\Delta^*_{SR}$, the policy has no effect on the cost of capital wedge, investment scale, and the individual firm's demand for social capital. By the market-clearing condition, a higher $K_{SR}$ implies a higher equilibrium mass of green firms $m^*_g$. Therefore, a more relaxed capital requirement will promote sustainability investments and improve social welfare.

Oehmke and Opp (2023) show that lowering capital requirements for clean loans may crowd in dirty lending. Moreover, they argue that carbon taxes are perhaps a more effective tool to address carbon emissions. Focusing on the endogenous market responses to the policy instrument, our analysis reveals that carbon-intensive firms that are induced to transit to green could bid up the green cost of capital and crowd out existing sustainable firms. Based on the market adjustment

[30] For simplicity, we have not considered rebating the tax revenue that a government collects from carbon taxes. It is conceivable that a tax rebate, e.g., to households, may help the overall social welfare. Similarly, we have not considered the government's financing of green subsidies. If a distortionary tax is levied, welfare will be further lowered.

[31] See, e.g., Dombrovskis (2017) and ECB (2021). Research on green capital requirements without endogenous financial constraints includes, for example, Thomä and Gibhardt (2019) and Dafermos and Nikolaidi (2021).

mechanism, we propose the ability to ease market competition for scarce social capital as a benefit of the green supporting factor.

# 6 Discussion

## 6.1 Comparison to the Greenium Literature

The literature on socially responsible investing has emphasized the importance of the cost-of-capital channel for facilitating green transitions. Prior work using asset pricing models has identified a "greenium" for sustainable firms, arising from various mechanisms. For instance, under sustainable investment mandates, the idiosyncratic risk for holding brown firms becomes significant (Heinkel et al., 2001, Hong and Kacperczyk, 2009). In Hong et al. (2023), green firms enjoy a lower cost of capital because of their commitment to build costly decarbonization capital, which results in a lower dividend yield. Our model departs from previous studies by focusing on SR funds which commit to a narrow mandate (non-consequentialist preferences, see Dangl et al. (2023)). This approach aligns more closely with the CAPM model of Pástor et al. (2021), where SR funds gain non-pecuniary benefits from firm's sustainable investments.

Our work introduces a greenium from a corporate finance perspective, without relying on risk-diversification arguments. The equilibrium cost-of-capital wedge we identify is novel in that it is driven solely by the agency problem associated with green investment, as demonstrated in Proposition 2 and funding advantage (22). Consequently, entrepreneurs must be provided sufficient financial incentives for engaging in green transitions. More broadly, our mechanism suggests that the non-contractibility of sustainable investment decisions—due to factors like asymmetric information and limited commitment—can similarly result in a greenium. Empirically identifying the contributions of these different mechanisms to the cost of capital for sustainable firms remains an important direction for future research.

## 6.2 How to Make Impact?

In addition to reducing a firm's cost of capital, some practitioners and academics advocate for divestment as a means to support sustainable development. Our model, however, emphasizes that active ownership is indispensable for successful green transitions. Active engagement by socially conscious shareholders has been shown to be an effective strategy for promoting green transformation (Dimson et al., 2015, 2023; Dyck et al., 2019; Kim et al., 2019; Naaraayanan et al., 2021; Broccardo et al., 2022). Interestingly, Berk and van Binsbergen (2021) also support ESG activism but argue against the importance of the cost-of-capital channel.

Our work emphasizes investor activism and low-cost capital as key conditions for green transitions. That said, investor activism might not be necessary if green projects are not prohibitively expensive from an entrepreneur's perspective, meaning that deep brown projects offer limited private benefits. In such cases, SR funds could save on monitoring costs but would need to provide greater financial incentives to address agency issues. The question boils down to the relative efficiency of activism versus incentive pay. However, the model's assumption that monitoring can eliminate deep brown projects captures a practical scenario where active engagement complements a firm's sustainable investments. In other words, active shareholders can potentially create additional value by exercising their control rights to influence a firm's commitment to sustainability. We believe that greater impact can be achieved when value is created through active investing.

The backfiring effect of market competition for social capital offers valuable insights for investors aiming to make a social impact. Our findings indicate that aggregate social impact is highest when the price of social capital is lowest. To maximize social impact, responsible investors might consider committing to not raising their required returns when demand for green funds is strong. Alternatively, such investors could implement self-imposed credit limit to each firm, which allows them to fund a larger number of green firms, thereby amplifying their overall impact.

### 6.3 Modeling Assumptions

**Task independence.** In our model, effort and sustainability policy independently affect financial and social outcomes. In practice, intensive production leads to pollution or safety issues, creating a strong tension between profit maximization and sustainability. With endogenous financial constraints arising from agency problems being the driving force, our main insights remain applicable even when tasks are technologically dependent. Although a brown firm might contract on social outcomes for information filtering, financial investors still incur additional agency costs when implementing a green project that offers them no direct value.

**Entrepreneur's social preferences.** To isolate the effects of socially responsible investors, our model assumes entrepreneurs are neutral to social outcomes. Obviously, if entrepreneurs prefer green initiatives, smaller ES-linked pay is needed for incentive provisions. In fact, we argue in Appendix B.3 that the effects of introducing entrepreneur's social preference are equivalent to a green subsidy matching the preference intensity.

# 7 Conclusion

This paper develops a novel equilibrium model, wherein socially responsible investors engage actively with firms, playing the dual role of capital suppliers and monitors. Central to our model is the concept of the funding advantage of social capital, a key element that not only creates a cost-of-capital wedge but also alleviates the financial constraints of firms. Thus, our paper provides a novel perspective on the cost-of-capital channel for sustainability investment, emphasizing the important role of financial intermediaries in mitigating agency frictions.

Our research sheds new light on the relationship between social awareness and sustainability outcomes. We demonstrate that an increase in social preferences, without a simultaneous increase in the supply of social capital, may lead to unintended consequences. Specifically, heightened competition for social capital could reduce the share of green firms in the economy, impacting overall welfare negatively.

Additionally, our contribution extends to the literature on optimal security design for sustainable firms. We propose innovative financing arrangements, involving the issuance of sustainability-linked debt to financial investors, with entrepreneurs and financial intermediaries as residual claim holders. These structures provide a practical avenue for aligning the interests of entrepreneurs and socially responsible funds with environmental and social performance.

Our findings imply that policy interventions must prioritize increasing the supply of social capital. Government initiatives, such as relaxing capital requirements for financial intermediaries involved in sustainable investments, can catalyze green transitions and contribute to overall welfare enhancement. Furthermore, we identify a sufficient condition for carbon taxation to impact sustainability, which emphasizes the crucial role of regulatory demands for transparent corporate sustainability disclosure.

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# Appendix

## A Proof of the Main Results

### A.1 Proof of Lemma 2

For completeness, we provide the primitive set of incentive constraints. First, assuming high effort, for the green project to be chosen over brown,

$$p\left(qX_G + (1-q)X_B\right) \geq p\left(\left(q - \Delta q\right)X_G + \left(1 - q + \Delta q\right)X_B\right) + \lambda_S.$$

This leads to (12). Second, assuming a green project, high effort is preferred over shirking if

$$p\left(qX_G + (1-q)X_B\right) \geq \left(p - \Delta p\right)\left(qX_G + (1-q)X_B\right) + \lambda_R.$$

which simplifies to (13), or equivalently,

$$X_B + q\left(X_G - X_B\right) \geq \frac{\lambda_R}{\Delta p}. \tag{A.1}$$

Lastly, for the effort-green policy to dominate the shirking-brown policy,

$$p\left(qX_G + (1-q)X_B\right) \geq \left(p - \Delta p\right)\left((q - \Delta q)X_G + (1 - q + \Delta q)X_B\right) + \lambda_R + \lambda_S.$$

This implies (14). Equivalently, this constraint can also be written as

$$X_B + \Delta q\left(\frac{p}{\Delta p} + \frac{q - \Delta q}{\Delta q}\right)\left(X_G - X_B\right) \geq \frac{\lambda_R + \lambda_S}{\Delta p}. \tag{A.2}$$

We can depict the set of incentive-compatibility contracts on a $X_B$ vs. $X_G - X_B$ plane. Note that IC: effort from (A.1) has a slope $q$ and IC: effort+green from (A.2) has a slope $\Delta q\left(\frac{p}{\Delta p} + \frac{q-\Delta q}{\Delta q}\right)$. We have that IC: effort+green is steeper than IC: effort since

$$\Delta q\left(\frac{p}{\Delta p} + \frac{q - \Delta q}{\Delta q}\right) > q \iff p - \Delta p > 0.$$

To maximize the entrepreneur's net payoff (11), her expected compensation, $\mathbb{E}_g(X_S)$, must be minimized subject to all incentive-compatibility constraints. Thus, a necessary condition for the optimality is that the incentive constraint (14) must be binding, i.e., $\mathbb{E}_g(X_S) = \frac{\lambda_R}{\Delta p}$. Moreover, the objective (11) implies that indifference curves on $X_B$ vs. $X_G - X_B$ plane are linear and have a slope $q$. Optimization then implies that the optimal contract must lie on the red and bold

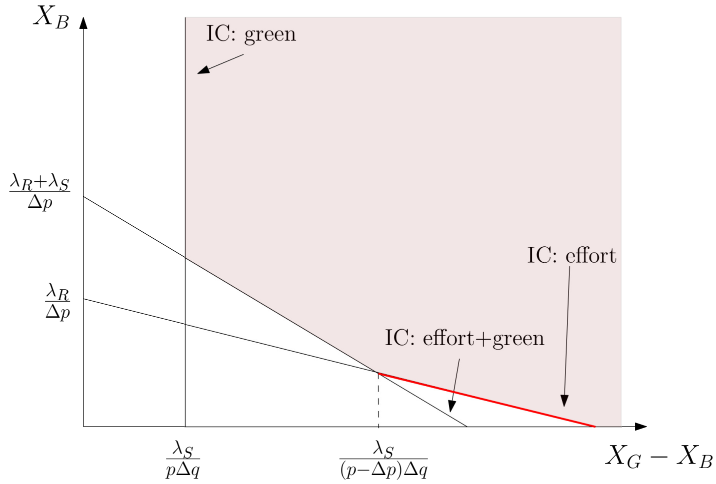


**Figure 8: The set of incentive-compatible contracts for the entrepreneur.** The shaded area gives all those $X_B$ and $X_G - X_B$ pairs that satisfy incentive constraints (12), (13), and (14).

segment in Figure 8: any other contract either results in $\mathbb{E}_g(X_S) > \frac{\lambda_R}{\Delta p}$ or violate at least one of the incentive constraints. This implies a second necessary condition: $X_G - X_B$ must be in the interval $\left[\frac{\lambda_S}{(p-\Delta p)\Delta q}, \frac{\lambda_R}{q\Delta p}\right]$, with the left endpoint solving (13) and (14), and the right endpoint solving (13) with $X_B = 0$.

## A.2 Proof of Proposition 1

Using Lemma 2, we substitute $\frac{\lambda_R}{\Delta p}$ for $\mathbb{E}_g(X_S)$ in the entrepreneur's net payoff (11) and obtain

$$U_E^g\left(r_{SR}, \mathbb{E}_g(Y_S)\right) = \frac{\pi + \Delta_{SR}\left(r_{SR}, \mathbb{E}_g(Y_S)\right)}{\rho_R - \pi - \Delta_{SR}\left(r_{SR}, \mathbb{E}_g(Y_S)\right)} A, \tag{A.3}$$

where $\rho_R \equiv \frac{p}{\Delta p}\lambda_R$ and $\Delta_{SR}\left(r_{SR}, \mathbb{E}_g(Y_S)\right) \equiv \frac{(r_F - r_{SR})p\mathbb{E}_g(Y_S)}{(1+r_{SR})(1+r_F)}$. It is obvious that the entrepreneur's payoff (A.3) is increasing in $\Delta_{SR}\left(r_{SR}, \mathbb{E}_g(Y_S)\right)$ given $r_F > r_{SR}$. It follows that the entrepreneur chooses to maximize $\mathbb{E}_g(Y_S)$. Note that the incentive constraint (12) requires $X_G > X_B$, which implies $R - X_G < R - X_B$ as illustrated by the upper bounds for $Y_S$'s in Figure 9 (The green line and brown lines). As the upper bounds restrict $Y_S's$, the feasible set of $Y_S's$ depends on $X_S's$. Given this information, we solve for the optimal contract below.

First, consider the case $\gamma_{SR} \leq \frac{c}{(G+B)\Delta q}$. The black line (IC: monitoring) in the left panel in Figure 9, $Y_G = Y_B + \frac{c - \gamma_{SR}(G+B)\Delta q}{p\Delta q}$, must have a non-negative intercept, i.e., be on or above the 45-degree line on the $Y_B$-$Y_G$ plane. Hence, the set of feasible contracts is given by the triangular area between the green upper bound $R - X_G$ and the intercept $\frac{c-\gamma_{SR}(G+B)\Delta q}{p\Delta q}$ in the left panel in Figure 9. Then, $\mathbb{E}_g(Y_S)$ can be maximized by setting $Y_G = R - X_G$ and $Y_B = R - X_G - \frac{c-\gamma_{SR}(G+B)\Delta q}{p\Delta q}$, which is the point $C$ in the figure where the green upper bound crosses the SR funds' incentive constraint

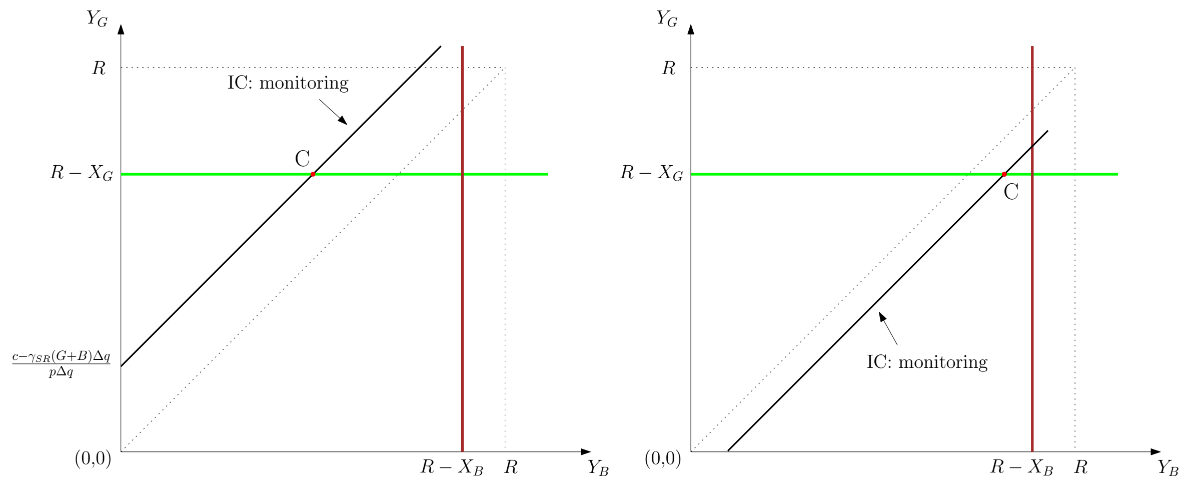


**Figure 9: The optimal** $(Y_G, Y_B)$**.** Given $(X_G, X_B)$, the residual cash flows $R - X_G$ and $R - X_B$ impose upper bounds on $Y_S$'s. Incentive-compatible $(Y_G, Y_B)$ are on and above the line named IC: monitoring, which is given by (16). The upward-sloping dotted line is a 45-degree line. Point $C$ is the optimal $(Y_G, Y_B)$.

(16). Obviously, $Y_G > Y_B$, and

$$\mathbb{E}_g(Y_S) = R - X_G - (1-q)\frac{c - \gamma_{SR}(G+B)\Delta q}{p\Delta q}.$$

This implies $\mathbb{E}_g(Y_S)$ decreases with $X_G$. Moreover, as the effort constraint (13) must be binding, a lower $X_G$ corresponds to a higher $X_B$. That is, by sliding left and upward along the red segment in Figure 8, the incentive constraint (14) must bind too. Solving (13) and (14) simultaneously, we obtain (17). Overall, the solution maximizes $Y_G = R - X_G$ (the green line) but the reduction in $R - X_B$ (the brown line) has no impact on $Y_B$ since the monitoring constraint binds first.

Next, consider the case $\frac{c}{(G+B)\Delta q} < \gamma_{SR} \leq \gamma_{SR}^M \equiv \frac{1}{G+B}\left(\frac{c}{\Delta q} + \frac{p\lambda_S}{(p-\Delta p)\Delta q}\right)$. The black line (IC: monitoring) will have a negative intercept. Suppose $X_G$ and $X_B$ are given by the contract as in the first case, then

$$Y_B = R - \frac{\lambda_R}{\Delta p} - \frac{(1-q)\lambda_S}{(p-\Delta p)\Delta q} - \frac{c - \gamma_{SR}(G+B)\Delta q}{p\Delta q} \text{ and } X_B = \frac{\lambda_R}{\Delta p} - \frac{q\lambda_S}{(p-\Delta p)\Delta q}.$$

It follows that $Y_B + X_B \leq R$ if and only if $\gamma_{SR} \leq \gamma_{SR}^M$. Geometrically, the black line is below the 45-degree line and passes through the maximized green line from below as shown in the right panel of Figure 9. Since $Y_G = R - X_G$ is maximized, any deviation involving reducing $Y_G$ is suboptimal. Hence, point $C$: $Y_G = R - X_G$ and $Y_B = R - X_G - \frac{c-\gamma_{SR}(G+B)\Delta q}{p\Delta q}$ with $X_G$ and $X_B$ given by (17) is optimal.

Lastly, for $\gamma_{SR} > \gamma_{SR}^M$, and suppose $X_G$ and $X_B$ are given by (17). Then, the black line has a position as in Figure 10. Optimization requires $Y_G = R - X_G$ and $Y_B = R - X_B$, i.e., Point C in the figure. It follows that the monitoring constraint (16) does not bind. The problem is that there might be deviations from the contract (17) that improves the entrepreneur's payoff. Note

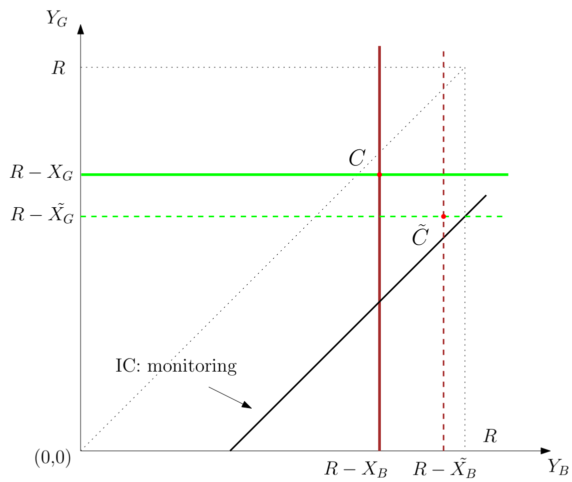


**Figure 10: The effect of raising $X_G$ and reducing $X_B$ on the upper bounds for $Y_G$ and $Y_B$.**

that, along the red segment, the only possible deviation from the contract (17) is to lower $X_B$ to some $\tilde{X_B}$, which moves the brown line to the right, and to increase $X_G$ to some $\tilde{X_G}$, which lowers the green line. In Figure 10, the deviation results in changes in the upper bounds from the solid green/brown lines to the dashed lines. Optimization still requires the corner, point $\tilde{C}$, to be the solution.

We claim that the entrepreneur is indifferent from $C$ to $\tilde{C}$. Formally, for $\epsilon > 0$, let $\Delta X_B = -\epsilon < 0$. The change must respect (13), resulting in $\Delta X_G = \frac{1-q}{q}\epsilon > 0$ which leaves $\Delta \mathbb{E}_g(X_S) = 0$. And since $Y_G = R - X_G$ and $Y_B = R - X_B$, $\Delta \mathbb{E}_g(Y_S) = -\Delta \mathbb{E}_g(X_S) = 0$. In other words, the entrepreneur's payoff (A.3) is left unchanged by this deviation. Note that if the deviation is large enough, the monitoring constraint (16) will bind again, and thus, reducing $Y_G$ (the green line), which lowers the entrepreneur's payoff. Therefore, for $\gamma_{SR} > \gamma_{SR}^M$, the the corner solution ($Y_G = R - X_G$, $Y_B = R - X_B$) is attained and $\mathbb{E}_g(Y_S) = R - \frac{\lambda_R}{\Delta p}$. Since the entrepreneur is indifferent $C$ to $\tilde{C}$, for ease of presentation, we stay the proposition in terms of the contract that attains the maximum $Y_G$.

### A.3 Market Equilibrium and Proof of Proposition 2

In this appendix, we establish the existence and uniqueness of the market equilibrium. In the process, we also prove Proposition 2.

Observe that the optimal contract described in Proposition 1 is independent of the exact value of $r_{SR}$ as long as $r_F > r_{SR}$. Hence, we can suppress the dependence of the funding advantage of social capital on the optimal expectation $\mathbb{E}_g(Y_S)$, and simply write

$$\Delta_{SR}(r_{SR}) = \frac{(r_F - r_{SR})p\mathbb{E}_g(Y_S)}{(1 + r_{SR})(1 + r_F)}.$$

In the next two steps, we first characterize the equilibrium return on social capital $r_{SR}^*$ and the equilibrium mass of green firm $m_g^*$. Then, in step 3, we establish the existence and uniqueness result.

**Step 1: solving for the equilibrium return on social capital $r^*_{SR}$.** Denote the marginal payoff of the green project to the entrepreneur as

$$\Delta U_E \equiv \frac{\pi + \Delta_{SR}(r_{SR})}{\rho_R - \pi - \Delta_{SR}(r_{SR})} - \frac{\pi + \Lambda_S}{\rho_R - \pi}$$

The entrepreneur chooses the green project if and only if $\Delta U_E \geq 0$.
With some algebra, the marginal payoff of the green project can be expressed as

$$\begin{aligned}\Delta U_E =& \frac{\rho_R \Delta_{SR}(r_{SR}) - \Lambda_S(\rho_R - \pi - \Delta_{SR}(r_{SR}))}{(\rho_R - \pi - \Delta_{SR}(r_{SR}))(\rho_R - \pi)} \\ =& \frac{\rho_R(\rho_R + \Lambda_S)}{(\rho_R - \pi - \Delta_{SR}(r_{SR}))(\rho_R - \pi)} \left[\frac{\pi + \Delta_{SR}(r_{SR})}{\rho_R} - \frac{\pi + \Lambda_S}{\rho_R + \Lambda_S}\right]. \end{aligned} \tag{A.4}$$

This implies that the sign of $\Delta U_E$ is the same as the sign of the squared bracket term in (A.4). Therefore, the optimality condition (19) is equivalent to

$$\frac{\pi + \Delta^*_{SR}}{\rho_R} = \frac{\pi + \Lambda_S}{\rho_R + \Lambda_S}, \tag{A.5}$$

where $\Delta^*_{SR} = \Delta_{SR}(r^*_{SR})$. Solving (A.5) for $\Delta^*_{SR}$, we obtain the equilibrium funding advantage (22). Note that (22) can be expressed as

$$\Delta^*_{SR} = \frac{(\rho_R - \pi)\Lambda_S}{\rho_R + \Lambda_S} > 0, \tag{A.6}$$

where the positivity follows from Assumption 2 ($\rho_R > \pi$); and also, this shows that $\Delta^*_{SR}$ is fully determined by the primitives and has no direct dependence on $r^*_{SR}$. Hence, we can use the definition

$$\Delta^*_{SR} = \frac{(r_F - r^*_{SR})p\mathbb{E}_g(Y_S)}{(1 + r^*_{SR})(1 + r_F)},$$

to solve for $r^*_{SR}$, as $\Delta^*_{SR}$ is understood to be a constant. The resulting return is

$$r^*_{SR} = \frac{r_F p\mathbb{E}_g(Y_S) - \Delta^*_{SR}(1 + r_F)}{p\mathbb{E}_g(Y_S) + \Delta^*_{SR}(1 + r_F)}, \tag{A.7}$$

which can be rearranged into (21). Now, since $\Delta^*_{SR} > 0$ by (A.6), we have $r_F > r^*_{SR}$. This step 1 provides a proof of Proposition 2.

**Step 2: solving for the equilibrium mass of green firms $m^*_g$.** Inverting (20), we have

$$m^*_g = \frac{K_{SR}}{A} \frac{1 + r^*_{SR}}{p\mathbb{E}_g(Y_S)} (\rho_R - \pi - \Delta^*_{SR}). \tag{A.8}$$

For $K_{SR}$ sufficiently small, $m^*_g < 1$.
Using (A.7), we can compute $1 + r^*_{SR}$; and using (22), we can show that $\rho_R - \pi - \Delta^*_{SR} = \frac{\rho_R(\rho_R - \pi)}{\rho_R + \Lambda_S}$.

Then, we can also express (A.8) as

$$m_g^* = \frac{K_{SR}}{A} \frac{1 + r_F}{p\mathbb{E}_g(Y_S) + \Delta_{SR}^*(1 + r_F)} \frac{\rho_R(\rho_R - \pi)}{\rho_R + \Lambda_S}. \tag{A.9}$$

This highlights that the $\gamma_{SR}$ and $c$ influence the equilibrium mass of green firms only through their effects on $\mathbb{E}_g(Y_S)$.

**Step 3: the existence and uniqueness of the solution.** Consider the behavior of the left-hand side of (A.5) as $r_{SR}$ varies. First, for $r_{SR} > -1$, $\frac{(r_F - r_{SR})}{(1+r_{SR})(1+r_F)}$ is continuous and decreasing in $r_{SR}$, and it has a positive sign given $r_F > r_{SR}$. Moreover, it converges to zero as $r_{SR} \to r_F$. Second, in the optimal contract (Proposition 1), $\mathbb{E}_g(Y_S) > 0$ and is independent of $r_{SR}$ as long as $r_{SR} < r_F$. Therefore, $\Delta_{SR}(r_{SR}) = \frac{(r_F - r_{SR})}{(1+r_{SR})(1+r_F)} p\mathbb{E}_g(Y_S)$ decreases with $r_{SR}$. Lastly, we consider the left-hand side of (A.5). As $r_{SR} \to -1$, $\frac{\pi + \Delta_{SR}(r_{SR})}{\rho_R} \to \infty$, and as $r_{SR} \to \infty$, converges to $\frac{\pi - p\mathbb{E}_g(Y_S)}{\rho_R}$.
Now, we argue that if

$$\frac{\pi + \Lambda_S}{\rho_R + \Lambda_S} > \frac{\pi}{\rho_R} \tag{A.10}$$

then there always exists a unique $r_{SR}^*$ satisfying (A.5). The key is that (A.10) always holds in our model. By Assumption 2, $\rho_R > \pi$, and together with $\Lambda_S > 0$, we have $\rho_R \Lambda_S > \pi \Lambda_S$, which implies $\rho_R \pi + \rho_R \Lambda_S > \rho_R \pi + \pi \Lambda_S$. That is, $\frac{\pi + \Lambda_S}{\rho_R + \Lambda_S} > \frac{\pi}{\rho_R}$. Thus, condition (A.10) is guaranteed. Finally, $\mathbb{E}_g(Y_S) > 0$, it must be that $\frac{\pi}{\rho_R} > \frac{\pi - p\mathbb{E}_g(Y_S)}{\rho_R}$. Therefore, the left-hand side of (A.5) has a limit as $r_{SR} \to \infty$ that is below $\frac{\pi + \Lambda_S}{\rho_R + \Lambda_S}$. By the Intermediate Value theorem, there exists a unique $r_{SR}^*$ that satisfies (A.5). The corresponding result for $m_g^*$ simply follows from (A.8). Formally, we prove the following proposition.

**Proposition 8.** *Under Assumption 2, the market equilibrium always exists and is unique.*

**Market equilibrium under difference parameter values.** To allow our model to generate novel predictions for a wide range of $\gamma_{SR}$ values, we choose parameter constellations such that $\gamma_{SR}^{PC} < \gamma_{SR}^{M}$.[32] There are three interesting ranges as follows:

1. $\gamma_{SR} < \gamma_{SR}^{PC}$. No firm implements the green policy since SR funds are unwilling to finance it. We have an entirely brown economy, i.e., $m_g^* = 0$.

2. $\gamma_{SR}^{PC} \leq \gamma_{SR} < \gamma_{SR}^{M}$. Green firms are funded by a mix of social and financial capital. Equally important is that $\mathbb{E}_g(Y_S)$ (see equation (18)) increases with $\gamma_{SR}$ in this range, which crucially affects the key equilibrium quantities we study in the next sections.

3. $\gamma_{SR} \geq \gamma_{SR}^{M}$. Green firms are funded only by social capital. I.e., $\mathbb{E}_g(Y_S) = R - \frac{\lambda_R}{\Delta p}$, which is independent of $\gamma_{SR}$. Further increases in social preferences beyond $\gamma_{SR}^{M}$ may have limited impact.

[32] In Appendix A.7, we pin down a condition for parameter values satisfying $\gamma_{SR}^{PC} < \gamma_{SR}^{M}$. We also show that $Y_B$ (see Proposition 1) is never negative, provided that $\gamma_{SR} \geq \gamma_{SR}^{PC}$.

### A.4 Proof of Proposition 3

Substituting $\Delta_{SR}^*$ out using (22) in the optimal investment (24), we have

$$\begin{aligned}
I_g =& \frac{A}{\rho_R - \pi - \frac{(\rho_R-\pi)\Lambda_S}{\rho_R+\Lambda_S}} \\
=& \frac{A}{\rho_R - \pi}\frac{\rho_R + \Lambda_S}{\rho_R} \\
=& I_b\left(1 + \frac{\Lambda_S}{\rho_R}\right),
\end{aligned}$$

where the last equality uses the brown investment (23). It follows that $I_g > I_b$ with the relative magnitude depending on $\Lambda_S$ and $\rho_R$.

### A.5 Proof of Proposition 4

Under the implementation (Figure 1), it is easy to see that $r_{wacc}^g$ is the discount rate such that the present value of future free cash flow $pRI_g$ equals the value of liabilities and equities. That is,

$$\begin{aligned}
\frac{pRI_g}{1+r_{wacc}^g} =& \left(\frac{p\left(R - \mathbb{E}_g(X_S+Y_S)\right)}{1+r_F} + \frac{p\mathbb{E}_g(Y_S)}{1+r_{SR}^*} + \frac{p\mathbb{E}_g(X_S)}{1+r_F}\right) I_g; \\
=& \left(\frac{pR}{1+r_F} + \frac{(r_F - r_{SR}^*)p\mathbb{E}_g(Y_S)}{(1+r_{SR}^*)(1+r_F)}\right) I_g.
\end{aligned}$$

Solving for $r_{wacc}^g$, we obtain (25).

### A.6 Proof of Proposition 5

First, we focus on the individual demand for social capital, given by the binding price condition (3), $I_{SR} = \frac{p\mathbb{E}_g(Y_S)}{1+r_{SR}^*} I_g$, in the market equilibrium. Note that (i) $I_g$ (equation (24)) is independent of $\gamma_{SR}$ and $c$. (ii) By $r_{SR}^*$ (equation (A.7)), we can show that

$$\frac{p\mathbb{E}_g(Y_S)}{1+r_{SR}^*} = \frac{p\mathbb{E}_g(Y_S) + \Delta_{SR}^*(1+r_F)}{1+r_F}. \tag{A.11}$$

Since $\Delta_{SR}^*$ is a constant independent of SR funds' characteristics, $\gamma_{SR}$ and $c$ affect the right-hand side of (A.11) only through $\mathbb{E}_g(Y_S)$, given by (18). It follows that

$$\begin{aligned}
\frac{\partial I_{SR}}{\partial \gamma_{SR}} =& \frac{I_g}{1+r_F}(1-q)\left(G+B\right) > 0; \\
\frac{\partial I_{SR}}{\partial c} =& -\frac{I_g}{1+r_F}\frac{1-q}{\Delta q} < 0.
\end{aligned}$$

Second, the effects of $\gamma_{SR}$ and $c$ can be immediately obtained from the market-clearing condition (20). More directly, we can make use of (A.9). That expression shows that $\gamma_{SR}$ and $c$ affect $\mathbb{E}_g(Y_S)$

in the denominator on the right-hand side. Therefore,

$$\frac{\partial m_g^*}{\partial \gamma_{SR}} < 0 \text{ and } \frac{\partial m_g^*}{\partial c} > 0.$$

If $\gamma_{SR} \geq \gamma_{SR}^{Y_B = R - X_B}$, then $\mathbb{E}_g[Y_S] = R - \frac{\lambda_R}{\Delta p}$. Consequently, neither $I_{SR}$ nor $m_g^*$ depends on $\gamma_{SR}$ or $c$.

### A.7 Derivations and Conditions for the Cutoff Values of $\gamma_{SR}$

Equation (A.11) implies

$$I_{SR} = \frac{p\mathbb{E}_g(Y_S)}{1 + r_{SR}^*} I_g = \left( \frac{p\mathbb{E}_g(Y_S)}{1 + r_F} + \Delta_{SR}^* \right) I_g.$$

Plugging the above expression of $I_{SR}$ into $\gamma_{SR}^{PC}$ (see SR funds' participation constraint (5) and simplifying yields

$$\begin{aligned}
\gamma_{SR}^{PC} &\equiv \frac{1}{\mathbb{E}_g(S)} \left( \frac{(r_F - r_{SR}^*) I_{SR}}{I_g} + c \right) \\
&= \frac{1}{\mathbb{E}_g(S)} \left( \left( \frac{p\mathbb{E}_g[Y_S]}{1 + r_F} + \Delta_{SR}^* \right) \frac{\Delta_{SR}^* (1 + r_F)^2}{p\mathbb{E}_g(Y_S) + \Delta_{SR}^* (1 + r_F)} + c \right) \\
&= \frac{1}{\mathbb{E}_g(S)} \left( \Delta_{SR}^* (1 + r_F) + c \right) \\
&= \frac{1}{\mathbb{E}_g(S)} \left( (1 + r_F) \frac{(\rho_R - \pi)\Lambda_S}{\rho_R + \Lambda_S} + c \right). \qquad \text{(A.12)}
\end{aligned}$$

We focus on parameter constellations such that

$$\gamma_{SR}^{PC} < \gamma_{SR}^{M}.$$

After long and tedious algebra, it can be shown that $\gamma_{SR}^{PC} < \gamma_{SR}^{M}$ requires

$$\frac{\mathbb{E}_g(S)}{-\mathbb{E}_b(S)} \left( \frac{p}{p - \Delta p} \lambda_S - (1 + r_F) \frac{\rho_R - \pi}{\rho_R + \Lambda_S} \Lambda_S \frac{\mathbb{E}_g[S] - \mathbb{E}_b[S]}{\mathbb{E}_g[S]} \right) > c, \qquad \text{(A.13)}$$

which we assume to hold in the numerical analysis.
Moreover, the limited liability constraint implies that $Y_B \geq 0$, or equivalently,

$$\gamma_{SR} \geq \gamma_{SR}^{Y_B = 0} \equiv \frac{1}{G + B} \left( \frac{c}{\Delta q} + p\left( X_G - R \right) \right). \qquad \text{(A.14)}$$

In order to have $\gamma_{SR}^{PC} > \gamma_{SR}^{Y_B = 0}$, we require

$$c > \frac{\mathbb{E}_g[S]}{-\mathbb{E}_b[S]} \left( p\Delta q (X_G - R) - (1 + r_F) \frac{\rho_R - \pi}{\rho_R + \Lambda_S} \Lambda_S \frac{\mathbb{E}_g[S] - \mathbb{E}_b[S]}{\mathbb{E}_g[S]} \right). \qquad \text{(A.15)}$$

But the above inequality always holds since its right-hand side is strictly negative, while the monitoring cost on the left-hand side is positive. In other words, provided that $\gamma_{SR} \geq \gamma_{SR}^{PC}$, $Y_B$ is never negative in a competitive equilibrium.

# B Extensions with Environmental Policies

In this appendix, we first put both carbon taxes and green investment subsidies together and provide key equations for the equilibrium characterization. Then we separately provide proof of the effects of policies in subsections. Given carbon tax $\tau_C$ and green subsidy $z$, the incentive constraints that restrict an entrepreneur's behavior becomes the following. First, given high effort, the green the policy is chosen if

$$p\left(qX_G + (1-q)X_B\right) + z \geq p\left((q-\Delta q)X_G + (1-q+\Delta q)X_B\right) + \lambda_S.$$

Second, given the green policy, entrepreneurs provide efforts over shirking if

$$p\left(qX_G + (1-q)X_B\right) + z \geq (p-\Delta p)\left(qX_G + (1-q)X_B\right) + \lambda_R + z.$$

Lastly, effort-green is chosen over shirking-brown if

$$p\left(qX_G + (1-q)X_B\right) + z \geq (p-\Delta p)\left((q-\Delta q)X_G + (1-q+\Delta q)X_B\right) + \lambda_R + \lambda_S.$$

Therefore, only the green investment subsidy $z$ would change the entrepreneur's compensation contract, not the carbon tax $\tau_C$ which is levied on the date-1 cash flows. We can replace $\lambda_S$ with $\lambda_S^z \equiv \lambda_S - z$ in the contract (17) so that we can express

$$X_G = \frac{\lambda_R}{\Delta p} + \frac{(1-q)\lambda_S^z}{(p-\Delta p)\Delta q} \text{ and } X_B = \frac{\lambda_R}{\Delta p} - \frac{q\lambda_S^z}{(p-\Delta p)\Delta q}.$$

Note that $\mathbb{E}_g(X_S; z) = \mathbb{E}_g(X_S; z=0) = \frac{\lambda_R}{\Delta p}$. For SR funds' contract, recall that the transfers depend on $\gamma_{SR}$. For small $\gamma_{SR}$ such that the monitoring constraint (16) is binding, $Y_G = R - X_G$ and $Y_B = Y_G - \frac{c-\gamma_{SR}(G+B)\Delta q}{p\Delta q}$. Thus, the subsidy $z$ affects $Y_G$ but the carbon tax $\tau_C$ has no effect. In the case of a large value of $\gamma_{SR}$, $Y_G = R - X_G$ and $Y_B = (1-\tau_C)R - X_B$ and thus, both the subsidy and the carbon tax affect $Y_S$. Equating the expressions of $Y_B$ from both cases and solving for $\gamma_{SR}^M$, we obtain

$$\gamma_{SR}^M(\tau_C, z) \equiv \frac{1}{G+B}\left(\frac{c}{\Delta q} + \frac{p\lambda_S^z}{(p-\Delta p)\Delta q} - \tau_C pR\right).$$

The expected SR fund's compensation is then given by

$$\mathbb{E}_g(Y_S; \tau_C, z) = \begin{cases} \mathbb{E}_g(Y_S; \tau_C = 0, z = 0) - (1-q)\tau_C R & \text{if } \gamma_{SR} > \gamma_{SR}^M(\tau_C, z), \\ \mathbb{E}_g(Y_S; \tau_C = 0, z = 0) + \frac{(1-q)z}{(p-\Delta p)\Delta q} & \text{if } \gamma_{SR} \leq \gamma_{SR}^M(\tau_C, z). \end{cases} \tag{B.1}$$

The entrepreneur's net payoff from implementing the deep brown policy, funded exclusively by financial investors, is $U_E^b(\tau_C, z) = \frac{\pi_b(\tau_C)+\Lambda_S}{\rho_R - \pi_b(\tau_C)}A$; and from implementing the green policy, funded by both financial investors and SR funds, her net payoff is $U_E^g(\tau_C, z) = \frac{\pi_g(\tau_C)+z_0+\Delta_{SR}}{\rho_R - \pi_g(\tau_C)-\Delta_{SR}}A$, where

$z_0 = \frac{z}{1+r_F}$ is the date-0 value of the investment subsidies. The indifference condition for the market equilibrium now takes the form of

$$\frac{\pi_g(\tau_C) + z_0 + \Delta_{SR}(r_{SR})}{\rho_R - \pi_g(\tau_C) - \Delta_{SR}(r_{SR})} = \frac{\pi_b(\tau_C) + \Lambda_S}{\rho_R - \pi_b(\tau_C)}. \tag{B.2}$$

Using the same derivation procedure for the main results, the equilibrium funding advantage is

$$\Delta^*_{SR}(\tau_C, z) = (\rho_R + z_0)\,\frac{\pi_b(\tau_C) + \Lambda_S}{\rho_R + \Lambda_S} - (\pi_g(\tau_C) + z_0), \tag{B.3}$$

and the equilibrium return on social capital is

$$r^*_{SR}(\tau_C, z) = r_F - \frac{\Delta^*_{SR}(\tau_C, z)(1 + r_F)^2}{p\mathbb{E}_g(Y_S; \tau_C, z) + \Delta^*_{SR}(\tau_C; z)(1 + r_F)}. \tag{B.4}$$

## B.1 Carbon Taxes: Proposition 6

First, it is straightforward to show that the equilibrium funding advantage is

$$\Delta^*_{SR}(\tau_C) = \Delta^*_{SR}(0) + \frac{\tau_C pR}{1 + r_F}(1 - q)\frac{\rho_R}{\rho_R + \Lambda_S}\left(\frac{\Lambda_S}{\rho_R} - \frac{\Delta q}{1 - q}\right).$$

Thus, the carbon tax reduces the equilibrium funding advantage, provided condition (27) holds. This is intuitive since the condition implies that the expected carbon tax payment is higher for brown firms than for green firms. Moreover, we have

$$\frac{\pi_b(\tau_C) + \Lambda_S}{\pi_g(\tau_C) + \Delta^*_{SR}(\tau_C)} = \frac{I_g(\tau_C)}{I_b(\tau_C)} = \frac{\rho_R + \Lambda_S}{\rho_R} = \frac{\pi + \Lambda_S}{\pi + \Delta^*_{SR}(0)} = \frac{I_g(0)}{I_b(0)}.$$

Hence, it must be that $I_g(\tau_C) < I_g(0)$ because $I_b(\tau_C) = \frac{A}{\rho_R - \pi_b(\tau_C)} < \frac{A}{\rho_R - \pi_b(0)} = I_b(0)$. Taken these results, $\Delta^*_{SR}(\tau_C) < \Delta^*_{SR}(0)$ and $I_b(\tau_C) < I_b(0)$, together,

$$\begin{aligned}
I_{SR}(\tau_C) &= \left(\frac{p\mathbb{E}_g(Y_S; \tau_C)}{1 + r_F} + \Delta^*_{SR}(\tau_C)\right)\frac{A}{\rho_R - \pi_b(\tau_C)}\frac{\rho_R + \Lambda_S}{\rho_R} \\
&\leq \left(\frac{p\mathbb{E}_g(Y_S; 0)}{1 + r_F} + \Delta^*_{SR}(\tau_C)\right)\frac{A}{\rho_R - \pi_b(\tau_C)}\frac{\rho_R + \Lambda_S}{\rho_R} \\
&< \left(\frac{p\mathbb{E}_g(Y_S; 0)}{1 + r_F} + \Delta^*_{SR}(0)\right)\frac{A}{\rho_R - \pi_b(0)}\frac{\rho_R + \Lambda_S}{\rho_R} \\
&= I_{SR}(0)
\end{aligned}$$

where the second inequality follows from $\mathbb{E}_g(Y_S; \tau_C) \leq \mathbb{E}_g(Y_S; 0)$ from ((B.1)), where it holds as equality if $\gamma_{SR} \leq \gamma^M_{SR}(\tau_C)$ and as strict inequality if $\gamma_{SR} > \gamma^M_{SR}(\tau_C)$. From the market-clearing condition (20), $m^*_g$ with $\tau_C > 0$ is higher than $m^*_g$ with $\tau_C = 0$.

Lastly, SR funds' participation constraint becomes

$$\begin{aligned}\gamma_{SR}^{PC}(\tau_C) &= \frac{1}{\mathbb{E}_g(S)}\Big(\Delta_{SR}^*(\tau_C)(1+r_F)+c\Big)\\ &= \gamma_{SR}^{PC}(0)+\frac{\tau_C}{\mathbb{E}_g(S)}pR(1-q)\frac{\rho_R}{\rho_R+\Lambda_S}\left(\frac{\Lambda_S}{\rho_R}-\frac{\Delta q}{1-q}\right)\end{aligned}$$

which decreases with $\tau_C$ given condition (27). I.e., the carbon tax also encourages SR funds' participation in funding green firms. This is a direct consequence of the fact that the carbon tax reduces the equilibrium funding advantage, thereby relaxing the participation constraint.

### B.2 Green Investment Subsidies: Proposition 7

With only the green subsidy the optimal investment scale for green firms are

$$\begin{aligned}I_g(z) =&\frac{A}{\rho_R-\pi-\Delta_{SR}^*(z)}\\ =&\frac{A}{\rho_R-\pi-\Delta_{SR}^*(z=0)+\frac{z}{1+r_F}\frac{\rho_R-\pi}{\rho_R+\Lambda_S}}.\end{aligned}$$

In addition, we can also show that

$$I_g(z)=I_b\frac{\rho_R+\Lambda_S}{\rho_R+z_0}<I_b\frac{\rho_R+\Lambda_S}{\rho_R}=I_g(0).$$

Simply put, the investment subsidy reduces the equilibrium funding advantage and thus, tightens green firms' endogenous financial constraint, which leads to a smaller investment scale for green firms. The participation constraint cutoff value becomes

$$\gamma_{SR}^{PC}(z)=\frac{1}{\mathbb{E}_g(S)}\Big(\Delta_{SR}^*(z)(1+r_F)+c\Big)$$

and thus, $\gamma_{SR}^{PC}(z)$ decreases with $z$ via decreased $\Delta_{SR}^*(z)$.
By Assumption 2, $\rho_R>\pi$, and thus, $I_g(z)$ decreases with $z$. With the subsidy, the equilibrium return on social capital is

$$r_{SR}^*(z)=r_F-\frac{\Delta_{SR}^*(z)(1+r_F)^2}{p\mathbb{E}_g(Y_S;z)+\Delta_{SR}^*(z)(1+r_F)}.$$

By (B.1), $\mathbb{E}_g(Y_S;z)$ weakly increase with $z$ and, by (29), $\Delta_{SR}^*(z)=\Delta_{SR}^*(z=0)-z_0\frac{\rho_R-\pi}{\rho_R+\Lambda_S}$ decreases with $z$, then the combined effect is that the cost of capital wedge decreases with $z$ and $r_{SR}^*(z)$ increases with $z$. For the equilibrium mass of green firms $m_g^*=\frac{K_{SR}}{I_{SR}(z)}$, where SR funds invest

$$I_{SR}(z)=\frac{p\mathbb{E}_g(Y_S;z)+\Delta_{SR}^*(z)(1+r_F)}{1+r_F}\frac{\rho_R+\Lambda_S}{(\rho_R+z_0)(\rho_R-\pi)}A.$$

We have a nonlinear effect of $z$ on $I_{SR}(z)$ since both $\Delta_{SR}^*(z)$ and $\frac{\rho_R+\Lambda_S}{(\rho_R+z_0)(\rho_R-\pi)}$ decreases with $z$ but $\mathbb{E}_g(Y_S;z)$ weakly increase with $z$. This implies that the equilibrium mass of green firms is also nonlinear in $z$.

Note that each green firm's borrowing capacity of social capital is not affected by the investment subsidy. This is so because the investment subsidy does not change the entrepreneur's expected compensation, though it does decrease the entrepreneur's compensation spread $X_G - X_B$. In other words, with the extra incentive provided by the investment subsidy, the optimal compensation is adjusted to reduce the spread between $X_G$ and $X_B$. However, to maximize the use of social capital, the optimal contract minimizes $\mathbb{E}_g[X_S]$, which results in the same value as that derived without the investment subsidy.

### B.3 What If Entrepreneurs Care About Sustainability?

Similar treatments can be made to modeling entrepreneurs' social preferences:

| Type: | Green | Brown | Deep Brown |
|---|---|---|---|
| Private benefit | 0 | $\lambda_S$ | $\Lambda_S$ |
| EN's social benefit | $\gamma_E \mathbb{E}_g(S)$ | $\gamma_E \mathbb{E}_b(S)$ | $\gamma_E \mathbb{E}_b(S)$ |
| Total benefit | $\gamma_E \mathbb{E}_g(S)$ | $\lambda_S + \gamma_E \mathbb{E}_b(S)$ | $\Lambda_S + \gamma_E \mathbb{E}_b(S)$ |
| (Normalized) Total benefit | $\gamma_E \Big( \mathbb{E}_g(S) - \mathbb{E}_b(S) \Big)$ | $\lambda_S$ | $\Lambda_S$ |

In the above formulations, entrepreneurs' social preferences have the same effects as the investment subsidy $z$. Technically, setting $\gamma_E \Big( \mathbb{E}_g(S) - \mathbb{E}_b(S) \Big) = z$ will result in the same equilibrium outcomes. One caveat is that the investment subsidy and entrepreneurs' social preferences may have different implications for social welfare.