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Abstract

We study the optimal design of sustainable debt when a for-profit borrower raises capital from socially responsible investors and motivates a for-profit manager to exert sustainability effort through an executive compensation contract. We ask when fixed-rate bonds or loans are sufficient and when sustainability-linked debt is required, given that executive compensation can also be tied to ESG performance. The analysis shows that the optimal debt contract depends jointly on the investment structure faced by socially responsible investors and the borrower's ability to commit to ESG-linked managerial compensation. When the borrower can adjust ESG-based compensation appropriately, non-contingent debt can replicate the incentive effects of sustainability-linked debt in some environments, whereas explicit sustainability-linked payments remain valuable in others. The results clarify how sustainable debt and ESG-linked executive pay interact as alternative incentive instruments and provide implications for the design of sustainable bonds and loans.

JEL Classification: D86, G12, G20, G32, M14.

Keywords: ESG, managerial compensation, managerial incentives, sustainability-linked debt, sustainable debt.

1. Introduction

The global sustainable debt market has grown rapidly. According to the latest Global State of the Market 2025 report by the Climate Bonds Initiative, cumulative aligned issuance reached $6.8 trillion by the end of 2025.[1] Among sustainable debt instruments, the most common labelled products are green bonds and loans, whose proceeds are restricted to financing eligible environmental or social projects, and sustainability-linked bonds and loans, whose contractual terms are tied to specified environmental, social, and governance (ESG) performance targets but whose proceeds are not restricted to specific uses. Although green bonds and loans remain the dominant segment of the sustainable debt market, sustainability-linked bonds and loans have recently become an important source of ESG-contingent financing (Kim, Kumar, Lee, and Oh, 2025).

At the same time, the incorporation of ESG metrics into executive compensation contracts has grown rapidly (Homroy, Mavruk, and Nguyen, 2023). A majority of investors also support the inclusion of ESG metrics in executive compensation contracts.

Although a growing literature examines sustainable debt and executive compensation tied to ESG performance, it has largely overlooked the theoretical interaction between these two contracting instruments. This paper studies how sustainable debt should be designed when a for-profit borrower raises funds from socially responsible investors while providing incentives for corporate commitment to sustainability through an executive compensation contract offered to a for-profit manager.

We address two questions. First, what is the optimal design of sustainable debt when executive compensation can be contingent on ESG performance? Is it sufficient for borrowers to issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans, rather than issuing sustainability-linked bonds or obtaining sustainability-linked loans? Second, how do debt market structure and the for-profit owner's commitment to executive compensation affect the design of sustainable debt?

To address these questions, we consider a firm in which a for-profit owner raises external funds from socially responsible investors by issuing debt and hires a for-profit manager

[1] See "Sustainable Debt Market Nears USD7 Trillion in Aligned Issuance, Demonstrating Strong Global Momentum," Climate Bonds Initiative, March 17, 2026, https://www.climatebonds.net/news-events/press-room/press-releases/sustainable-debt-market-nears-usd7-trillion-aligned-issuance-demonstrating-strong-global-momentum

to undertake a project that generates both pecuniary returns and social waste. The debt issued by the for-profit owner is sustainable debt whose repayment can be contingent on the firm's ESG performance.

The manager can exert costly effort that increases expected pecuniary returns while reducing expected social waste. The for-profit owner offers the manager an executive compensation contract that depends on both the firm's pecuniary returns and its ESG performance. We distinguish between two cases: (i) the for-profit owner can commit in the initial period to the terms of an executive compensation contract that cannot be revised in the interim period; and (ii) the for-profit owner cannot commit to such terms in the initial period.

Socially responsible investors care about both the financial value of their debt investments and the social waste associated with these investments, and they differ in their preferences over social waste. We also distinguish between two investment structures for socially responsible investors: (i) each individual investor invests directly in debt in the public debt market; and (ii) each individual investor invests in debt through a socially responsible fund (SRF), which in turn invests in debt in the over-the-counter debt market.[2] In the latter case, the for-profit owner bargains with the SRF over the terms of the debt contract and, if the owner can commit to the terms agreed upon through bargaining, over the executive compensation contract.

Our first main result shows that, in the public debt market, noncontingent fixed-rate bonds or loans are optimal and maximize the for-profit owner's expected value, regardless of whether she can commit in the initial period to the terms of the executive compensation contract, provided that project revenues are sufficiently large to cover fixed-rate debt repayments and the manager's compensation in the good state. Hence, sustainability-linked bonds or loans need not be issued.

The intuition is as follows. The manager's effort decision depends directly on executive compensation, but not directly on the debt contract. By contrast, investors' debt investment decisions depend on both the manager's effort decision and the debt contract. The promised debt repayment must therefore balance two effects: its effect on debt investment inflows from socially responsible investors and its effect on the for-profit owner's expected

[2] The SRF corresponds to various types of financial institutions, such as private debt funds, mutual funds, banks, insurance companies, and funds established by these institutions.

pecuniary payoff, net of debt repayments, per unit of investment in the good state.

In this environment, if the for-profit owner can adjust the ESG-linked compensation contract appropriately, she need only control the expected debt repayment in the good state to achieve her objective, because investors' debt inflows depend only on the expected repayment in that state. Thus, as long as the project yields sufficiently high returns in the good state, the for-profit owner can make debt repayments that are independent of the firm's ESG performance in that state, even though the manager's compensation is ESG-linked. Accordingly, by using noncontingent fixed-rate bonds or loans, the for-profit owner can choose a debt contract that attracts her preferred level of investment from socially responsible investors without unnecessarily reducing her expected pecuniary payoff, net of debt repayments, per unit of investment. This conclusion holds regardless of whether she can commit to the executive compensation contract in the initial period.

Our second main result concerns the over-the-counter debt market. If the for-profit owner can commit to the executive compensation contract in the initial period, noncontingent fixed-rate bonds or loans are optimal and attain the maximum value of the bargaining problem, provided that the project yields sufficiently high returns in the good state. If, however, the for-profit owner cannot commit to an executive compensation contract in the initial period, sustainability-linked bonds or loans must be issued.

The intuition again follows from the interaction between debt design and managerial incentives. If the for-profit owner can commit in the initial period to an executive compensation contract that cannot be revised in the interim period, she and the SRF negotiate both the executive compensation contract and the debt contract in the initial period. Even in this case, the promised debt repayment must balance two effects: its effect on debt investment inflows attracted by the SRF from socially responsible investors and its effect on the for-profit owner's expected pecuniary payoff, net of debt repayments, per unit of investment in the good state. The for-profit owner and the SRF thus need only control the expected debt repayment in the good state to achieve their bargaining objectives. Hence, if the project yields sufficiently high returns in the good state, debt repayments can be independent of the firm's ESG performance in that state, and noncontingent fixed-rate bonds or loans are optimal.

By contrast, if the for-profit owner cannot commit in the initial period to an executive compensation contract that cannot be revised in the interim period, she and the

SRF negotiate only the debt contract in the initial period, and she offers the manager an executive compensation contract in the interim period at her sole discretion. The effort induced by the compensation contract that the for-profit owner offers in the interim period therefore differs from the effort that would be induced by a compensation contract negotiated jointly by the owner and the SRF in the initial period. To address this discrepancy, the for-profit owner and the SRF must design the debt contract in the initial period to affect the ESG-linked compensation contract that the owner later offers on her own in the interim period. Because the compensation contract is contingent on ESG performance, the debt repayment must also be contingent on ESG performance to achieve this objective. Accordingly, sustainability-linked bonds or loans must be used.

We explore several extensions of the baseline model. In one extension, we examine how renegotiation-proofness of the executive compensation contract affects the optimal type of debt. Our main results continue to hold except in the case in which the for-profit owner can renegotiate the executive compensation contract in the interim period in the over-the-counter debt market. In this case, noncontingent fixed-rate bonds or loans are optimal as long as project revenues are sufficiently large to cover fixed-rate debt repayments and the manager's compensation in the good state, because both debt repayment and managerial compensation must be determined jointly at date 1 to prevent renegotiation of the executive compensation contract.

In another extension, we allow observable random shocks to occur in the interim period. We show that, if the for-profit owner can commit to the executive compensation contract in the initial period, our main results continue to hold. If, however, the for-profit owner cannot commit to an executive compensation contract in the initial period, sustainability-linked bonds or loans must be used, regardless of whether debt is traded in the public debt market or in the over-the-counter debt market.

We next discuss implications for the design of debt securities or contracts when the for-profit borrower can adjust ESG-linked executive compensation appropriately. Our results show that the design of debt financing under ESG-linked executive compensation depends on two factors: debt market structure and the borrower's commitment to the executive compensation contract. We interpret the strength of the borrower's commitment to the executive compensation contract as closely related to the strength of its governance structure. In addition, our extensions indicate that the design of such debt financing also depends on the borrower's exposure to changes in the external environment.

Given these factors, we provide the following guidance for debt financing under ESG-linked executive compensation. First, suppose that borrowers do not face relatively high exposure to exogenous shocks. In this case, it is sufficient for borrowers to issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans not only when they raise funds in the public debt market, but also when they raise funds in the over-the-counter debt market and have robust governance. However, when borrowers rely on the over-the-counter debt market and have weak governance, sustainability-linked bonds or loans are likely to be needed.

Second, suppose that borrowers face relatively high exposure to exogenous shocks. In this case, it is sufficient for borrowers to issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans when they have robust governance, whereas sustainability-linked bonds or loans are likely to be needed when they have weak governance.

The remainder of the paper is organized as follows. Section 2 reviews the related literature, and Section 3 presents the basic model. Section 4 examines debt financing in the public debt market, while Section 5 studies debt financing in the over-the-counter debt market. Section 6 explores several extensions of the baseline model and examines the robustness of the main results. Section 7 discusses implications. The final section concludes. Appendix A contains the proofs of all propositions and lemmas.

2. Related Literature

Several studies examine optimal managerial compensation contracts based on monetary incentives and social performance metrics. Baron (2008) investigates the balance between monetary incentives and social performance. Chaigneau and Sahuguet (2025) study how socially responsible boards set managerial compensation contingent on firm profits, stock prices, and ESG scores. Geczy, Jeffers, Musto, and Tucker (2021) empirically study how impact funds' compensation contracts adapt to serve multiple goals, while Cohen, Kadach, Ormazabal, and Reichelstein (2023) empirically examine several potential explanations for firms' adoption of executive compensation tied to ESG metrics.[3] These studies focus on the role of managerial compensation in shaping ESG performance but do not consider its

[3] For a more comprehensive list of the empirical literature on ESG-based compensation, see Chaigneau and Sahuguet (2025).

interaction with sustainability-linked bonds or loans.

Other studies examine the contractual features of sustainability-linked bonds and loans. Mariani, D'Ercole, Frascati, and Fraccalvieri (2025) and Braun and Ruffing-Straube (2025) empirically study the contract design and incentive structure of sustainability-linked bonds. By contrast, Aleszczyk, Loumioti, and Serafeim (2023), Du, Harford, and Shin (2023), and Kim, Kumar, Lee, and Oh (2025), and de Novellis, Perdichizzi, and Stella (2026) empirically investigate the effectiveness of sustainability-linked loans in inducing corporate commitments to sustainability. Barbalau and Zeni (2025) analyze the optimal design of outcome-based and project-based green securities in the presence of greenwashing. However, these studies do not examine the interaction between sustainability-linked bonds or loans and managerial compensation.

Chowdhry, Davies, and Waters (2019) study financial contracting on social outcomes under joint financing by profit-motivated and socially responsible investors. Because their model focuses on equity financing, its implications for social impact bonds are limited. Similarly, Oehmke and Opp (2025) examine the optimal financial arrangement that induces for-profit firms to reduce negative externalities under agency frictions when the supply of commercial capital is perfectly elastic. However, their contracts are not contingent on social outcomes, and their framework does not consider ESG-based managerial compensation or sustainability-linked bonds and loans.

In related work on firms' financing constraints, Inderst and Heider (2022) study optimal environmental policy under such constraints, whereas Döttling and Rola-Janicka (2025) analyze optimal carbon pricing. However, these studies do not consider financial contracting on social outcomes.

We contribute to this literature by analyzing how sustainable debt is optimally designed when executive compensation can be contingent on ESG performance. By analyzing the interaction between these two instruments for inducing firms to improve ESG performance, we examine whether it is sufficient for firms to issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans, rather than sustainability-linked bonds or loans.

3. Basic Setup

3.1. Basic environment.—

There are three dates, $(t = 1, 2, 3)$, and three types of agents: a profit-motivated owner, a profit-motivated project manager, and a continuum of heterogeneous outside values-aligned investors with measure $\overline{\theta}$. We refer to the first two agents as the for-profit owner and the for-profit manager, respectively. All agents are risk neutral over financial payoffs and do not discount future payoffs. We impose limited liability, so no agent can receive a negative cash flow.

The for-profit owner owns a firm with a project that can generate both an observable monetary payoff $\widetilde{X}$ per unit of investment and an observable negative externality, social waste, $\widetilde{Z}$ per unit of investment.[4,5] To undertake the project, the for-profit owner must hire the for-profit manager and expend investment at date 1. Aside from the project, neither the for-profit owner nor the for-profit manager has an outside option.

If the project is undertaken, the for-profit manager chooses unobservable operational effort, $a \geq 0$, at date 2. The manager incurs a nonpecuniary effort cost $c(a)$, where $c(0) = 0$, $c'(a) > 0$, and $c''(a) > 0$. This effort affects both the monetary payoff and the probability that the project generates a negative externality.[6]

In our baseline model, greater operational effort increases the monetary payoff while reducing the probability of a negative externality.[7] As shown below, the for-profit owner derives no direct benefit from a reduction in the probability of a negative externality unless the reduction also increases the monetary payoff. The owner benefits indirectly from such a reduction only insofar as it attracts investment from socially responsible investors.

Specifically, conditional on success, the project yields $\widetilde{X} = X(a)$ per unit of investment, where $X(0) > 1$, $X'(a) > 0$ and $X''(a) < 0$; conditional on failure, it yields $\widetilde{X} = 0$. The probability of success, or the good state, is $\delta > 0$, and the probability of failure, or the bad state, is $1 - \delta$. We also assume that the project has zero liquidation value. Our main results continue to hold, however, if δ depends on a, or if the project has a positive

[4]Our results are unaffected even when the observed value of $\widetilde{Z}$ is noisy and cannot be measured precisely; see Section 6.3.

[5]We can interpret the for-profit owner as the founder, the board acting on behalf of shareholders, or a dominant shareholder.

[6]Chowdhry, Davies, and Waters (2019) and Oehmke and Opp (2025) also develop impact investment models that incorporate operational effort.

[7]This assumption captures the idea that reducing social waste may simultaneously help firms avoid costly operational adjustments induced by carbon taxes or environmental regulations, mitigate technological obsolescence (e.g., the obsolescence of technologies for gasoline-powered vehicles resulting from the transition to hybrid or electric vehicles), and limit legal liability for emissions or pollution. See Stroebel and Wurgler (2021).

liquidation value, as discussed in Sections 6.1 and 6.2.

Regardless of the monetary payoff, the project generates either no negative externality, $\widetilde{Z} = 0$ or a negative externality, $\widetilde{Z} = Z > 0$. The probability of no negative externality is $\Pr(\widetilde{Z} = 0 \mid a) \equiv \zeta_0 + \zeta_1 a$, and the probability of a negative externality is $\Pr(\widetilde{Z} = Z \mid a)$ $\equiv 1 - \zeta_0 - \zeta_1 a$, where $\zeta_0 > 0$ and $\zeta_1 > 0$. We restrict the parameter range so that $\zeta_0 + \zeta_1 a \in (0,\, 1)$.

We assume that neither the for-profit owner nor the for-profit manager has initial wealth. Thus, the for-profit owner must raise outside financing from heterogeneous outside investors at date 1. The for-profit owner issues debt with a face value of one and promises investors a repayment per unit of debt that is contingent on the realized negative externality: r_0 if $\widetilde{Z} = 0$ and r_Z if $\widetilde{Z} = Z$. We restrict attention to debt contracts with $r_0 \geq 1$ and $r_Z \geq 1$. This debt can be interpreted as a sustainability-linked bond or loan if $r_0 \neq r_Z$. If $r_0 = r_Z$, it reduces to a noncontingent fixed-rate bond or loan. In addition, both types of debt have contractual priority over the claims of the for-profit owner and the for-profit manager.

Because of the agency problem between the for-profit owner and the for-profit manager, the for-profit owner offers the manager a compensation contract contingent on both the monetary payoff and the negative externality. This contract can be interpreted as executive compensation tied to ESG metrics. Let $w_{\widetilde{X}\widetilde{Z}}$ denote the manager's compensation when $\widetilde{X} \in \{X(a), 0\}$ and $\widetilde{Z} \in \{0, Z\}$. For notational simplicity, we abbreviate $w_{X(a)\widetilde{Z}}$ as $w_{X\widetilde{Z}}$ in the subsequent analysis. Limited liability requires $w_{\widetilde{X}\widetilde{Z}} \geq 0$ for all $\widetilde{X} \in \{X(a), 0\}$ and $\widetilde{Z} \in \{0, Z\}$. Regarding commitment to the executive compensation contract offer, we distinguish between two cases. In the commitment case, the for-profit owner can commit at date 1 to a compensation contract that cannot be revised in the subsequent period. In the no-commitment case, the for-profit owner cannot make such a commitment at date 1 and instead retains the discretion to offer the manager a compensation contract at date 2, after investors have allocated their funds. Once the compensation contract is offered at date 2, however, it cannot be revised.[8]

ESG-contingent contracting has become increasingly common in both executive compensation and external financing. In particular, executive compensation tied to ESG

[8]In the baseline model, we contrast only the full-commitment case with the no-commitment case. In Section 6.4, we extend the analysis to the renegotiation case, in which the initial compensation contract can be replaced if both the for-profit owner and the manager agree to the replacement.

targets and sustainability-linked bonds or loans have gained prominence as socially conscious capital has grown and ESG metrics have become more precise.[9]

Each investor is endowed with one unit of capital and can invest it in the firm's debt at date 1. Investors also have access to an alternative storage technology, such as cash, that yields a fixed net return of zero.

Investors derive utility not only from financial returns but also from heterogeneous values-aligned preferences: they care about the negative externalities generated by the firms in which they invest.[10] Specifically, if an investor of type θ provides debt financing to the firm, the investor's expected payoff is reduced by $\theta\widetilde{Z}$ per unit invested, where θ is an idiosyncratic sensitivity parameter that captures the intensity of the investor's values-aligned preferences. Investors with higher θ have stronger values-aligned preferences. We assume that θ is uniformly distributed on $[0, \overline{\theta}]$, so that $H(\theta') \equiv \Pr(\theta \leq \theta') = \frac{\theta'}{\overline{\theta}}$.[11]

In the subsequent analysis, we distinguish between two investment arrangements, in addition to the two cases regarding the timing of, and commitment to, the executive compensation contract. In the first arrangement, individual investors invest directly in the firm's debt. This case corresponds to a public debt market in which the borrower faces many atomistic investors. In the second arrangement, individual investors invest in the firm's debt only through a socially responsible fund (SRF). The financial institutions represented by the SRF may include various types of funds, such as private debt funds and mutual funds, as well as banks, insurance companies, and funds established by these institutions. We model this arrangement as an over-the-counter market in which the for-profit owner bargains with the SRF over debt financing. We assume that the SRF's objective function is the unweighted sum of the expected payoffs of the individual investors who invest through the SRF. The second arrangement can be interpreted as the case in which the borrower issues bonds or obtains loans through a small number of large financial institutions that collect funds from various individual investors. We analyze the first arrangement in the next section and the second arrangement in Section 5.

We assume that the monetary payoff $\widetilde{X}$ and the negative externality $\widetilde{Z}$ are observable

[9] See Cohen, Kadach, Ormazabal, and Reichelstein (2023) and Kim, Kumar, Lee, and Oh (2025).

[10] For empirical evidence, see Haber et al. (2022), Hong and Kostovetsky (2012), Giglio et al. (2023), and Riedl and Smeets (2017).

[11] Landier and Lovo (2025) make the same assumption on the distribution of the idiosyncratic sensitivity parameter.

and verifiable. By contrast, neither the manager's effort a nor the effort cost $c(a)$ is observable. In addition, the investor's idiosyncratic sensitivity parameter θ is private information.

Finally, we assume that promised debt repayments are senior to executive compensation, and assume that executive compensation is senior to equity payouts. Thus, the for-profit owner is the residual claimant on the firm's cash flows.

3.2. Timing and equilibrium.—

The sequence of events depends on how individual investors allocate their capital. Figure 1 illustrates the timing structure in the public debt market.

(1) Public debt market: direct investment by individual investors.

(i) Date 1.

(a) The for-profit owner raises a total amount of debt, B, by offering individual investors a debt contract that promises a repayment r_0 if $\widetilde{Z} = 0$ and r_Z if $\widetilde{Z} = Z$, per unit of debt.

(b) If the for-profit owner can commit at date 1 to a compensation contract that cannot be revised in the subsequent period, the owner offers the manager a compensation contract $w_{\widetilde{X}\widetilde{Z}}$, where $\widetilde{X} \in \{X, 0\}$ and $\widetilde{Z} \in \{0, Z\}$.[12]

(c) Each individual investor allocates her unit of capital between the firm's debt and the alternative storage technology, taking the promised repayments as given.

(iii) Date 2.

If the for-profit owner cannot commit at date 1 to a compensation contract that cannot be revised in the subsequent period, the owner offers the manager a compensation contract $w_{\widetilde{X}\widetilde{Z}}$ at date 2, after investors have allocated their funds. Once the compensation contract is offered at date 2, it cannot be revised. The manager then chooses operational effort a.

(iv) Date 3.

Project outcomes are realized, and each agent receives the contractual payoff.

(2) Over-the-counter debt market: investment through the SRF.

(i) Date 1.

(a) The for-profit owner bargains with the SRF over a debt contract that specifies the

[12]For notational simplicity, we abbreviate $w_{X(a)\widetilde{Z}}$ as $w_{X\widetilde{Z}}$.

total amount of debt, B, and promised repayments r_0 if $\widetilde{Z} = 0$ and r_Z if $\widetilde{Z} = Z$, per unit of debt.
(b) If the for-profit owner can commit at date 1 to a compensation contract that cannot be revised in the subsequent period, the owner also bargains with the SRF over the manager's compensation contract, $w_{\widetilde{X}\widetilde{Z}}$ where $\widetilde{X} \in \{X, 0\}$ and $\widetilde{Z} \in \{0, Z\}$. The owner then offers the manager the agreed-upon compensation contract.
(c) Each individual investor allocates her unit of capital between the SRF and the alternative storage technology, taking the promised repayments as given.
(iii) Date 2 and Date 3
The events at these dates are the same as those given in case (1).

We define an equilibrium outcome as follows. First, market clearing requires that the aggregate demand for debt by individual investors or the SRF equals the aggregate supply of debt issued by the for-profit owner. Second, the expected gross payoff to investors must be weakly greater than one, because their outside option, the alternative storage technology, yields a fixed net return of zero, or equivalently, a gross payoff of one. Third, each agent chooses a strategy that maximizes his/her expected payoff, taking the other agents' strategies as given and correctly anticipating their equilibrium behavior.

4. Public Debt Market with Many Investors

4.1. Optimal decisions of each agent.—

This section characterizes the debt contract and the executive compensation contract when individual investors invest directly in the firm's debt in the public debt market. As described in Section 3.2, if the for-profit owner can commit at date 1 to an executive compensation contract that cannot be revised in the subsequent period, she chooses both the debt contract and the executive compensation contract at date 1. Otherwise, she chooses the debt contract at date 1 but offers the executive compensation contract at date 2.

We first analyze the commitment case, in which the for-profit owner chooses both the debt contract and the executive compensation contract at date 1. We begin by characterizing the manager's effort choice at date 2. If the project fails so that $\widetilde{X} = 0$, the for-profit owner has no resources with which to pay the manager. Limited liability therefore implies $w_{0\widetilde{Z}} = 0$ for $\widetilde{Z} \in \{0, Z\}$. Hence, taking $w_{X\widetilde{Z}}$ for $\widetilde{Z} \in \{0, Z\}$ as given, the manager solves

$$\max_{a \geq 0} \left[\delta(\zeta_0 + \zeta_1 a) w_{X0} + \delta(1 - \zeta_0 - \zeta_1 a) w_{XZ} - c(a) \right], \tag{1}$$

where the first term in (1) is the manager's expected compensation when $\widetilde{X} = X$ and $\widetilde{Z} = 0$, the second term in (1) is the manager's expected compensation when $\widetilde{X} = X$ and $\widetilde{Z} = Z$, and the third term is the manager's effort cost.

We assume that (1) has an interior solution. Because the manager's cost function is increasing and convex in a, the first-order condition with respect to a implies

$$\delta\zeta_1(w_{X0} - w_{XZ}) - c'(a) = 0. \tag{2}$$

Hence, the manager's optimal effort level, a^*, is given by

$$a^* = c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ})), \tag{3}$$

where c'^{-1} is the inverse of the marginal cost function c'. In the following analysis, we assume throughout that a^* satisfies the relevant constraints: $a^* > 0$ and $\zeta_0 + \zeta_1 a^* < 1$.[13]

We next characterize investors' optimal investment choice at date 1. Recall that r_0 and r_Z denote the promised debt repayments from the firm to investors when $\widetilde{Z} = 0$ and $\widetilde{Z} = Z$, respectively, and that investors receive no payment if the project fails, that is, if $\widetilde{X} = 0$. An investor of type θ has idiosyncratic values-aligned preferences per unit of investment. Hence, the expected net payoff of a type-θ investor per unit of debt investment is

$$\delta(\zeta_0 + \zeta_1 a^*) r_0 + \delta(1 - \zeta_0 - \zeta_1 a^*) r_Z - (1 - \zeta_0 - \zeta_1 a^*)\theta Z - 1, \tag{4}$$

where the first two terms in (4) capture the expected repayment per unit of debt investment, the third term captures the expected disutility from the negative externality per

[13] If $a^* = 0$ is optimal for the for-profit owner, she need not provide the manager with any executive compensation. If $\zeta_0 + \zeta_1 a^* = 1$, the project never generates a negative externality, so that sustainability-linked bonds or loans are unnecessary. We therefore exclude these cases from the analysis.

unit of debt investment, and the final term is the unit cost of debt investment.

Because each investor is endowed with one unit of capital and can instead invest in the alternative storage technology, which yields a zero net return, any investor who invests in the firm's debt must receive an expected gross payoff weakly greater than one. Therefore, the marginal investor earns an expected gross payoff of one from debt investment:

$$\delta(\zeta_0 + \zeta_1 a^*) r_0 + \delta(1 - \zeta_0 - \zeta_1 a^*) r_Z - (1 - \zeta_0 - \zeta_1 a^*)\theta Z = 1. \tag{5}$$

Define $\widehat{\theta}(r_0, r_Z, a^*)$ as the type that satisfies (5) for a given triple (r_0, r_Z, a^*):

$$\widehat{\theta}(r_0, r_Z, a^*) = \frac{\delta(\zeta_0 + \zeta_1 a^*) r_0 + \delta(1 - \zeta_0 - \zeta_1 a^*) r_Z - 1}{(1 - \zeta_0 - \zeta_1 a^*) Z}. \tag{6}$$

Then, $\widehat{\theta}(r_0, r_Z, a^*)$ is the idiosyncratic values-aligned preference intensity for the marginal investor. Hence, inframarginal investors with $\theta < \widehat{\theta}(r_0, r_Z, a^*)$ obtain a strictly positive expected net payoff from debt investment. Because investors obtain an expected net payoff zero from the alternative storage technology, all types $\theta \in [0, \widehat{\theta}(r_0, r_Z, a^*)]$ prefer the firm's debt to the outside option, whereas investors with $\theta > \widehat{\theta}(r_0, r_Z, a^*)$ prefer the outside option, provided that the for-profit owner accommodates debt demand.

Given the characterization of investors' optimal decisions and $H(\theta') = \frac{\theta'}{\overline{\theta}}$, total investor demand for the firm's debt, B_D, is given by

$$B_D = H(\widehat{\theta}(r_0, r_Z, a^*)) = \frac{\delta(\zeta_0 + \zeta_1 a^*) r_0 + \delta(1 - \zeta_0 - \zeta_1 a^*) r_Z - 1}{\overline{\theta}(1 - \zeta_0 - \zeta_1 a^*) Z}. \tag{7}$$

In equilibrium, total investor demand for the firm's debt, B_D, equals the total amount of debt issued by the for-profit owner, B.

Finally, we analyze the for-profit owner's optimization with respect to the debt contract and the executive compensation contract offered at date 1. For now, we proceed under the tentative assumption that both the total debt repayment, $r_{\widetilde{Z}} B$, and the manager's compensation, $w_{H\widetilde{Z}}$, are feasible, that is, $[X(a^*) - r_{\widetilde{Z}}]B - w_{H\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0.Z\}$. We verify this assumption in Lemma 1.

The for-profit owner maximizes her expected payoff by choosing $(w_{X0}, w_{XZ}, r_0, r_Z, B)$. As we assume $[X(a^*) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$, and the for-profit owner receives no payoff when $\widetilde{X} = 0$, her expected payoff at date 1 is

$$\Pi^O(w_{X0}, w_{XZ}, r_0, r_Z, B, a^*)$$
$$= \delta(\zeta_0 + \zeta_1 a^*)\{[X(a^*) - r_0]B - w_{X0}\} + \delta(1 - \zeta_0 - \zeta_1 a^*)\{[X(a^*) - r_Z]B - w_{XZ}\}, \quad (8)$$

where the first and second terms in (8) are her expected payoffs when $\widetilde{Z} = 0$ and $\widetilde{Z} = Z$, respectively.

To attain the for-profit owner's objective, the chosen contracts must satisfy several constraints. First, the for-profit owner must ensure that the manager obtains at least his outside option. Because the manager's objective function is strictly concave in a, and because we assume that $a^* > 0$, $c(0) = 0$, and $(w_{X0}, w_{XZ}) \geq 0$, the manager's expected payoff is positive. As the manager has no outside option, his individual rationality constraint is therefore always satisfied. Second, because the manager's effort is unobservable, his incentive compatibility constraint, denoted by (ICF) and given by (3), must hold. Third, the debt market clearing condition requires B to equal investor demand B_D, as given by (7). Fourth, we impose the following maintained assumptions, which we verify below:

$$\left[X(a^*) - r_{\widetilde{Z}}\right] B \geq w_{X\widetilde{Z}}, \qquad for\ \widetilde{Z} \in \{0, Z\}. \quad (9)$$

Finally, the manager's limited liability constraints and the nonnengativity constraint on B must hold:[14]

$$w_{X0} \geq 0, \quad w_{XZ} \geq 0, \quad r_0 \geq 1, \quad r_Z \geq 1, \quad B \geq 0. \quad (10)$$

When the for-profit owner chooses both the debt contract and the executive compensation contract at date 1, her date-1 optimization problem is

$$\max_{(w_{X0}, w_{XZ}, r_0, r_Z, B, a^*)} \Pi^O(w_{X0}, w_{XZ}, r_0, r_Z, B, a^*) \equiv \max_{(w_{X0}, w_{XZ}, r_0, r_Z, B, a^*)} \{\delta(\zeta_0 + \zeta_1 a^*)[(X(a^*)$$
$$- r_0)B - w_{X0}] + \delta(1 - \zeta_0 - \zeta_1 a^*)[(X(a^*) - r_Z)B - w_{XZ}]\}, \quad (11)$$

subject to (3), (7), (9), and (10), evaluated at $B = B_D$.

[14] The constraint $B \geq 0$ ensures that $\delta(\zeta_0 + \zeta_1 a^*) r_0 + \delta(1 - \zeta_0 - \zeta_1 a^*) r_Z \geq 1$.

To proceed with the analysis, we need to verify the following lemma:

Lemma 1. *In characterizing optimal contracts, the for-profit owner can, without loss of generality, restrict attention to contracts that satisfy* $[X(a^*) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ *for* $\widetilde{Z} \in \{0, Z\}$.

Lemma 1 allows us to restrict attention to the case in which $[X(a^*) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$. Thus, it suffices to consider problem (11).

We next formalize the for-profit owner's optimization problem when she cannot commit at date 1 to an executive compensation contract that cannot be revised in the subsequent period. In this case, she chooses the debt contract at date 1 but offers the executive compensation contract at date 2. In our baseline model, however, no outside shock occurs between dates 1 and 2, and the for-profit owner must commit at date 1 to the promised debt repayments if the project succeeds. Hence, the for-profit owner's maximization problem is

$$
\begin{aligned}
&\max_{(r_0, r_Z, B)} \left[\max_{(w_{X0}, w_{XZ}, a^*)} \Pi^O(w_{X0}, w_{XZ}, r_0, r_Z, B, a^*) \right] \\
&\equiv \max_{(r_0, r_Z, B)} \{ \max_{(w_{X0}, w_{XZ}, a^*)} \delta(\zeta_0 + \zeta_1 a^*)[(X(a^*) - r_0)B - w_{X0}] \\
&+ \delta(1 - \zeta_0 - \zeta_1 a^*)[(X(a^*) - r_Z)B - w_{XZ}]\}, \qquad (12)
\end{aligned}
$$

subject to (3), (7), (9), and (10), evaluated at $B = B_D$. Lemma 1 continues to hold in this case.

4.2. Optimal debt and executive compensation contracts.—

We now solve optimization problems (11) and (12) to derive the optimal debt and executive compensation contracts. In the subsequent analysis, we assume for simplicity that the constraint $B \geq 0$ is slack at the optimal solutions to (11) and (12) and that the for-profit owner's expected payoffs under the optimal contracts are strictly positive.[15] In addition, to ensure an interior solution with $a > 0$, we assume that the for-profit owner's objective is increasing in a in a neighborhood of $a = 0$. Let $(w_{X0}^{c*}, w_{XZ}^{c*}, r_0^{c*}, r_Z^{c*}, B^{c*}, a^{c*})$ and $(w_{X0}^{n*}, w_{XZ}^{n*}, r_0^{n*}, r_Z^{n*}, B^{n*}, a^{n*})$ denote the optimal debt and executive compensation

[15] If $B = 0$, the firm cannot implement the project. Moreover, because the for-profit owner's outside option is zero, cases in which the for-profit owner's expected payoff is nonpositive are not relevant for our analysis. We can therefore impose these assumptions without loss of generality.

contracts that solve problems (11) and (12), respectively.

We assume that the second-order conditions for optimality are satisfied. The following proposition characterizes the optimal contracts.

Proposition 1. *In the public debt market, the following results hold regardless of whether the for-profit owner can commit* at date 1 *to an executive compensation contract that cannot be revised in the subsequent period. For* $i \in \{c, n\}$*, if* $R_1^{i*} = \frac{\delta X(a^{i*})+1}{2\delta} \leq X(a^{i*}) - \frac{w_{X0}^{i*}}{B}$*, then the debt contract satisfying* $r_0^{i*} = r_Z^{i*} = R_1^{i*}$ *is optimal and attains the maximum value of the for-profit owner's problem. Otherwise, the optimal debt contract satisfies* $r_0^{i*} \neq r_Z^{i*}$*. In addition, the optimal executive compensation contract satisfies* $w_{X0}^{i*} > w_{XZ}^{i*} = 0$.

Proposition 1 shows that, in the public debt market, noncontingent fixed-rate bonds or loans are optimal and maximize the for-profit owner's expected payoff, regardless of whether she can commit at date 1 to an executive compensation contract that cannot be revised in the subsequent period, as long as project revenues in the success state are sufficiently large to cover fixed-rate debt repayments and the manager's compensation. Thus, if the for-profit owner can adjust the executive compensation contract appropriately and secure sufficient net project revenues in the success state, she need not issue sustainability-linked bonds or loans.[16]

The intuition is as follows. In the model, the manager's effort choice depends directly on the executive compensation contract but is unaffected by the debt contract (see (3)). By contrast, investors' debt investment decisions depend on both the manager's effort choice and the debt contract (see (7)). The promised repayment must therefore balance two effects: its effect on debt investment inflows from socially responsible investors and its effect on the for-profit owner's expected pecuniary payoff, net of debt repayments, per unit of investment in the success state. In the model, the for-profit owner makes no payments to investors in the failure state.

Indeed, regardless of whether the for-profit owner faces a commitment problem with respect to the executive compensation contract, once she can use ESG-linked compensation to induce the manager's effort appropriately, she need only control the expected

[16] The conditions $X(a^{i*}) - \frac{w_{X0}^{i*}}{B} \geq \frac{\delta X(a^{i*})+1}{2\delta}$ for $i \in \{c, n\}$ are consistent with standard functional forms. For example, under $X(a) = \beta + \log(3 + a)$ and $c(a) = \frac{c}{2}a^2$, both conditions can hold, and their respective slacks can increase with β.

debt repayment in the success state, $(\zeta_0 + \zeta_1 a^*)r_0 + (1 - \zeta_0 - \zeta_1 a^*)r_Z$, to achieve her objective. This is because, as shown in (7), investors' debt inflows are determined not by the individual repayment terms r_0 and r_Z, but by the aggregate repayment $(\zeta_0 + \zeta_1 a^*)r_0 + (1 - \zeta_0 - \zeta_1 a^*)r_Z$. Moreover, if the for-profit owner can secure sufficiently high net project returns in the success state so that the condition in Proposition 1 holds, repayments to investors that are independent of the firm's ESG performance are feasible in that state, even though the manager's compensation is ESG-linked. In this situation, distinguishing between r_0 and r_Z in the debt contract has no effect on investment by socially responsible investors or on the for-profit owner's expected pecuniary payoff, net of debt repayments, per unit of investment. Accordingly, it is sufficient for the for-profit owner to issue noncontingent fixed-rate bonds or loans rather than sustainability-linked bonds or loans.

Several remarks are in order. First, although sustainability-linked bonds or loans can be optimal, borrowers in practice may have to pay higher fees on such instruments, likely reflecting additional administrative and monitoring costs associated with their sustainability features (see Kim, Kumar, Lee, and Oh, 2025). Thus, if borrowers can adjust executive compensation contracts appropriately and secure sufficient net project returns in the success state, noncontingent fixed-rate bonds or loans provide a plausible alternative. Second, this feature differs in an important respect from the equity issuance model of Chowdhry, Davies, and Waters (2019), in which limited commitment to the executive compensation substantially affects the result when renegotiation is ruled out. In their model, the impact investor provides an upfront security payment, or subsidy, to the for-profit owner, whereas the for-profit owner makes no payment when the project succeeds. By contrast, in our model, the for-profit owner commits to making bond or loan repayments whenever she is able to do so.

5. Over-the-Counter debt Market

5.1. Optimal decisions of each agent.—

In this section, we examine the case in which individual investors invest in debt only through an SRF, while the for-profit owner bargains with the SRF over debt financing in an over-the-counter market. As shown in Section 3.2, if the for-profit owner can commit at date 1 to an executive compensation contract that cannot subsequently be revised, she negotiates both the debt contract and the executive compensation contract with the SRF at date 1 and offers the agreed-upon executive compensation contract to the manager. Otherwise, she negotiates only the debt contract with the SRF at date 1 and retains the discretion to offer the manager an executive compensation contract at date 2. For the moment, in both cases, we again assume that the total debt repayment, $r_{\widetilde{Z}}B$, and the managerial compensation, $w_{X\widetilde{Z}}$, satisfy $[X(a^{**}) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$, where a^{**} denotes the manager's optimal effort choice at date 2 in these cases. We verify this assumption in Lemma 2.

We begin by considering the first case, in which the for-profit owner negotiates both a debt contract and an executive compensation contract at date 1. In this case, a^{**} is determined by the same expression as that determines a^* in (3). For socially responsible investors' optimal investment choices at date 1, we assume that investors anticipate the outcome of the negotiation between the for-profit owner and the SRF. They therefore expect the return on their investment in the SRF to be equal to the return on investment in the debt issued by the for-profit owner. Accordingly, the strength of values-aligned preferences of the marginal investor, $\widehat{\theta}(r_0, r_Z, a^{**})$, and the total investment in the SRF by all investors, B, are given by the same expressions as $\widehat{\theta}(r_0, r_Z, a^{**})$ in (6) and B_D in (7), respectively.[17]

Thus, it remains only to analyze the bargaining between the for-profit owner and the SRF over the debt contract and the executive compensation contract. Because we assume that the SRF's objective function is given by the unweighted sum of the payoffs of the individual investors who invest in the SRF, it can be written as

$$\begin{aligned}&\Pi^S(r_0, r_Z, a^{**})\\&\equiv \int_{\theta\in[0,\,\widehat{\theta}(r_0,r_Z,a^{**})]} [\delta(\zeta_0 + \zeta_1 a^{**})r_0 + \delta(1-\zeta_0-\zeta_1 a^{**})r_Z - (1-\zeta_0-\zeta_1 a^{**})\theta Z - 1]d\theta.\end{aligned} \tag{13}$$

Note that all investors with types $\theta \in [0, \widehat{\theta}(r_0, r_Z, a^{**})]$ prefer debt to the outside option, whereas investors with types $\theta > \widehat{\theta}(r_0, r_Z, a^{**})$ prefer the outside option.

Let the for-profit owner's bargaining power be κ, and let the SRF's bargaining power

[17] In these equations, a^* is replaced by a^{**}.

be $1-\kappa$. Because each party's outside option is zero, the bargaining outcome maximizes the Nash product of the expected payoff gains from agreement with respect to $(w_{H0}, w_{HZ}, r_0, r_Z, B, a^{**})$:

$$\max_{(w_{H0}, w_{HZ}, r_0, r_Z, B, a^{**})} \left[\Pi^O(w_{X0}, w_{XZ}, r_0, r_Z, B, a^{**})\right]^{\kappa} \left[\Pi^S(r_0, r_Z, a^{**})\right]^{1-\kappa}, \tag{14}$$

subject to (3), (7), (9), and (10), with B_D and a^* replaced by B and a^{**}, respectively. Here, $\Pi^O(w_{H0}, w_{HZ}, r_0, r_Z, B, a^{**})$ is defined as the for-profit owner's objective function given inside the large brackets in (11), with a^* replaced by a^{**}, where B is given by B_D.

We next formalize the case in which the for-profit owner bargains with the SRF over only the debt contract at date 1 and offers the manager an executive compensation contract at date 2. The for-profit owner's date-2 optimization problem over the executive compensation contract is then given by

$$\begin{aligned} &\Pi_2^O(r_0, r_Z, B) \\ &\equiv \max_{(w_{H0}, w_{HZ}, a^{**})} \{\delta(\zeta_0 + \zeta_1 a^{**})[(X(a^{**}) - r_0)B - w_{H0}] \\ &+ \delta(1 - \zeta_0 - \zeta_1 a^{**})[(X(a^{**}) - r_Z)B - w_{HZ}]\}, \end{aligned} \tag{15}$$

subject to (3), $w_{X0} \geq 0$, and $w_{XZ} \geq 0$, with a^* replaced by a^{**}, where B is given by B_D.

Given (15), the date-1 bargaining problem between the for-profit owner and the SRF over the debt contract (r_0, r_Z, B) at date 1 is formalized by:

$$\max_{(r_0, r_Z, B, a^{**})} \left[\Pi_2^O(r_0, r_Z, B)\right]^{\kappa} \left[\Pi^S(r_0, r_Z, a^{**})\right]^{1-\kappa}, \tag{16}$$

subject to (3), (7), (9), $r_0 \geq 1$, $r_Z \geq 1$, and $B \geq 0$, with B_D and a^* replaced by B and a^{**}, respectively.

Given (14)–(16), we obtain the following lemma:

Lemma 2. *Regardless of whether the for-profit owner can commit at date 1 to an executive compensation contract that cannot subsequently be revised, the for-profit owner and the SRF can, without loss of generality, restrict attention to contracts satisfying* $[X(a^{**}) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ *for* $\widetilde{Z} \in \{0, Z\}$ *when searching for optimal bargaining outcomes.*

Lemma 2 again guarantees that, irrespective of whether the for-profit owner can commit to the executive compensation contract specified at date 1, we can focus on the case in which $[X(a^{**}) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$ in problems (14)–(16).

5.2. Optimal debt and executive compensation contracts.—

We now solve the optimization problems introduced in the preceding subsection to characterize the equilibrium. Again, in the subsequent analysis, we assume that the constraint $B \geq 0$ is slack at the optimal solution to (14) and at the optimal solution to (15) and (16). We also assume that the for-profit owner's expected payoff under the optimal contract is strictly positive in these optimization problems. Let $(w_{X0}^{c**}, w_{XZ}^{c**}, r_0^{c**}, r_Z^{c**}, B^{c**}, a^{c**})$ denote the optimal debt and executive compensation contracts in problem (14), and let $(w_{X0}^{n**}, w_{XZ}^{n**}, r_0^{n**}, r_Z^{n**}, B^{n**}, a^{n**})$ denote the optimal debt and executive compensation contracts in problems (15) and (16).

We begin by solving problem (14) and examining the optimal debt and executive compensation contracts when the for-profit owner can commit to the executive compensation contract specified at date 1. In this case, she negotiates both the debt contract and the executive compensation contract with the SRF at date 1. We assume that the second-order conditions for optimality are satisfied. We then establish the following proposition.

Proposition 2. *Suppose that, in the over-the-counter debt market, the for-profit owner can commit to the executive compensation contract specified at date* 1.
(i) If $R_2^{c**} \leq X(a^{c**}) - \frac{w_{X0}^{c**}}{B}$, *where* R_2^{c**} *is determined by (A18) in Appendix A, then the debt contract satisfying* $r_0^{c**} = r_Z^{c**} = R_2^{c**}$ *is optimal and attains the maximum value of the bargaining problem between the for-profit owner and the SRF. Otherwise, the optimal debt contract satisfies* $r_0^{c**} \neq r_Z^{c**}$.
(ii) In addition, the optimal executive compensation contract satisfies $w_{X0}^{c**} > w_{XZ}^{c**} = 0$.

Proposition 2 shows that, if the for-profit owner can commit in the over-the-counter debt market to the executive compensation contract specified at date 1, noncontingent fixed-rate bonds or loans are optimal and attain the maximum value of the bargaining problem, as long as project revenues in the success state are sufficiently large to cover fixed-rate debt repayments and the manager's compensation. Thus, if the for-profit owner can adjust the executive compensation contract appropriately and secure sufficient net project revenues in the success state, she need not issue sustainability-linked bonds or loans, even though such instruments may also be optimal.[18]

The intuition is as follows. Unlike in the public debt market model, the for-profit owner and the SRF negotiate both the debt contract and the executive compensation contract at date 1. Thus, when the for-profit owner can commit to the executive compensation contract specified at date 1, the promised repayment must balance two effects: its effect on debt investment attracted by the SRF through inflows from socially responsible investors, and its effect on the for-profit owner's expected pecuniary revenue, net of debt repayments, per unit of investment in the success state.

However, as in the intuition for Proposition 1, the for-profit owner and the SRF need only control the expected debt repayment in the success state to achieve their bargaining objectives when ESG-linked compensation can be used to induce the manager's effort appropriately.[19] Again, if the for-profit owner can secure sufficiently high net project returns in the success state so that the condition in Proposition 2 holds, repayments that are independent of the firm's ESG performance are feasible in that state, even though the manager's compensation is ESG-linked. Because distinguishing between r_0 and r_Z in debt repayments has no effect on investment from socially responsible investors or on the for-profit owner's expected pecuniary revenue, net of debt repayments, per unit of investment, noncontingent fixed-rate bonds or loans are optimal and maximize the weighted Nash product of the bargainers' expected surpluses.

We next solve problems (15) and (16) and examine the optimal debt and executive compensation contracts when the for-profit owner cannot commit to an executive compensation contract specified at date 1. In this case, she negotiates only the debt contract with the SRF at date 1 and offers the manager an executive compensation contract at date 2 at her sole discretion. To simplify the analysis, we assume that $c(a) = \frac{c}{2}a^2$. Relaxing this parametric assumption does not alter the results. We continue to assume that the second-order conditions for optimality are satisfied. We then obtain the following proposition.

Proposition 3. *If the for-profit owner cannot commit in the over-the-counter debt mar-*

[18] See the discussion of the higher fees associated with such bonds and loans at the end of Section 4.2. Similarly, the condition $X(a^{c**}) - \frac{w_{X0}^{c**}}{B} \geq R_2^{c**}$ is consistent with standard functional forms. For example, under $X(a) = \beta + \log(3 + a)$ and $c(a) = \frac{c}{2}a^2$, the condition can hold, and its slack can increase with β.

[19] In this case as well, investors' debt inflows are determined not by r_0 and r_Z individually, but by the aggregate repayment $(\zeta_0 + \zeta_1 a^*)r_0 + (1 - \zeta_0 - \zeta_1 a^*)r_Z$.

ket to an executive compensation contract specified at date 1*, the optimal debt contract satisfies* $r_0^{n**} \neq r_Z^{n**}$*. In addition, the optimal executive compensation contract satisfies* $w_{X0}^{n**} > w_{XZ}^{n**} = 0$*.*

Proposition 3 shows that, if the for-profit owner cannot commit in the over-the-counter debt market to an executive compensation contract specified at date 1, noncontingent fixed-rate bonds or loans are not optimal. Instead, the for-profit owner must issue sustainability-linked bonds or loans.

The intuition is as follows. If the for-profit owner cannot commit in the over-the-counter debt market to an executive compensation contract specified at date 1, she and the SRF negotiate only the debt contract at date 1, and she offers the manager an executive compensation contract at date 2 at her sole discretion. The executive compensation contract that the for-profit owner offers at date 2 therefore differs from the contract that would have been specified through date-1 negotiation between the owner and the SRF. As a result, the manager's effort induced by the date-2 executive compensation contract also differs from the effort that would have been induced by the contract specified through date-1 negotiation. To offset this discrepancy, the for-profit owner and the SRF must adjust the debt repayment specified in the date-1 debt contract so that it affects the executive compensation contract that the owner later chooses unilaterally at date 2. Because the executive compensation contract is contingent on ESG performance, the debt repayment must also be contingent on ESG performance to achieve this objective. Accordingly, sustainability-linked bonds or loans must be used, and noncontingent fixed-rate bonds or loans are no longer optimal.

Propositions 1–3 have important implications for the design of ESG debt when the for-profit owner can appropriately structure the executive compensation contract. Suppose first that individual investors purchase debt directly in the public debt market, or that the for-profit owner bargains with the SRF over debt contracts in the over-the-counter debt market and can commit to the executive compensation contract specified at date 1. In these cases, Propositions 1 and 2 imply that the for-profit owner can issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans, rather than relying on sustainability-linked bonds or loans, provided that project returns in the good state are sufficiently high.

By contrast, when the for-profit owner bargains with the SRF over debt contracts in the over-the-counter debt market but cannot commit to an executive compensation contract specified at date 1, Proposition 3 shows that sustainability-linked bonds or loans become necessary. In this case, noncontingent fixed-rate bonds or loans are no longer optimal.

Chowdhry, Davies, and Waters (2019) use their results on equity issuance and executive compensation to clarify the role of social-outcome-contingent securities, such as sustainability-linked bonds and loans. However, their model does not explicitly analyze the interaction between the issuance of sustainability-linked bonds or the provision of sustainability-linked loans and managerial compensation. Their analysis therefore has limited scope for evaluating when sustainability-linked bonds or loans are needed. Feldhütter and Pedersen (2025) show that commitment to making debt payments contingent on social outcomes can help explain the use of social impact bonds or loans. By contrast, our analysis suggests that a lack of commitment to executive compensation contracts gives sustainability-linked bonds and loans a distinct economic role in the over-the-counter debt market.

6. Extensions and Robustness

We discuss several extensions that demonstrate the robustness of our results and generate additional insights.

6.1. Operational effort that affects the probability of success.—

We assume in the baseline model that the probability of success, δ, is independent of operational effort. Suppose instead that δ depends on a. If $\frac{c'(a)}{\delta'(a)}$ is increasing in a and $\delta(a)$ is concave in a, our main results continue to hold because the manager's effort remains increasing in $w_{X0} - w_{XZ}$ in equilibrium.

6.2. Liquidation value of the project.—

In the baseline model, we assume that the project has zero liquidation value. We relax this assumption and suppose that, if the project fails, it has a liquidation value L (< 1). Because debt claims are senior to the claims of the for-profit owner and the manager, debt investors receive the entire liquidation value and distribute it among themselves. This relaxation therefore merely increases investors' expected net payoff and the threshold $\widehat{\theta}(r_0, r_Z, a^*)$, leaving our main results unaffected.

6.3. Imprecise measures of social value.—

The baseline model assumes that negative externalities, $\widetilde{Z}$, are observable and verifiable. However, many scholars have argued that ESG metrics are imperfect and imprecise and may be subject to manipulation.

To examine this issue, suppose that each agent instead observes a noisy public signal, χ, about $\widetilde{Z}$. If the debt and executive compensation contracts can be made contingent on χ, this extension does not affect our main results. The reason is that the proofs of our main results continue to apply after replacing $\widetilde{Z}$ with the public signal χ. Furthermore, if $\widetilde{Z}$ can be manipulated at no cost, Barbalau and Zeni (2025) show that project-based securities are preferred to outcome-based securities. In terms of our model, their finding implies that sustainability-linked bonds or loans are not optimal.

6.4. Renegotiation of the executive compensation contract.—

In the previous sections, we contrast only the full-commitment case with the no-commitment case. In this subsection, we extend the analysis to the renegotiation case, in which the initial compensation contract can be replaced if both the for-profit owner and the manager agree to the replacement. Chowdhry, Davies, and Waters (2019) show that, if the for-profit owner can renegotiate the socially minded manager's compensation contract, namely stock-based compensation, the for-profit owner has an incentive to sell a fraction of the firm's equity to the socially responsible investor to overcome the commitment problem. Absent renegotiation, the for-profit owner has no incentive to sell an equity claim in the firm to the socially responsible investor.

In our debt-finance model, if the for-profit owner can commit to the executive compensation contract specified at date 1, renegotiation does not arise. Therefore, the result of Proposition 1 in the commitment case and the result of Proposition 2 continue to hold.

By contrast, suppose that, in the public debt market model, the for-profit owner chooses both the debt contract and the executive compensation contract at date 1 but can renegotiate the executive compensation contract with the manager at date 2. Even in this case, no outside shock occurs between dates 1 and 2 in our model, and the for-profit owner remains committed to making the debt repayment if the project succeeds. We can therefore restrict attention at date 1 to renegotiation-proof compensation contracts, under which there exists no alternative compensation contract that makes both the for-profit owner and the manager better off (see Bolton and Dewatripont, 2005). Under this restriction, the for-profit owner chooses both the debt contract and the executive compensation contract at date 1, and no renegotiation occurs at date 2. Consequently, by applying a procedure similar to that used in the commitment case in Proposition 1, the result of Proposition 1 in the no-commitment case also continues to hold.[20]

Finally, suppose that, in the over-the-counter debt market model, the executive compensation contract may be renegotiated between the for-profit owner and the manager at date 2, even when the for-profit owner and the SRF negotiate that contract at date 1. Again, under the restriction that the executive compensation contract must be renegotiation-proof, the for-profit owner and the SRF negotiate both the debt contract and the executive compensation contract at date 1, and the executive compensation contract is not renegotiated at date 2. Accordingly, by applying a procedure similar to that used in Proposition 2, we can derive the following proposition:

Proposition 4. *In the over-the-counter debt market, suppose that the for-profit owner can renegotiate the date* 1 *executive compensation contract with the manager at date* 2.
(i) If $R^{r**} \leq X(a^{r**}) - \frac{w_{X0}^{r**}}{B}$*, then the debt contract satisfying* $r_0^{r**} = r_Z^{r**} = R^{r**}$ *is optimal and attains the maximum value of the bargaining problem between the for-profit owner and the SRF. Otherwise, the optimal debt contract satisfies* $r_0^{r**} \neq r_Z^{r**}$*.*
(ii) The optimal compensation contract for the manager is renegotiation-proof and satisfies $w_{X0}^{r**} > w_{XZ}^{r**} = 0$*.*

Proposition 4 shows that, even if the for-profit owner can renegotiate the executive compensation contract specified at date 1 in the over-the-counter debt market, noncontingent fixed-rate bonds or loans are optimal and attain the maximum value of the bargaining problem, provided that project revenues are sufficiently large to cover fixed-rate debt repayments and the manager's compensation when the project succeeds. Intuitively, renegotiation-proofness requires the debt repayment and the manager's compensation to be jointly determined at date 1 so as to preclude subsequent renegotiation of the executive compensation contract. As a result, by applying an argument similar to that in Proposition 2, the debt repayment need not be contingent on ESG performance, provided

[20] This feature distinguishes our debt issuance model from the equity issuance model of Chowdhry, Davies, and Waters (2019), in which limited commitment to the executive compensation contract changes the result obtained when renegotiation is ruled out. This contrast is discussed in the final paragraph of Section 4.2.

that project revenues are sufficiently large in the success state.[21].

6.5. Observable random shocks between dates 1 and 2.—

In our baseline model, no outside shock occurs between dates 1 and 2. Suppose instead that observable random shocks occur between these dates. Even in this case, if the for-profit owner can commit to the executive compensation contract specified at date 1, she does not change the terms of the contract. Therefore, the result of Proposition 1 in the commitment case and the result of Proposition 2 continue to hold.

By contrast, if the for-profit owner cannot commit to an executive compensation contract specified at date 1, she has an incentive to offer the manager a new contract at date 2 that incorporates the realized shock and differs from the contract specified at date 1. Thus, the result in Proposition 1 for the no-commitment case no longer holds, whereas the result in Proposition 3 continues to hold. Accordingly, in this extension, if the for-profit owner cannot commit to an executive compensation contract specified at date 1, sustainability-linked bonds or loans become necessary, regardless of whether debt is traded in the public debt market or in the over-the-counter debt market.

7. Discussions and empirical implications

Using Propositions 1–3 together with the arguments in Section 6, we provide guidance on the design of social impact debt under ESG-linked executive compensation. Our framework has implications for profit-seeking borrowers that raise financing from socially responsible investors through bond issuance or lending under ESG-linked executive compensation. Sections 4 and 5 show that the design of such debt financing depends on two key factors: (i) debt market structure and (ii) the borrower's ability to commit to the executive compensation contract. We interpret the strength of this commitment as closely related to the strength of the borrower's governance structure. Section 6 further shows that the design of such debt financing also depends on the borrower's exposure to changes in the external environment. In the following discussion, we focus on the case in which project revenues are sufficiently large to cover fixed-rate debt repayments and managerial compensation when the project succeeds.

[21] Extending this argument, our results continue to hold even if the for-profit owner is allowed to renegotiate the debt contract.

Given these considerations, we provide the following guidance for debt financing under ESG-linked executive compensation by distinguishing among borrower types.

(i) Suppose that borrowers do not have relatively high exposure to exogenous shocks.
(a) If borrowers raise funds in the public debt market, or if they raise funds in the over-the-counter debt market and have robust governance, it is sufficient for them to issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans.
(b) If borrowers rely on the over-the-counter debt market but have weak governance, sustainability-linked bonds or loans are likely to be necessary.
(ii) Suppose that borrowers have relatively high exposure to exogenous shocks.
(a) If borrowers have robust governance, it is sufficient for them to issue noncontingent fixed-rate bonds or obtain noncontingent fixed-rate loans.
(b) If borrowers have weak governance, sustainability-linked bonds or loans are likely to be necessary.

By contrast, nonprofit borrowers, such as local governments, are unlikely to adopt ESG-linked executive compensation. Our results therefore do not directly apply to such borrowers. Indeed, sustainability-linked bonds are often issued by public-sector entities (see Pauly and Swanson, 2017).

If borrowers raise funds through sustainability-linked bonds or loans even though noncontingent fixed-rate bonds or loans would be sufficient, such financing may not substantially improve their ESG performance. Kim, Kumar, Lee, and Oh (2025) report that borrowers do not significantly improve their ESG performance after raising sustainability-linked loans. In their sample, sustainability-linked loans tend to be arranged between large publicly listed borrowers and large syndicates composed of reputable global banks with preexisting lending relationships. Therefore, if some of these firms adopt ESG-linked executive compensation, face relatively limited exposure to exogenous shocks, and have robust governance structures, our results may explain their finding.[22]

[22] Several other empirical studies also show that sustainability-linked loans provide little additional incentive to improve ESG performance. Comparing green loans and sustainability-linked loans, de Novellis, Perdichizzi, and Stella (2026) find that sustainability-linked loans are associated with weaker and less robust improvements in CO_2 emissions after issuance, although sustainability-linked loans with high-quality key performance indicators exhibit stronger improvements in environmental ratings. Du, Harford, and Shin (2023) show that borrowers' sustainability performance does not improve after sustainability-linked loan initiation. Aleszczyk, Loumioti, and Serafeim (2023) report that sustainability-linked loans often include immaterial performance indicators and weak targets that are unrelated to borrowers' ESG risk.

Barbalau and Zeni (2025) provide evidence that firms operating in industries undergoing technological change and facing greater uncertainty during the green transition are more likely to issue outcome-based securities, such as sustainability-linked loans. If these firms have weak governance, this evidence is consistent with our model's prediction that sustainability-linked bonds or loans are likely to be necessary when firms are highly exposed to exogenous shocks but lack strong governance.

8. Conclusion

We study the optimal design of sustainable debt when a for-profit borrower raises funds from socially responsible investors and induces a for-profit manager to exert sustainability effort through an executive compensation contract. In particular, we examine whether borrowers can rely on noncontingent fixed-rate bonds or loans rather than sustainability-linked bonds or loans when executive compensation can also be tied to ESG performance.

We show that the optimal design of sustainable debt depends on both the investment structure faced by socially responsible investors and the borrower's ability to commit to the executive compensation contract. We also derive implications for the design of debt securities and contracts when borrowers can adjust ESG-linked executive compensation appropriately.

Appendix A

Proof of Lemma 1. To justify the assumption that $[X(a) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$, suppose instead that $[X(a) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} < 0$ for some realization of $\widetilde{Z}$. Under the seniority rule, the effective debt payment per unit of debt investment is $r_{\widetilde{Z}}$ if $X(a) - \frac{1}{B}w_{X\widetilde{Z}} < r_{\widetilde{Z}} \leq X(a)$, and $X(a)$ if $X(a) < r_{\widetilde{Z}}$. The manager's effective compensation is $[X(a) - r_{\widetilde{Z}}]B$ if $X(a) - \frac{1}{B}w_{X\widetilde{Z}} < r_{\widetilde{Z}} \leq X(a)$, and 0 if $X(a) < r_{\widetilde{Z}}$. Define $(r'_{\widetilde{Z}}, w'_{X\widetilde{Z}})$ as follows: $(r'_{\widetilde{Z}}, w'_{X\widetilde{Z}}) = (r_{\widetilde{Z}}, w_{X\widetilde{Z}})$ if $r_{\widetilde{Z}} \leq X(a) - \frac{1}{B}w_{X\widetilde{Z}}$, $(r'_{\widetilde{Z}}, w'_{X\widetilde{Z}}) = (r_{\widetilde{Z}}, (X(a) - r_{\widetilde{Z}})B)$ if $X(a) - \frac{1}{B}w_{X\widetilde{Z}} < r_{\widetilde{Z}} \leq X(a)$, and $(r'_{\widetilde{Z}}, w'_{X\widetilde{Z}}) = (X(a), 0)$ if $X(a) < r_{\widetilde{Z}}$. If all agents understand that debt payments and managerial compensation are made according to the seniority rule, replacing $(r_{\widetilde{Z}}, w_{X\widetilde{Z}})$ with $(r'_{\widetilde{Z}}, w'_{X\widetilde{Z}})$ satisfies $[X(a) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$, as well as the other constraints of the for-profit owner, while leaving the for-profit owner's objective function unchanged. Therefore, without loss of generality, we can assume that $[X(a) - r_{\widetilde{Z}}]B - w_{X\widetilde{Z}} \geq 0$ for $\widetilde{Z} \in \{0, Z\}$. ■

Proof of Proposition 1. We begin with the commitment case. We initially assume that the constraints $r_0 \geq 1$ and $r_Z \geq 1$ hold with strict inequalities. To solve problem (11), let λ_{10} and λ_{1Z} denote the nonnegative multipliers associated with the constraints $X(a) - r_0 \geq \frac{w_{X0}}{B}$ and $X(a) - r_Z \geq \frac{w_{XZ}}{B}$, respectively. These constraints are obtained by dividing the constraints in (9) by B.[23]

Using (3) and (7), with $B = B_D$ to eliminate a and B, we can rewrite the for-profit owner's maximization problem, (11), as follows:

$$\max_{(w_{H0}, w_{HZ}, r_0, r_Z)} \left\{\delta X(c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))) - \delta[\zeta_0 + \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_0 \right.$$
$$\left. -\delta[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_Z\right\}$$
$$\times \frac{\delta[\zeta_0 + \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_0 + \delta[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_Z - 1}{\overline{\theta}[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]Z}$$
$$- \delta[\zeta_0 + \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]w_{X0} - \delta[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]w_{XZ}, \quad \text{(A1)}$$

[23] As noted at the beginning of Section 4.2, throughout this Appendix we assume that the constraint $B \geq 0$ holds with strict inequality at the optimal solution to (11)

subject to

$$X(c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))) - r_0 \\ \geq \frac{\overline{\theta}[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]Zw_{X0}}{\delta[\zeta_0 + \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_0 + \delta[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_Z - 1}, \quad \text{(A2)}$$

$$X(c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))) - r_Z \\ \geq \frac{\overline{\theta}[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]Zw_{XZ}}{\delta[\zeta_0 + \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_0 + \delta[1 - \zeta_0 - \zeta_1 c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))]r_Z - 1}, \quad \text{(A3)}$$

$$w_{X0} \geq 0, \quad w_{XZ} \geq 0. \quad \text{(A4)}$$

Because we assume that the constraint $B \geq 0$ holds with strict inequality at the optimal solution to (11), and because we tentatively assume that the constraints $r_0 \geq 1$ and $r_Z \geq 1$ hold with strict inequalities, we do not consider the constraints (10) except for $w_{X0} \geq 0$ and $w_{XZ} \geq 0$.

Solving problem (A1) and rewriting the resulting conditions using (3) and (7), with $B = B_D$, we obtain the first-order conditions with respect to r_0 and r_Z as follows:[24]

$$J_1(a^{c*}) + \left[J_2(a^{c*}, w^*_{X0}) - \frac{1}{\delta(\zeta_0 + \zeta_1 a^{c*})}\right]\lambda_{10} + J_3(a^{c*}, w^*_{XZ})\lambda_{1Z} = 0, \quad \text{(A5)}$$

$$J_1(a^{c*}) + J_2(a^{c*}, w^*_{X0})\lambda_{10} + \left[J_3(a^{c*}, w^*_{XZ}) - \frac{1}{\delta(1 - \zeta_0 - \zeta_1 a^{c*})}\right]\lambda_{1Z} = 0, \quad \text{(A6)}$$

where

$$J_1(a) = -B + \frac{\delta[X(a) - (\zeta_0 + \zeta_1 a)\, r_0 - (1 - \zeta_0 - \zeta_1 a)r_Z]}{\overline{\theta}\,(1 - \zeta_0 - \zeta_1 a)\, Z}, \quad \text{(A7)}$$

$$J_2(a, , w_{X0}) = \frac{\overline{\theta}\,(1 - \zeta_0 - \zeta_1 a)\, Zw_{X0}}{[\delta(\zeta_0 + \zeta_1 a)r_0 + \delta(1 - \zeta_0 - \zeta_1 a)r_Z - 1]^2}, \quad \text{(A8)}$$

$$J_3(a, w_{XZ}) = \frac{\overline{\theta}\,(1 - \zeta_0 - \zeta_1 a)\, Zw_{XZ}}{[\delta(\zeta_0 + \zeta_1 a)r_0 + \delta(1 - \zeta_0 - \zeta_1 a)r_Z - 1]^2}. \quad \text{(A9)}$$

[24] To simplify notation, we rewrite a and a^{c*} in place of $c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))$ and $c'^{-1}(\delta\zeta_1(w^{c*}_{X0} - w^{c*}_{XZ}))$, respectively. We also rewrite the equations using B.

In fact, rearranging equations (A5) and (A6) yields

$$J_1(a^{c*}) + J_2(a^{c*}, w^*_{X0})\lambda_{10} + J_3(a^{c*}, w^*_{XZ})\lambda_{1Z} = \frac{1}{\delta(\zeta_0 + \zeta_1 a^{c*})}\lambda_{10} = \frac{1}{\delta(1 - \zeta_0 - \zeta_1 a^{c*})}\lambda_{1Z}.$$

Furthermore, we can show that $\lambda_{10} = \lambda_{1Z} = 0$ in equilibrium. Suppose first that $\lambda_{10} > 0$ and $\lambda_{1Z} > 0$. Then, $X(a^{c*})B - w^*_{X0} = r_0 B$ and $X(a^{c*})B - w^*_{XZ} = r_Z B$, which imply that the for-profit owner's expected payoff is zero. This contradicts our assumption that the for-profit owner's expected payoff under the optimal contract is strictly positive. Therefore, $\lambda_{10} > 0$ and $\lambda_{1Z} > 0$ are inconsistent with equilibrium. Next, suppose that $\lambda_{10} > \lambda_{1Z} = 0$. It follows from (A5) and (A6) that $\frac{1}{\delta(\zeta_0+\zeta_1 a^{c*})}\lambda_{10} = 0$, which contradicts $\lambda_{10} > 0$. Similarly, If $\lambda_{1Z} > \lambda_{10} = 0$, then $\frac{1}{\delta(1-\zeta_0-\zeta_1 a^{c*})}\lambda_{1Z} = 0$, which contradicts $\lambda_{1Z} > 0$. These arguments imply that $\lambda_{10} = \lambda_{1Z} = 0$ in equilibrium. Hence, (A5) and (A6) reduce to the same equation.

Because the two first-order conditions coincide, they identify only one relationship between the two choice variables. The objective function, however, depends on r_0 and r_Z only through the aggregate variable $R_1 = (\zeta_0 + \zeta_1 a^{c*})r_0 + (1 - \zeta_0 - \zeta_1 a^{c*})r_Z$. Thus, taking a^{c*} as given, we can characterize the maximum of the objective function using the first-order condition with respect to R_1. After obtaining R_1^{c*}, we can choose $r_0 = r_Z = R_1^{c*}$, provided that this choice satisfies $X(a^{c*}) - r_0 \geq \frac{w^{c*}_{X0}}{B}$ and $X(a^{c*}) - r_Z \geq \frac{w^{c*}_{XZ}}{B}$. If both constraints are satisfied, $r_0 = r_Z = R_1^{c*}$ solves the original constrained maximization problem. Otherwise, every solution to the original constrained problem must have $r_0 \neq r_Z$. The unconstrained optimum, R_1^{c*}, is characterized by the following first-order condition:

$$\frac{\delta[\delta X(a^{c*}) - 2\delta R_1 + 1]}{\overline{\theta}\,(1 - \zeta_0 - \zeta_1 a^{c*})\,Z} = 0.$$

Solving the above equation for R_1, we obtain

$$R_1^{c*} = \frac{\delta X(a^{c*}) + 1}{2\delta}. \tag{A10}$$

To check whether $r_0 = r_Z = R_1$ is a solution, we need to characterize w^{c*}_{X0} and w^{c*}_{XZ}. If $w^{c*}_{X0} = w^{c*}_{XZ}$, then it follows from (3) that $a^{c*} = 0$. Because we assume that the for-profit owner prefers a marginal increase in a when a is close to zero and that a higher a increases the monetary payoff and reduces the expected negative externality, the owner optimally sets $w^{c*}_{X0} > w^{c*}_{XZ} = 0$. It follows that $X(a^{c*}) - \frac{w^{c*}_{X0}}{B} < X(a^{c*}) - \frac{w^{c*}_{XZ}}{B} = X(a^{c*})$.

Accordingly, if $R^{c*}_1 \leq X(a^{c*}) - \frac{w^{c*}_{X0}}{B}$, then the pair (r^{c*}_0, r^{c*}_Z) satisfying $r^{c*}_0 = r^{c*}_Z = R^{c*}_1$ satisfies the constraints and therefore solves the original problem. By contrast, if $X(a^{c*}) - \frac{w^{c*}_{X0}}{B} < R^{c*}_1$, then the optimal solution must be a pair (r^{c*}_0, r^{c*}_Z) satisfying $r^{c*}_0 \neq r^{c*}_Z$.[25]

Finally, we verify that these solutions continue to hold after relaxing the tentative assumption that the constraints $r_0 \geq 1$ and $r_Z \geq 1$ hold with strict inequalities. Suppose first that $r^{c*}_0 = r^{c*}_Z = R^{c*}_1$ is an optimal solution. If R^{c*}_1 is sufficiently small, the constraints $r_0 \geq 1$ and $r_Z \geq 1$ imply that $(r^{c*}_0, r^{c*}_Z) = (1, 1)$. However, it follows from (7) and $\delta < 1$ that $B = B_D < 0$, a contradiction. Next suppose that the optimal solution is a pair (r^{c*}_0, r^{c*}_Z) satisfying $r^{c*}_0 \neq r^{c*}_Z$. If this pair does not satisfy both $r_0 > 1$ and $r_Z > 1$, then the only possible cases are $r^{c*}_0 > 1$ and $r^{c*}_Z = 1$ or $r^{c*}_0 = 1$ and $r^{c*}_Z > 1$, because $r^{c*}_0 = r^{c*}_Z = 1$ contradicts $r^{c*}_0 \neq r^{c*}_Z$. Thus, the solution continues to satisfy $r^*_0 \neq r^*_Z$. Hence, the above solutions continue to hold after relaxing the tentative assumption that $r_0 \geq 1$ and $r_Z \geq 1$ hold with strict inequalities.

We next consider the no-commitment case. By the envelope theorem, the first-order conditions with respect to r_0 and r_Z have the same forms as (A5) and (A6). Accordingly, by applying a procedure similar to that used in the commitment case, we can prove the result of this proposition in the no-commitment case. ■

Proof of Lemma 2. By applying the same argument as in the proof of Lemma 1, we can verify the statement of this lemma. ■

Proof of Proposition 2. We again initially assume that the constraints $r_0 \geq 1$ and $r_Z \geq 1$ hold with strict inequalities. Let λ_{10} and λ_{1Z} denote the nonnegative multipliers associated with the constraints $X(a) - r_0 \geq \frac{w_{X0}}{B}$ and $X(a) - r_Z \geq \frac{w_{XZ}}{B}$, respectively. These constraints are obtained by dividing the corresponding constraints in (9) by B.

Note that a^{**}, $\widehat{\theta}(r_0, r_Z, a^{**})$, and B are determined by the same expressions as a^* in (3), $\widehat{\theta}(r_0, r_Z, a^*)$ in (6), and B_D in (7), respectively. In particular, $B = \frac{\widehat{\theta}(r_0, r_Z, a^{**})}{\overline{\theta}}$. Using these observations and treating B as a function of r_0 and r_Z, we solve the bargaining problem

[25] Note that w^{c*}_{X0}, w^{c*}_{XZ}, and a^{c*} are jointly determined by (3) and the first-order conditions with respect to w_{X0} *and* w_{XZ} for maximizing the objective function subject to $w_{XZ} \geq 0$. Because relaxing a constraint weakly expands the feasible set without changing the objective function, the resulting maximum cannot be lower than the maximum obtained under the more restrictive constraint set.

in (14) and obtain the following first-order conditions with respect to r_0 and r_Z:[26]

$$
\begin{aligned}
&\kappa \frac{\frac{\partial \Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**})}{\partial r_0}}{\Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**})} + (1-\kappa)\frac{\frac{\partial \Pi^S(r_0, r_Z, a^{c**})}{\partial r_0}}{\Pi^S(r_0, r_Z, a^{c**})} \\
&+ [\delta(\zeta_0 + \zeta_1 a^{c**}) J_2(a^{c**}, w_{X0}^{c**}) - 1]\lambda_{10} + \delta(\zeta_0 + \zeta_1 a^{c**}) J_3(a^{c**}, w_{XZ}^{c**})\lambda_{1Z} \\
&= 0,
\end{aligned} \tag{A11}
$$

$$
\begin{aligned}
&\kappa \frac{\frac{\partial \Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**})}{\partial r_Z}}{\Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**})} + (1-\kappa)\frac{\frac{\partial \Pi^S(r_0, r_Z, a^{c**})}{\partial r_Z}}{\Pi^S(r_0, r_Z, a^{c**})} \\
&+ \delta(1 - \zeta_0 - \zeta_1 a^{c**}) J_2(a^{c**}, w_{X0}^{c**})\lambda_{10} + [\delta(1 - \zeta_0 - \zeta_1 a^{c**}) J_3(a^{c**}, w_{XZ}^{c**}) - 1]\lambda_{1Z} \\
&= 0,
\end{aligned} \tag{A12}
$$

where

$$\frac{\partial \Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**})}{\partial r_0} = \delta(\zeta_0 + \zeta_1 a^{c**}) J_1(a^{c**}), \tag{A13}$$

$$\frac{\partial \Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**})}{\partial r_Z} = \delta(1 - \zeta_0 - \zeta_1 a^{c**}) J_1(a^{c**}), \tag{A14}$$

$$\frac{\partial \Pi^S(r_0, r_Z, a^{c**})}{\partial r_0} = \delta(\zeta_0 + \zeta_1 a^{c**}) J_4(a^{c**}), \tag{A15}$$

$$\frac{\partial \Pi^S(r_0, r_Z, a^{c**})}{\partial r_Z} = \delta(1 - \zeta_0 - \zeta_1 a^{c**}) J_4(a^{c**}), \tag{A16}$$

$$J_4(a) = \frac{\delta(\zeta_0 + \zeta_1 a) r_0 + \delta(1 - \zeta_0 - \zeta_1 a) r_Z - 1}{\overline{\theta}(1 - \zeta_0 - \zeta_1 a) Z}. \tag{A17}$$

Dividing (A11) by $\delta(\zeta_0 + \zeta_1 a^{c**})$ and (A12) by $\delta(1 - \zeta_0 - \zeta_1 a^{c**})$, and then comparing the rearranged equations using arguments analogous to those in the proof of Proposition 1, we show that the first-order conditions with respect to r_0 and r_Z reduce to the same equation and that $\lambda_{10} = \lambda_{1Z} = 0$ in equilibrium.

Define $R_2 = (\zeta_0 + \zeta_1 a^{c**}) r_0 + (1 - \zeta_0 - \zeta_1 a^{c**}) r_Z$. Then, applying arguments analogous to those in the proof of Proposition 1, we obtain the result of Proposition 2. Note that

[26] We take the logarithm of the objective function: $\kappa \log \Pi^O(w_{X0}^{c**}, w_{XZ}^{c**}, r_0, r_Z, B, a^{c**}) + (1 - \kappa) \log \Pi^S(r_0, r_Z, a^{c**})$. To simplify notation, we write a and a^{c**} for $c'^{-1}(\delta\zeta_1(w_{X0} - w_{XZ}))$ and $c'^{-1}(\delta\zeta_1(w_{X0}^{c**} - w_{XZ}^{c**}))$, respectively. We also rearrange the equations by using B.

R_2^{c**} is determined by the first-order condition with respect to R_2 for the unconstrained maximization of the objective function:[27]

$$\frac{\kappa\left[\delta X(a^{c**})-2R_2+1\right]}{\Pi^O(w_{X0}^{c**},w_{XZ}^{c**},r_0,r_Z,B,a^{c**})}+\frac{(1-\kappa)\left(\delta R_2-1\right)}{\Pi^S(r_0,r_Z,a^{c**})}=0. \tag{A18}$$

■

Proof of Proposition 3. We first solve maximization problem (15). Note that a^{**} is determined by the same expression that determines a^* in (3). Then, as in the proof of Proposition 1, we can show that $w_{X0}^{n**}>w_{XZ}^{n**}\geq 0$. Given this result and $c(a)=\frac{c}{2}a^2$, solving (15) with respect to w_{X0} and w_{XZ}, taking (r_0,r_Z,B) as given, yields the following first-order conditions:

$$-\delta\zeta_0+\frac{(\delta\zeta_1)^2}{c}\left[r_Z-r_0+\frac{1}{\zeta_1}X'\left(\frac{\delta\zeta_1(w_{X0}^{n**}-w_{XZ}^{n**})}{c}\right)\right]B=0, \tag{A19}$$

$$\delta(1-\zeta_0)+\frac{(\delta\zeta_1)^2}{c}\left[r_Z-r_0+\frac{1}{\zeta_1}X'\left(\frac{\delta\zeta_1(w_{X0}^{n**}-w_{XZ}^{n**})}{c}\right)\right]B-\mu_Z=0, \tag{A20}$$

where μ_Z is the nonnegative multiplier associated with the constraint $w_{XZ}\geq 0$. Subtracting (A19) from (A20) yields $-\delta+\mu_Z=0$, which implies $\mu_Z=\delta>0$. We thus verify that $w_{XZ}^{n**}=0$. Therefore, we can focus on (A19) to determine w_{X0}^{n**} given $w_{XZ}^{n**}=0$.

Rearranging (A19) by using (3), (7), $B=B_D$, $w_{XZ}^{n**}=0$, and $c(a)=\frac{c}{2}a^2$ yields

$$-\delta\zeta_0+\frac{(\delta\zeta_1)^2}{c}\left[r_Z-r_0+\frac{1}{\zeta_1}X'\left(\frac{\delta\zeta_1 w_{X0}^{n**}}{c}\right)\right]\frac{\delta\left[\zeta_0+\frac{\delta(\zeta_1)^2w_{X0}^{n**}}{c}\right]r_0+\delta\left[1-\zeta_0-\frac{\delta(\zeta_1)^2w_{X0}^{n**}}{c}\right]r_Z-1}{\overline{\theta}\left[1-\zeta_0-\frac{\delta(\zeta_1)^2w_{X0}^{n**}}{c}\right]Z}$$
$$=0. \tag{A19$'$}$$

Totally differentiating (A19′) with respect to w_{X0}, r_0, and r_Z, we have[28]

$$\frac{dw_{X0}^{n**}}{dr_0}=\frac{\left\{\overline{\theta}ZB\left(1-\zeta_0-\zeta_1a^{n**}\right)-\delta\left(\zeta_0+\zeta_1a^{n**}\right)\left[r_Z-r_0+\frac{1}{\zeta_1}X'(a^{n**})\right]\right\}\left(1-\zeta_0-\zeta_1a^{n**}\right)}{\left\{\left[r_Z-r_0+\frac{1}{\zeta_1}X'(a^{n**})\right]\zeta_1(\delta r_0-1)+\frac{1}{\zeta_1}X''(a^{n**})\overline{\theta}Z\left(1-\zeta_0-\zeta_1a^{n**}\right)^2\right\}\frac{\delta\zeta_1}{c}}, \tag{A21}$$

[27] For the joint determination of w_{X0}^{c**}, w_{XZ}^{c**}, and a^{c**}, see footnote 25.

[28] To simplify notation, we write a^{n**} for $\frac{\delta\zeta_1w_{X0}^{n**}}{c}$. We also rearrange the equations by using B.

$$\frac{dw_{X0}^{n**}}{dr_Z} = -\frac{\left\{\overline{\theta}ZB + \delta\left[r_Z - r_0 + \frac{1}{\zeta_1}X'(a^{n**})\right]\right\}(1-\zeta_0-\zeta_1 a^{n**})^2}{\left\{\left[r_Z - r_0 + \frac{1}{\zeta_1}X'(a^{n**})\right]\zeta_1(\delta r_0 - 1) + \frac{1}{\zeta_1}X''(a^{n**})\overline{\theta}Z\,(1-\zeta_0-\zeta_1 a^{n**})^2\right\}\frac{\delta\zeta_1}{c}}. \tag{A22}$$

We next solve maximization problem (16). Note that $\widehat{\theta}(r_0, r_Z, a^{n**})$ is determined by the same expression that determines $\widehat{\theta}(r_0, r_Z, a^*)$ in (6), and that $B = \frac{\widehat{\theta}(r_0, r_Z, a^{n**})}{\overline{\theta}}$ and $w_{XZ}^{n**} = 0$. We continue to denote by λ_{10} and λ_{1Z} the nonnegative multipliers associated with the constraints $X(a) - r_0 \geq \frac{w_{X0}}{B}$ and $X(a) - r_Z \geq 0$, respectively. These are the constraints in (9), divided by B, when $w_{XZ}^{n**} = 0$. Treating B as a function of r_0, r_Z, and $a^{n**} = \frac{\delta\zeta_1 w_{X0}^{n**}}{c}$ and solving bargaining problem in (16) together with (3), $w_{XZ}^{n**} = 0$, and $c(a) = \frac{c}{2}a^2$, we obtain the following first-order conditions with respect to r_0 and r_Z:[29]

$$\kappa\frac{\frac{\partial\Pi_2^O(r_0, r_Z, B)}{\partial r_0}}{\Pi_2^O(r_0, r_Z, B)} + (1-\kappa)\frac{\frac{\partial\Pi^S(r_0, r_Z, a^{n**})}{\partial r_0}}{\Pi^S(r_0, r_Z, a^{n**})} + \left[J_7(a^{n**}, w_{X0}^{n**}) - 1\right]\lambda_{10} + J_8(a^{n**}, w_{X0}^{n**})\lambda_{1Z} = 0, \tag{A23}$$

$$\kappa\frac{\frac{\partial\Pi_2^O(r_0, r_Z, B)}{\partial r_Z}}{\Pi_2^O(r_0, r_Z, B)} + (1-\kappa)\frac{\frac{\partial\Pi^S(r_0, r_Z, a^{n**})}{\partial r_Z}}{\Pi^S(r_0, r_Z, a^{n**})} + J_7(a^{n**}, w_{X0}^{n**})\lambda_{10} + \left[J_8(a^{n**}, w_{X0}^{n**}) - 1\right]\lambda_{1Z} = 0, \tag{A24}$$

where

$$\frac{\partial\Pi_2^O(r_0, r_Z, B)}{\partial r_0} = \delta(\zeta_0 + \zeta_1 a^{n**})J_1(a^{n**}) + J_5(a^{n**})\frac{dw_{X0}^{n**}}{dr_0}, \tag{A25}$$

$$\frac{\partial\Pi_2^O(r_0, r_Z, B)}{\partial r_Z} = \delta(1 - \zeta_0 - \zeta_1 a^{n**})J_1(a^{n**}) + J_5(a^{n**})\frac{dw_{X0}^{n**}}{dr_Z}, \tag{A26}$$

$$\frac{\partial\Pi^S(r_0, r_Z, a^{n**})}{\partial r_0} = \delta(\zeta_0 + \zeta_1 a^{n**})J_4(a^{n**}) + J_6(a^{n**})\frac{dw_{X0}^{n**}}{dr_0}, \tag{A27}$$

$$\frac{\partial\Pi^S(r_0, r_Z, a^{n**})}{\partial r_Z} = \delta(1 - \zeta_0 - \zeta_1 a^{n**})J_4(a^{n**}) + J_6(a^{n**})\frac{dw_{X0}^{n**}}{dr_Z}, \tag{A28}$$

[29] We take the logarithm of the objective function: $\kappa\log\Pi_2^O(r_0, r_Z, B) + (1-\kappa)\log\Pi^S(r_0, r_Z, a^{n**})$.

$$J_5(a^{n**}) = -\delta\zeta_0 + \frac{(\delta\zeta_1)^2}{c}\left[r_Z - r_0 + \frac{1}{\zeta_1}X'\left(a^{n**}\right)\right]B = 0, \tag{A29}$$

$$J_6(a^{n**}) = \left[\frac{(\delta\zeta_1)^2(r_0 - r_Z)}{c} + \frac{\delta(\zeta_1)^2\overline{\theta}Z}{2c}B\right]B, \tag{A30}$$

$$\begin{aligned} J_7(a^{n**}, w_{X0}^{n**}) = \delta(\zeta_0 + \zeta_1 a^{n**})J_2(a^{n**}, w_{X0}^{n**}) + \Bigg\{ & X'(a^{n**})\frac{\delta\zeta_1}{c} \\ & - \frac{\overline{\theta}Z\left(1 - \zeta_0 - \zeta_1 a^{n**}\right)}{[\delta(\zeta_0 + \zeta_1 a^{n**})r_0 + \delta(1 - \zeta_0 - \zeta_1 a^{n**})r_Z - 1]} \\ & + \frac{\overline{\theta}Z\delta\zeta_1 a^{n**}(r_0 - \frac{1}{\delta})}{[\delta(\zeta_0 + \zeta_1 a^{n**})r_0 + \delta(1 - \zeta_0 - \zeta_1 a^{n**})r_Z - 1]^2}\Bigg\}\frac{dw_{X0}^{n**}}{dr_0}, \end{aligned} \tag{A31}$$

$$\begin{aligned} J_8(a^{n**}, w_{X0}^{n**}) &= \delta(1 - \zeta_0 - \zeta_1 a^{n**})J_3(a^{n**}, 0) + X'\left(a^{n**}\right)\frac{\delta\zeta_1}{c}\frac{dw_{X0}^{n**}}{dr_Z} \\ &= X'\left(a^{n**}\right)\frac{\delta\zeta_1}{c}\frac{dw_{X0}^{n**}}{dr_Z}, \end{aligned} \tag{A32}$$

where the second equalities in (A29) and (A32) follow directly from (A19) and (A9), respectively.

It follows from (A7), (A25), (A26), and (A29), together with $w_{XZ}^{n**} = 0$, that

$$\frac{1}{\delta(\zeta_0 + \zeta_1 a^{n**})}\frac{\partial\Pi_2^O(r_0, r_Z, B)}{\partial r_0} = \frac{1}{\delta(1 - \zeta_0 - \zeta_1 a^{n**})}\frac{\partial\Pi_2^O(r_0, r_Z, B)}{\partial r_Z}.$$

However, (A21) and (A22) imply that the term $\frac{1}{\delta(\zeta_0+\zeta_1 a^{n**})}J_6(a^{n**})\frac{dw_{X0}^{n**}}{dr_0}$ in (A27) differs from the term $\frac{1}{\delta(1-\zeta_0-\zeta_1 a^{n**})}J_6(a^{n**})\frac{dw_{X0}^{n**}}{dr_Z}$ in (A28). Hence,

$$\frac{1}{\delta(\zeta_0 + \zeta_1 a^{n**})}\frac{\partial\Pi^S(r_0, r_Z, a^{n**})}{\partial r_0} \neq \frac{1}{\delta(1 - \zeta_0 - \zeta_1 a^{n**})}\frac{\partial\Pi^S(r_0, r_Z, a^{n**})}{\partial r_Z}.$$

Therefore, we cannot apply arguments analogous to those in the proofs of Proposition 1 and 2 in this case. This implies that a pair (r_0^{n**}, r_Z^{n**}) satisfying $r_0^{n**} = r_Z^{n**}$ does not solve the original problem. Thus, the optimal solution always satisfies $r_0^{n**} \neq r_Z^{n**}$. ■

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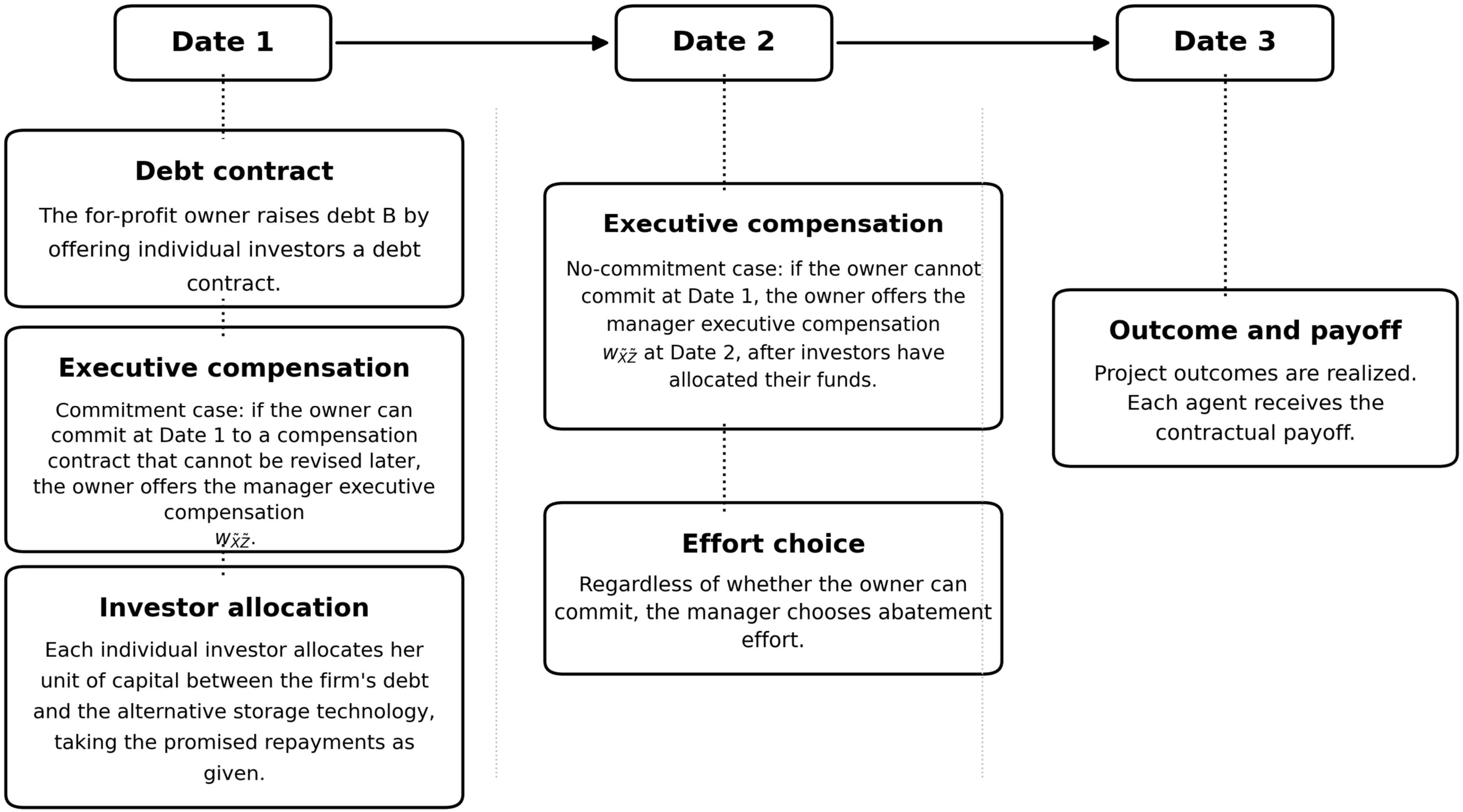

Figure 1. Timing structure in the public debt market.