The Optimal Design of Green Securities

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Abstract

We develop a model of green project financing which incorporates investors with green preferences into an otherwise standard framework of corporate financing with asymmetric information. Firms seek to finance green projects whose outcomes embed an uncertain component that is revealed only to the firm and which can be manipulated. Firms can raise funds using non-contingent debt contracts, such as green bonds, that specify ex-ante the projects to be financed using the proceeds, but make no commitment to green outcomes. Alternatively, they can use outcome-based contingent contracts, such as sustainability-linked bonds, that do not impose restrictions on the use of proceeds but embed contingencies which incentivize commitment to outcomes. We demonstrate that the co-existence of the two green debt contracts is an equilibrium result when reported green outcomes are manipulable and firm types differ in their ability to manipulate. In the presence of asymmetric information about firms' abilities to manipulate vs exert costly action, contingent debt is issued by low-type firms which seek to profit from manipulation, whereas non-contingent debt can be used as a costly signaling device. We provide empirical evidence consistent with these predictions.

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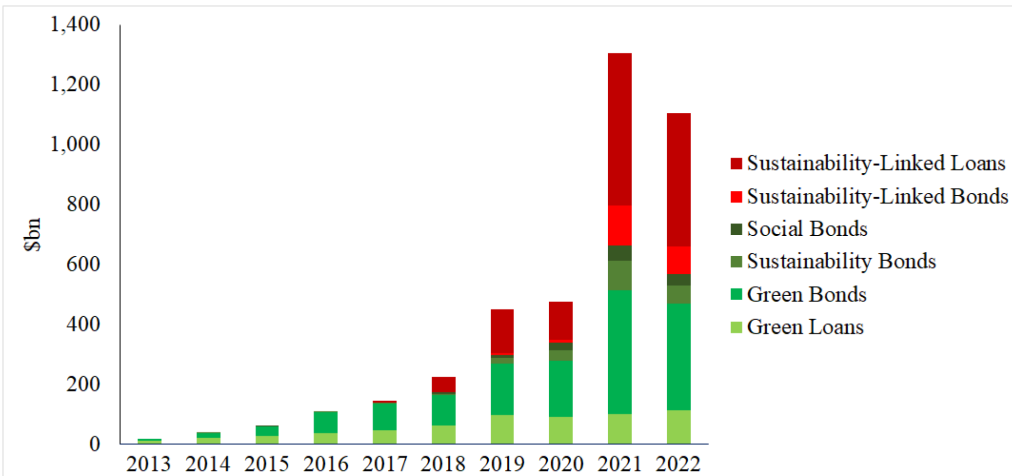
Financial markets are playing an increasingly important role in the fight against climate change and other sustainability issues by allowing sustainability-oriented investors to finance projects that have a positive environmental and social impact.[1] The corporate sustainable debt market opened slowly about a decade ago and has grown exponentially in recent years, reaching a cumulative issuance volume of approximately $4tn as of the end of 2022.[2]

Figure 1. Corporate Sustainable Debt Market

The figure shows the cumulative issuance volume of corporate sustainable debt securities in $ billions across years. Institutional details about the securities are reported in Appendix A.1.



The market has started with and has long been dominated by green bonds (see Figure 1). Green bonds (GBs) are fixed income securities which earmark proceeds for specific projects that have positive environmental and climate benefits. They are differentiated from regular bonds by a green label, which represents a commitment to exclusively use the funds raised to finance green projects. The contract focuses solely on specifying ex-ante the projects that the borrower can allocate the proceeds to, but it does not target nor it incentivises commitment to green outcomes. In contrast, the newly emerging class of sustainability-linked loans (SLLs) and bonds (SLBs) does not impose ex-ante constraints on the projects that the proceeds can be allocated to, but instead makes the cost of debt contingent on realized green outcomes, such as carbon emission reductions.[3]

[1] In line with the terminology employed in the International Capital Market Association (ICMA) standards governing the issuance of securities on the sustainable debt market, the term *sustainable* refers to environmental/climate as well as social and governance related issues, while the term *green* refers to environmental/climate related issues only.

[2] The size of total market including corporate and government issuances has grown from $109bn pre-2012 to $5,910bn as of the end of 2022.

[3] We generically refer to non-pecuniary outcomes as green outcomes, and focus empirically on carbon emissions,

The introduction of contingencies in securities' payoff addresses the limitations inherent to the design of action-based non-contingent securities such as GBs by eliminating the need to restrict borrower's actions ex-ante and by making outcomes rather than actions the focus of green financing. Importantly, this security design is in line with corporate finance theory which posits that optimal contracts should include all relevant contingencies (Hart and Holmström (1987)). It is thus unclear why despite the successful implementation of outcome-based contingent contracts such as SLLs and SLBs, we do not observe a complete switch to contingent financing but instead, the observed market outcome points to the co-existence of contingent and non-contingent contracts.

We propose a model of corporate financing which embeds moral hazard, measurement frictions and asymmetric information, to explain the debt issuance patterns observed in the market. The baseline model features two time periods, a representative investor and a firm. In the first time period, the firm has access to a business-as-usual project which has a fixed cost and which will yield, in the second time period, a *certain* monetary return. The firm can switch to a greener business model by implementing a green project which yields the same monetary return and, at some further cost, an *uncertain* green outcome. The green outcome is modelled as the sum of a measurable and an uncertain component. Whereas the measurable component represents the firm's costly action, which can be perfectly verified by the investor, the uncertain component can only be observed by the firm at an interim date and its reported value can be manipulated at a cost.[4]

The investor is risk-neutral and has green preferences, in the sense that she values both monetary and green outcomes.[5] The investor demands at least zero returns in expectation, and the rate at which she is willing to lend is a function of the green outcome delivered by the project. We consider three contract designs that are consistent with investor's participation constraint and resemble the ones currently observed in the market, namely: i) a plain vanilla contract that has a fixed interest rate and does not target a green project or outcome; ii) an action-based non-contingent green

but the model can more generally be applied to think about environmental, social or sustainability-related outcomes. Our preferred interpretation is in line with evidence reported in Appendix A.1 that the most common class of targets underlying sustainability-linked debt is environmental, and the specific metric is represented by carbon emissions.

[4]This specification captures the intuition that although a meaningful expectation about the average green outcome delivered by the project can be formed based on information about the scale of the investment, there is still residual uncertainty that will be gradually resolved and contribute to the final green outcome.

[5]Thus, we take as given the existence of a market that deploys capital to fund projects yielding non-pecuniary outcomes and focus solely on the firm's optimal debt financing choice. Further, we focus on contracting on non-pecuniary outcomes and abstract from uncertainty about financial outcomes, as well as trade-offs between financial and non-pecuniary outcomes. The latter assumption is also driven by the fact that it is not clear what should be the sign of the relationship between pursuing sustainability-related outcomes and future financial returns.

contract similar to GBs, which fixes the interest rate conditional on ex-ante commitment to a green project; iii) an outcome-based contingent green contract similar to SLLs/SLBs, which does not commit the proceeds to a specific use but makes the interest rate contingent on the realized green outcome reported by the firm. Thus, while the non-contingent green contract fixes the interest rate ex-ante based on the expected green outcome, the contingent green contract allows it to vary ex-post with the realized green outcome.

The baseline single firm model shows that vanilla contracts are affected by a moral hazard problem and can only finance business-as-usual projects, with the implication that a specialised green finance market is needed to finance green projects. Non-contingent green contracts correct for moral hazard by adhering to a use-of-proceeds principle which ensures credible commitment, but give rise to an opportunity cost of committing to projects before learning their green outcome potential. Contingent green contracts eliminate this commitment cost, but to the extent that the measurement systems on which contingencies are based can be manipulated, they are affected by a distortion discount. If the firm's distortion cost is high, we find that contingent contracts such as SLLs/SLBs are first-best. On the other hand, if the cost of distortion is low, then non-contingent contracts such as GBs become optimal.

This baseline result sheds light on the time-series evolution of the sustainable debt market and explains the initial dominance of GBs in terms of the absence of reliable measurement systems which characterised the early stages of the market. Subsequent improvements in measurement systems explain the co-existence of the two green contract designs, which is a result of an active trade-off between the opportunity cost of ex-ante commitment associated with non-contingent contracts such as GBs, which arises as a correction for moral hazard, and the distortion discount associated with contingent contracts such as SLLs/SLBs, which arises because of measurement frictions.

The trade-off between the cost of commitment and distortion also generates a non-monotonic relationship between the uncertainty surrounding a green project's outcome and the firm's preference for issuing a certain type of green debt contract to finance it, which sheds light on observed issuance patterns across industries. The model predicts that projects which are more likely to be financed using non-contingent green debt are those with either very high or very low levels of green outcome uncertainty. We verify this prediction empirically by proxying green outcomes using carbon emissions and documenting that GB issuance is more prevalent in industries with either a very high degree of measurability and control over their carbon emissions such as utilities (due to a low cost of commitment), or a very low degree of measurability and control over their carbon emissions such as financials (due to a high distortion discount).[6]

We extend the model to a multi-firm setup to explain issuance patterns across firms. Specifically, we introduce firm types that are differentiated with respect to the cost of action and the cost of distortion they face. We assume that these costs are negatively correlated, and conceptualize low-type firms as those that are more likely to manipulate reported outcomes than to exert costly action to deliver green outcomes, and vice-versa. When investors are perfectly informed about firm types, the model predicts that the issuance of contingent contracts such as SLLs/SLBs is u-shaped as a function of firm type, with the highest-type firms always issuing contingent green debt. However, in the presence of asymmetric information the issuance of contingent green debt is monotonically decreasing in firm type, and it is high-type firms that are more likely to issue non-contingent contracts such as GBs. The intuition behind this is that with asymmetric information, the investor learns something about the firm type from the financing contract proposed, and non-contingent contracts such as GBs become costly signalling devices which allow high types to credibly reveal their ability to commit ex-ante. On the other hand, when a firm issues a contingent contract in the presence of asymmetric information, the distortion discount that it receives is one that averages across all firm types that the investor believes are issuing this contract. Consequently, high-type firms with low ability to manipulate internalize the fact that by issuing this contract they would subsidize low-type firms, and thus prefer non-contingent contracts such as GBs in equilibrium.

We bring our model predictions to the data by combining security-level information from Bloomberg, balance-sheet and carbon emissions data from Standard & Poor Trucost, and ESG ratings from Sustainalytics. Our descriptive statistics indicate that contingent debt issuers are smaller yet more polluting than non-contingent debt issuers, and despite having higher ESG ratings, they are also more likely to experience environmental fines and incidents than non-contingent debt issuers. Taken together, this evidence suggests that may be worse positioned to deliver green outcomes and more likely to merely portray a positive image, in line with the equilibrium outcome

[6]We capture uncertainty about green outcomes using the emission Scopes 1, 2 and 3 as defined by the GHG Protocol standard, which decrease in the level of measurability/control that a firm has over its emissions inventory. Consequently, a relatively high share of Scope 3 emissions implies a high degree of green outcome uncertainty because this class of emissions cannot be well controlled and measured by the firm. A similar ordering of carbon emissions' scopes according to their level of control can be found in Kacperczyk and Peydró (2022).

of our model with measurement and information frictions which predicts that low-type firms issue contingent green debt contracts.

Furthermore, we also test the model prediction that, as a result of the combined presence of measurement and information frictions, the expected interest rate on contingent contracts should be higher than that of non-contingent green contracts, because investors anticipate that the latter will be issued by lower type firms and thus deliver lower green outcomes in expectation. We empirically test this prediction in the sustainable bond market by measuring the green premium associated with contingent and non-contingent bonds at issuance, where the latter is estimated as the yield differential between a green security and an otherwise equivalent conventional security from the same issuer.[7] Specifically, we pair each of the green securities in our bond sample with a set of conventional bonds from the same issuer and with same coupon type, maturity type, seniority, and currency, as well as similar size and tenor. We document that contingent green securities are much more likely to have callable maturities than non-contingent green securities, in line with evidence by Kölbel and Lambillon (2022); Ul Haq and Doumbia (2022). Importantly, we find that the average green premium on non-contingent bonds is significantly higher than the green premium on contingent bonds, once we control for the fact that the latter are much more likely to have callable maturities than their non-contingent counterparts. The result is in line with the equilibrium prediction of the model with asymmetric information, according to which contingent securities are issued by low-type firms which can profit from manipulating reported green outcomes.

1 Related Literature

Our paper is related to the literature on sustainable investing, which explores the conditions under and channels through which financial markets can catalyze the transition to a sustainable economy.[8] Notable papers in this literature stream include Heinkel, Kraus, and Zechner (2001) who study how exclusionary ethical investing impacts corporate behavior, Pástor, Stambaugh, and Taylor (2021) who study how shifts in customers' tastes for green products and investors' tastes for green holdings produce positive social impact, Oehmke and Opp (2022) who study the conditions

[7]Whereas the contingent bonds category includes sustainability-linked bonds, the types of securities categorized as non-contingent include green bonds, social bonds and sustainable bonds.

[8]There is no consensus on the terminology used to refer to investments that have non-pecuniary benefits. The terms impact, sustainable, responsible, or ESG investing tend to be used interchangeably.

for impact in a context in which investors can relax firms' financial constraints for responsible production, and Landier and Lovo (2020) who study how ESG funds should invest to maximize social welfare in a setup in which financing markets are subject to a search friction. The paper most related to ours in this literature strand is Chowdhry, Davies, and Waters (2019), who also make the case for introducing contingencies in financing contracts. In their model, firms that cannot commit to social goals are jointly financed by profit and socially-motivated investors, and thus face a trade-off regarding which output to emphasize. In contrast to our paper, this paper has an investor focus and an important role is played by the existence and behavior of groups of investors with heterogeneous beliefs and tastes regarding non-pecuniary motives.[9]

Our paper also relates to the empirical literature on corporate GBs, which has by and large sought to rationalize their existence in terms of providing cost of capital benefits. A fairly large literature that aims to estimate the return that investors demand for holding GBs relative to otherwise equivalent conventional bonds, or the so-called green premium, provides mixed evidence. Whereas some studies report evidence in support of the existence of a green premium (Ehlers and Packer, 2017; Kapraun and Scheins, 2019; Baker, Bergstresser, Serafeim, and Wurgler, 2022), studies using tighter methodological approaches do not find any such evidence (Larcker and Watts, 2020; Flammer, 2021). A systematic literature review by MacAskill, Roca, Liu, Stewart, and Sahin (2021) confirms the existence of a green premium within 56% of primary and 70% of secondary market studies, particularly for those green bonds that are government issued, investment grade, and that follow defined green bond governance and reporting procedures. A relatively smaller but growing literature looks into the pricing of sustinability-linked debt, aiming to identify who stands to benefit from the issuance of SLBs (Kölbel and Lambillon, 2022; Ul Haq and Doumbia, 2022; Berrada, Engelhardt, Gibson, and Krueger, 2022) and SLLs (Loumioti and Serafeim, 2022; Carrizosa and Ghosh, 2022; Kim, Kumar, Lee, and Oh, 2022; Du, Harford, and Shin, 2022). We contribute to this literature by being the first to theoretically rationalize the co-existence of contingent debt such as SLBs with non-contingent debt such as GBs (as a result of measurement and information frictions), and by estimating and comparing the green premia associated with these two categories.

[9]Among the relatively fewer works that take a firm perspective there is Ramadorai and Zeni (2021) who document and rationalize corporate commitment to reduce carbon emissions around a regulatory announcement with a strategic model of reputation, and Bolton and Kacperczyk (2021) who provide an empirical analysis of corporate voluntary disclosure initiatives driven by institutional investors.

The economic mechanisms employed in our paper are related to the literature on contract design, and in particular the literature seeking to explain missing contingencies in optimal contracts. Contract theory suggests that optimal contracts should include many contingencies that take account of all relevant information (Hart and Holmström (1987)). A number of papers study various frictions that explain empirically observed departures from this theoretical prediction.[10] The paper most related to ours is Allen and Gale (1992), which uses measurement distortions and adverse selection to explain missing contingencies in optimal contracts in the context of a generic transaction between a buyer and a seller. Our model differs importantly in that firms themselves are not perfectly informed at the time of entering the contract, but receive complete information about their green output only after issuing the security so there is a cost of commitment associated with the non-contingent contract. In Allen and Gale (1992) the contingent contract creates incentives to manipulate so firms pool at the non-contingent contract because it does not reveal any information about the firm type. In our model, the contingent contract does not only create incentive to manipulate but it also offers flexibility, so firms separate with good types choosing the non-contingent to signal their type. Another paper related to ours is Manso, Strulovici, and Tchistyi (2010) who study performance sensitive debt (PSD), a debt instrument whose interest payments varies ex-post with the financial performance of the borrower. When market frictions are limited to tax benefits and bankruptcy costs, PSD is sub-optimal because it leads to earlier default, but when there is asymmetric information between investors and the borrowing firms, PSD is optimally issued by the best (high-growth) firm types as it can be used as an inexpensive screening device. These predictions are markedly different from ours and depend importantly on the assumption that the performance metric underlying the contract is perfectly measurable by the investor and cannot be manipulated.

[10] Holmstrom and Milgrom (1991) explain missing contingencies in employment contracts in a multitask principal-agent context in which the agent allocates limited effort among competing tasks and the principal monitors these tasks with different precisions. Nachman and Noe (1994) study a capital structure problem, and use asymmetric information and adverse selection to explain the optimality of issuing debt as opposed to equity, which map into non-contingent and contingent contracts respectively.

2 The Model

The baseline model features two time periods, an investor, and one firm in the economy. At time $t = 0$, the firm has access to a business-as-usual project which for an input of \$1 yields a certain monetary return of $\$1 + R$ at time $t = 1$. The firm can switch to a greener business model by investing in a green project, which delivers at time $t = 1$ the same monetary return, $\$1 + R$, and an uncertain green outcome, denoted $g(a, \tilde{z})$, which can be conceptualized as a reduction in carbon emissions. The green outcome is modelled as the sum of a predictable and an unpredictable component

$$g(a, \tilde{z}) = a + \sigma \tilde{z}. \tag{1}$$

The predictable component is the firm's costly action choice, a, which captures the firm's effort to deliver the green outcome and can be thought of as the scale of investment on the green project. The unpredictable component is an uncertain state capturing the true potential of the project to deliver a green outcome, which is revealed only to the firm at an interim date between $t = 0$ and $t = 1$. Thus, while the action a encompasses the measurable portion of the outcome that can be verified by the investor, the uncertain state $\tilde{z}$ is the component of the outcome that cannot be observed nor perfectly verified by the investor, and whose realized value can be manipulated by the firm at some cost. The parameter σ controls the degree of uncertainty surrounding the green outcome. The lower this uncertainty parameter relative to the measurable component of the green outcome given by the firm's action choice, the more measurable and easier to control the green outcome is. This specification captures the intuition that although a meaningful expectation about the average green outcome delivered by the project can be formed based on ex-ante information about the scale of the investment, there is still residual uncertainty that will be gradually resolved and contribute to the final green outcome.[11]

The investor's utility at time $t = 1$ is linear in consumption, c, and the green outcome, $g(a, \tilde{z})$. Denoting $x = \{0, 1\}$ the firm's binary choice of whether to implement the green project, investor's

[11]The additive specification implies that the uncertainty regarding the final green outcome is independent of the firm's effort to deliver the outcome, which in turn implies that as the firm's action increases the green outcome uncertainty per unit of action decreases. Put differently, the more the firm invests in a certain green project, the lower the uncertainty about the project outcome. In Appendix C.1 we provide evidence that is in line with this assumption based on detailed data on firms' environmental disclosures from CDP.

utility is[12]

$$\mathcal{U}^I = c + xg(a, \tilde{z}). \tag{2}$$

At time $t = 0$, the investor has deep pockets and access to a risk-free storage technology with return $r < R$. The firm, on the other hand, has monetary preferences only, zero endowments, and incurs a quadratic cost for taking action to produce the green outcome. The firm's utility is

$$\mathcal{U}^f = c - x\frac{\theta}{2}a^2, \tag{3}$$

with θ the action cost parameter. Before introducing the details of the firm's financing problem, it is useful to derive a first-best benchmark given by the choice of a perfectly informed social planner.

2.1 Centralized Problem

We consider the problem of a social planner, indexed by s, which is perfectly informed about the realization of the uncertain state, i.e. $\tilde{z} = z$, and maximizes the aggregate utility of the agents in the economy with respect to the project and action choices

$$\mathcal{U}^s = \max_{x,a} \ \mathcal{U}^I + \mathcal{U}^f = \max_{x,a} R - r + x(g(a, z) - \frac{\theta}{2}a^2). \tag{4}$$

The first-order conditions yield the following optimal project and action choices

$$x^s(z) = \mathbb{1}\{\frac{1}{2}a^s + \sigma z > 0\} \ \text{ with } \ a^s = \frac{1}{\theta}. \tag{5}$$

The first-best project choice depends on the realization of the state variable, z, meaning that it is optimal to wait for uncertainty to be resolved before deciding whether to implement the green project. Conditional on the project being implemented, the first-best level of action decreases with the action cost θ. Given these optimal choices, the social planner's expected utility is

$$\mathbb{E}[\mathcal{U}^s] = R - r + \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z})^+], \tag{6}$$

[12] The utility specification (2) could be modified to explicitly incorporate a green preference parameter η that would scale the green outcome as follows $\mathcal{U}^I = c + x\eta g(a, \tilde{z})$. For the sake of parsimony we normalize this parameter to one, and note that introducing it would only have implications for the intensive margin of the results we document.

where $(\cdot)^+$ yields the term in parenthesis if positive and zero otherwise.

2.2 Decentralized Problem

In the decentralized economy, the firm seeks to maximize utility in (3) by proposing a debt contract to the investor. The structure of a generic debt contract, denoted by y, is one which involves that at date $t = 0$ the investor lends \$1 to the firm, so that the latter can afford the implementation of at least the business-as-usual project, and repays the investor an amount $\$1 + \rho_y$ at time $t = 1$, with ρ_y denoting the interest rate associated with debt contract y.[13] Between time $t = 0$ and time $t = 1$, the firm will decide the optimal project and action choices given the design of the contract issued and its associated characteristics, denoted a_y and x_y, respectively.

The investor's expected utility upon lending via a generic debt contract y is

$$\mathbb{E}[\mathcal{U}_y^I] = \$1 + \mathbb{E}[\rho_y + x_y g(a_y, \tilde{z})], \tag{7}$$

whereas the utility from investing in the alternative storage technology is $\mathcal{U}_r^I = \$1 + r$. The investor is willing to enter the debt contract y at time $t = 0$ provided that $\mathbb{E}[\mathcal{U}_y^I] \geq \mathcal{U}_r^I$, which means that in expectation the interest rate ρ_y and the green outcome financed through the contract y must be higher than the return on the storage technology. This implies that the expected contract-specific interest rate must satisfy

$$\mathbb{E}[\rho_y] \geq r - \mathbb{E}[x_y g(a_y, \tilde{z})]. \tag{8}$$

Thus, the investor's participation constraint gives rise to a minimum interest rate that is a linear function of a fixed component given by the return on the storage technology and a variable component which depends on the green outcome that the green project is expected to deliver. The higher the latter component, the higher the discount relative to the baseline rate represented by the return on the storage technology.

Contract Designs. We restrict our attention to three types of linear debt contract designs that are consistent with the investor's participation constraint (8) and which resemble the ones

[13]It is worth noting that external financing is always profitable in equilibrium i.e. there are no equilibrium outcomes where no debt contract is issued. This is because the business-as-usual project has positive certain monetary return R, the firm has zero endowments at time $t = 0$, and the investor has deep pockets and an alternative storage technology with lower returns $r < R$.

observed in the market. Specifically, we consider a plain vanilla debt security which has a fixed interest rate and does not target a green project or outcome, a non-contingent green security which fixes the interest rate conditional on ex-ante commitment to a green project, and a contingent green security which does not fix the interest rate ex-ante but allows it to vary ex-post with the realization of the green outcome.

Vanilla contract. The non-contingent plain vanilla debt contract, indexed by v, is a standard fixed income security that does not target a green project or outcome, i.e. $x_v = a_v = 0$, and repays the investor a fixed interest rate

$$\rho_v = \bar{\rho}_v. \tag{9}$$

Action-based non-contingent contract. The action-based non-contingent green debt contract, indexed by g, is one that has an interest rate that remains fixed throughout the life of the contract, and thus is said to be non-contingent, conditional on ex-ante commitment to a project and action choice at the moment of issuing the security. The interest rate is given by

$$\rho_g = \bar{\rho}_g - x_g a_g, \tag{10}$$

where $\bar{\rho}_g$ is the baseline interest rate associated with contract g, x_g and a_g are the project and action choices announced by the firm upon entering the contract, which we assume can be perfectly verified by the investor. This is in line with the use-of-proceeds principle underlying non-contingent securities such as GBs, which involves that the issuer commits to use the proceeds for specific projects and places them in a dedicated account that can be verified by the investor. Insofar as actions can be verified because they can be backed out from the cost of investment, $\frac{1}{2}\theta a_g^2$, which is expressed in monetary terms and is thus measurable, ex-ante commitment to action is credible and the expected green outcome is equal to the actual one, $\mathbb{E}[x_g g(a_g, \tilde{z})] = x_g a_g$.[14]

Outcome-based contingent contract. The outcome-based contingent green debt contract, indexed by cg, is one which does not involve ex-ante selection of projects nor commitment to actions, but incentivizes commitment to outcomes by making the interest rate contingent on the realized

[14]In Appendix B.1, we extend the analysis to include a verification cost α that is incurred by the firm in order to make the commitment credible, similar in spirit to the costly state verification literature going back to Townsend (1979). None of the main results change but that specification delivers extra predictions regarding the issuance of vanilla debt securities by firms that are effectively excluded from the green finance market because they do not afford to pay the verification cost.

green outcome instead of fixing it ex-ante. Specifically, the rate varies ex-post with the realized green outcome reported by the firm

$$\rho_{cg} = \bar{\rho}_{cg} - x_{cg} g(a_{cg}, z_r), \tag{11}$$

where $\bar{\rho}_{cg}$ is the baseline interest rate determined at contract issuance, x_{cg} and a_{cg} are the firm's project and action choices conditional on having issued the *cg* security, and z_r is the *reported* uncertain component of the green outcome. Insofar as the realization of the uncertain component, z, is only observed by the firm, we allow for the possibility that its reported value, z_r, may be manipulated. Specifically, we assume that it contains a level of distortion, denoted d, which is optimally chosen by the firm

$$z_r = z + d,$$

where the distortion choice comes at a quadratic cost $\frac{1}{2}\psi d^2$, with ψ the distortion cost parameter.[15]

The interest rate specification in (11) implies that the firm will be rewarded with a lower interest rate if the reported green outcome is positive and vice-versa. This captures the design of existing contracts whereby the issuer is rewarded (penalized) if its sustainability performance is above (below) a predetermined target. Thus, the green outcome in our model should be interpreted as the performance relative to the target, such that failure to reach the target results in a negative green outcome and a interest rate increase, and vice-versa.

Worth noting is that we consider a linear contract design that is continuous in the green outcome, as it follows naturally from the investor's participation constraint in (8), but as detailed in Appendix A.3 most existing contracts have coupon step-ups/step-downs which effectively impose a fixed penalty/reward on the issuer depending on its performance against the target. However, firms are also setting multi-period target horizons and increasingly ambitious targets, which reflect the cumulative nature of negative externalities such as carbon emissions,[16] and a continuous interest-rate specification is an appropriate reduced-form approximation of the type of incentives introduced by such targets. In other words, a continuous specification captures in a static setting

[15] This is similar to the literature on strategic communication with lying costs (Kartik, 2009).

[16] An example of such a contract, is the SLL issued by Ford's Motor Company to JP Morgan in 2019, featuring coupon margin adjustments as a function of the firm's yearly performance against predetermined targets of increasing ambition. Information can be found in the SEC report `https://www.sec.gov/Archives/edgar/data/37996/000003799621000079/exhibit101toseptember29202.htm`.

the dynamic considerations faced by firms in practice.

Importantly, although we take a positive approach in our paper and give the firm a fixed menu of contracts approximating currently existing ones to choose from, we explore in Appendix C.2 the design of an optimal contract which turns out to combine verification of action costs and a contingency on reported green outcomes. These types of contracts are not prevalent in the market, as they may be too costly because they require a considerable level of ex-ante effort in discovering investment opportunities, as well as high monitoring costs throughout the lifetime of the contract.

In what follows, we derive the firm's utility upon issuing the plain vanilla, non-contingent and contingent green contract, $y = \{c, g, cg\}$, assuming a binding investor's participation constraint. We then solve for the optimal contract and discuss the forces and trade-offs driving a firm's choice.

2.2.1 Firm Problem

The *plain vanilla debt contract* is a traditional fixed income contract which does not embed any mechanism to incentivise the delivery of a green outcome. Given that taking action to deliver a green outcome is costly, this contract is affected by a standard moral hazard problem. The investor anticipates that funding provided via this contact will not yield a green outcome, i.e. $\mathbb{E}[g(a_v, \tilde{z})] = 0$, and demands the same monetary return as that associated with the storage technology $\rho_v = \bar{\rho}_v = r$. Therefore, the firm's utility conditional on issuing this contract is

$$\mathcal{U}_v^f = R - r. \tag{12}$$

The *action-based non-contingent green debt contract* is one which involves selecting the project to be financed using the proceeds at security issuance, and thus prior to the realization of the uncertain state affecting the green outcome. Making ex-ante project selection a defining feature of this stylised security is in line with the green bond principles, which require ex-ante specification of the use of proceeds.[17] We assume that the firm commits to a project and action choice, and such commitment is credible as the investor is able to verify the use of proceeds. The baseline interest rate associated with the action-based non-contingent contract is $\bar{\rho}_g = r$, which is obtained

[17]Worth noting is that in practice firms do not always commit to one project but might specify a range of potential projects, so our assumption that the firm commits ex-ante to one project captures commitment in a stark fashion. Allowing for a range of projects would weaken the cost of commitment but would only change our results quantitatively, and the fundamental trade-off and results would remain unchanged.

by substituting the interest rate specification (10) in the investor's participation constraint (8). The firm's utility upon issuing this contract is thus given by

$$\mathcal{U}_g^f = \max_{x,a} \; R - r + x(a - \frac{1}{2}\theta a^2), \tag{13}$$

which yields optimal project and action choices

$$x_g = \mathbb{1}\{\frac{1}{2}a_g > 0\} \;\; \text{with} \;\; a_g = \frac{1}{\theta}. \tag{14}$$

Unlike in the first-best case, the firm's choices are independent of the realized uncertain state, z, and implementing the green project is always optimal if the firm has a feasible green investment opportunity, i.e. $\theta < +\infty$. Provided that the investor has green preferences, available green projects can be financed through the issuance of this contract, which effectively enables the firm to monetize green preferences. The firm's utility given these optimal choices is

$$\mathcal{U}_g^f = \mathcal{U}_v^f + \frac{1}{2\theta}, \tag{15}$$

which is strictly higher than the firm's utility upon issuing the vanilla contract if $\frac{1}{2\theta} > 0$, which is precisely the condition for the implementation of the green project. Thus, the firm has a strict preference for issuing a non-contingent green contract, g, rather than a plain vanilla contract, v, if it implements a green project.

If the non-contingent green debt contract g is issued, the interest rate is $\rho_g = r - \frac{1}{\theta}$ and this is lower than the rate associated with the vanilla contract, $\rho_v = r$, meaning that the investor is willing to pay a green premium which reflects the expected green benefit delivered by the project. This is in line with empirical evidence on the existence of a green premium, namely green bonds having lower yields than their plain vanilla counterparts, which increases with the credibility of the issuer (Baker et al., 2022; Kapraun and Scheins, 2019). Thus, credible commitment resolves the moral hazard problem associated with the vanilla contract and makes possible the implementation of the green project. However, it also gives rise to an opportunity cost of commitment as the firm makes the project and action choices at issuance and thus forgoes the opportunity to wait and learn more about the output potential of the green project before implementing it.

The *outcome-based, contingent green debt contract* makes the cost of debt contingent on the realized green outcome reported by the firm. Thus, the firm does not commit to projects or actions ex-ante, but has the flexibility to choose them ex-post after observing the realization of the uncertain state $\tilde{z}$. This contract is therefore not affected by an opportunity cost of commitment, but insofar as reported green outcomes depend on imperfect measurement systems that can be manipulated, it is affected by a distortion cost.

The firm's problem upon issuing this contract is

$$\mathcal{U}_{cg}^{f} = \max_{x,a,d} \; R - \bar{\rho}_{cg} + x(g(a, z_r) - \frac{\theta}{2}a^2 - \frac{\psi}{2}d^2), \tag{16}$$

where the baseline rate $\bar{\rho}_{cg}$, obtained by substituting the interest rate specification (11) in the binding investor's participation constraint (8), is given by

$$\bar{\rho}_{cg} = r + \mathbb{E}[x_{cg}(g(a_{cg}, z_r) - g(a_{cg}, z))]. \tag{17}$$

Thus, the baseline rate increases in the level of distortion that the firm is expected to introduce. Specifically, at time $t = 0$, the investor rationally anticipates that the reported green outcome might be higher than the actual green outcome, and thus raises the cost of financing for the firm.

The first-order conditions of the firm problem in (16) yield optimal choices

$$x_{cg}(z) = \mathbb{1}\{\frac{1}{2}a_{cg} + \frac{\sigma}{2}d_{cg} + \sigma z > 0\} \text{ with } \; a_{cg} = \frac{1}{\theta} \text{ and } d_{cg} = \frac{\sigma}{\psi}. \tag{18}$$

As it was the case with the first-best, project implementation is conditional on the uncertain state realization, z. Worth noting is that a green project is unambiguously more likely to be implemented when manipulation is possible relative to the case when there is no manipulation. Whereas the firm's optimal action, a_{cg}, decreases with the cost of action, the firm's optimal distortion, d_{cg}, increases with the uncertainty surrounding the project green outcome, σ, and decreases with the distortion cost, ψ. Importantly, the distortion component of the reported green outcome may be optimally larger than the action component if the model parameters satisfy $\theta > \frac{\psi}{\sigma}$, namely if the cost of action is high, the uncertainty regarding the green outcome is high and the cost of distortion is low. This prediction implies that firms can achieve a high reported level of green benefits by manipulating the reported green outcome of projects with a hard-to-assess impact instead of investing in costly projects with a measurable impact. This result speaks to the documented practice of greenwashing, discussed in more detail in the empirical section, which consists of engaging in selective disclosure and manipulative practices in order to inflate perceived sustainability performance.

Given the optimal choices in (18) the firm's expected utility is

$$\mathbb{E}[\mathcal{U}^f_{cg}] = \mathcal{U}^f_v + r - \bar{\rho}_{cg} + \mathbb{E}[(\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z})^+], \tag{19}$$

and the baseline interest rate, assuming that the investor perfectly internalizes the distortion imposed by the firm, is

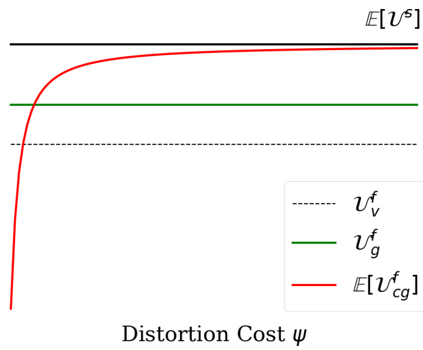
$$\bar{\rho}_{cg} = r + \mathbb{E}[\frac{\sigma^2}{\psi}\mathbb{1}\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} > 0\}]. \tag{20}$$

Note that if the baseline rate satisfies $\bar{\rho}_{cg} = r$, then the firm's utility from issuing the contingent contract *cg* to finance the green project is strictly higher than the utility achieved from issuing the non-contingent contract g. However, if manipulation is expected the baseline rate $\bar{\rho}_{cg}$ will be higher than r, and the investor is said to impose a *distortion discount* on the pricing of the contingent debt contract which can render it inferior relative to the non-contingent one. This distortion discount reflects investor's belief about the future level of manipulation, with the implication that the pricing of this contract depends on the investor's information about the firm's action and manipulation costs at issuance, an important difference relative to the other contracts.

In the remainder of this section, we solve for a firm's optimal contract choice assuming perfect information. In the next section, we introduce a continuum of firm types that differ with respect to the cost of action and distortion that they face, and allow for asymmetric information about firms' types as we solve for equilibrium issuance choices across firms.

Figure 2 shows the firm's utility associated with each contract $y = \{v, g, cg\}$, as well as the social planner's utility in the first-best, as a function of the distortion cost ψ. Note that the plain vanilla contract, v, is never an optimal contract for financing green projects. When distortion costs are very low the non-contingent green contract, g, adds value with respect to the vanilla by correcting the moral hazard problem, and it is also better than contingent green contract, *cg*, because the

Figure 2. Comparative Statics - Distortion Cost
The plot shows the firm utility upon issuance of the contracts $y = \{v, g, cg\}$ in black dashed line, green line and red line respectively as a function of the distortion cost ψ comparing it with the first best social planner utility in (6) (black thick line). Model parameters are $\theta = 0.5, \sigma = 5, R = r = 0$.



rational investor will anticipate a high level of manipulation and impose a high distortion discount on the pricing of the cg contract. On the other hand, when the distortion cost is very high, so that the reported green outcome cannot be manipulated, the contingent contract cg strictly dominates the non-contingent one g and achieves the first-best. Formally, we introduce the following

PROPOSITION 1. *For a given set of model parameters* $(\theta, \sigma) \in (0, \infty)$, *and* $R > r > 0$ *we have the following:*

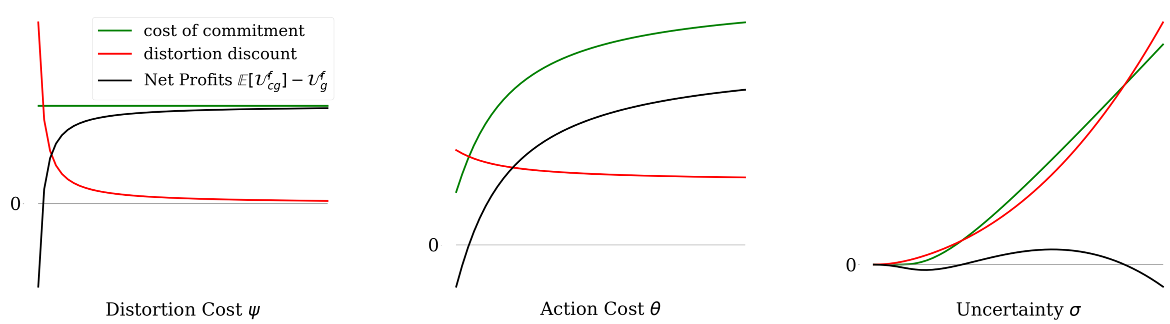
- *If* $\psi = +\infty$ *such that manipulation is not possible, then* $\bar{\rho}_{cg} = r$ *and issuing the contingent contract cg is always optimal and achieves the first-best.*
- *If* $\psi = 0$, *the expected level of manipulation is such that* $\bar{\rho}_{cg} = +\infty$ *and issuing the contingent green debt contract cg is never optimal.*

Proposition 1 sheds light on the evolution of the corporate sustainable debt market. Specifically, it explains the initial dominance of GBs in terms of the absence of reliable measurement systems which characterized the early stages of the market. GBs emerged as the unique viable way to respond to an emerging demand for pro-environmental outcomes driven by investors' green preferences, at a time when the measurement of these outcomes was particularly difficult. If measurement systems were highly precise such that no manipulation was possible, the model predicts that contingent contracts such as SLBs would be unambiguously optimal but in practice we have not seen these being issued until very recently. The current market environment, characterized by improving measurement systems and illustrated in the intermediate region of Figure 2, is one in which a firm's preference for issuing a contingent rather than a non-contingent security depends on the other variables faced by it. To understand how the forces driving such preference depend on the model parameters, let us decompose the firm's net profits from issuing a contingent rather than a non-contingent green contract as follows

$$\mathbb{E}[\mathcal{U}^f_{cg}] - \mathcal{U}^f_g = \underbrace{(\mathbb{E}[\mathcal{U}^s] - \mathcal{U}^f_g)}_{\text{cost of commitment}} - \underbrace{(\mathbb{E}[\mathcal{U}^s] - \mathbb{E}[\mathcal{U}^f_{cg}])}_{\text{distortion discount}}, \tag{21}$$

with $\mathbb{E}[\mathcal{U}^f_{cg}]$ and $\mathcal{U}^f_g(k)$ denoting the firm's expected utility in (19) and (15), respectively, and $\mathbb{E}[\mathcal{U}^s]$ denoting the social planner's utility in (6). Thus, the green financing contract optimally issued by the firm depends on an active trade-off between the opportunity cost of commitment associated with the non-contingent green contract g, which arises as a correction for moral hazard, and the distortion discount associated with the contingent green contract cg, which arises because green outcomes can be manipulated.

Figure 3. Comparative Statics - Components of the Trade-Off
The plots show the firm's expected net profits in (21) (black thick line) along with the commitment cost component (dashed black line) and the distortion cost component (dotted black line) as a function of the key model parameters. The parameter values are $\psi \in [2, 80]$, $\sigma = 3$, $\theta = 3$ (left plot), $\theta \in [0.5, 50]$, $\psi = 3$, $\sigma = 1$ (mid plot), and $\sigma \in [0, 2.5]$, $\theta = 1$, $\psi = 3$ (right plot).



As illustrated in Figure 3, the net profits in (21) increase monotonically with the cost of distortion ψ, due to a declining distortion discount (left plot), and they increase monotonically in the action cost θ, due to an increasing cost of commitment (mid plot). On the other hand, the net profits from issuing the contingent green contract cg are non-monotonic in the uncertainty surrounding the green outcome, σ, as shown in the right plot in Figure 3. Intuitively, high levels of uncertainty result in a high distortion discount which makes the issuance of the contingent contract cg contract unprofitable, whereas low levels of uncertainty result in a low cost of commitment which makes the non-contingent contract c relatively more appealing. Technically, this is due to the fact that the distortion discount is convex in uncertainty σ, whereas the opportunity cost of commitment is first convex and then concave in uncertainty σ. The distortion discount is convex in uncertainty because the expected level of distortion is quadratic in σ, as shown in (20).[18] The cost of commitment is convex in uncertainty for low values of uncertainty because the green outcome is mainly driven by firm's action choice and an increase in uncertainty increases the value of the option to wait in the standard quadratic manner (Dixit and Pindyck, 1994). However, as uncertainty increases the green outcome becomes increasingly decoupled from the firm's costly action and the expected benefits from manipulation increase, inducing an eventual decrease in the cost of commitment. This non-linear commitment cost dynamic is the main driver behind the non-monotonicity result.

The single-firm analysis with perfect information is useful to understand the key forces but in what follows we extend the model to a multi-firm setup to understand the conditions for the observed co-existence while allowing for information frictions.

3 Green Financing in Equilibrium

We extend the model to a multi-firm setting by introducing the notion of firm types which are differentiated with respect to the cost of action and the cost of distortion they face. Specifically, we assume that there is a continuum of firm types, k, drawn from a uniform distribution, $k \sim \mathcal{U}[0,1]$, with action and distortion costs

$$\theta_k = \theta \frac{1}{k} \quad \text{and} \quad \psi_k = \psi \frac{1}{1-k}. \tag{22}$$

This assumption implies that the highest-type firm, $k = 1$, has infinite distortion cost and therefore does not manipulate reported outcomes, while the lowest-type firm, $k = 0$, has infinite

[18] This follows from our assumption that the cost of distortion is independent of uncertainty, which implies that it is equally costly to manipulate all outcomes and as a consequence distortion is more likely the more uncertain an outcome is. An alternative specification in which distortion costs increase linearly in uncertainty, which implies that it is more costly to distort more uncertain outcomes, does not affect qualitatively the predictions of the model.

action cost and therefore cannot deliver any green outcome in expectation. Similar in spirit to Allen and Gale (1992), who consider a generic setup involving consumption goods and financial reporting, we assume that the ability to distort reported outcomes is *negatively correlated* with the ability to deliver the outcomes in the first place. This assumption plays an important role in deriving the equilibrium results that follow and captures the idea that it is firms that do not have systems in place to measure green outcomes that: 1) have leeway to misreport or manipulate, meaning they have a low cost of distortion; and 2) are less likely to take action to deliver green outcomes, meaning they have a high cost of action. The assumption is implicit in the definition that the Environmental Protection Agency (EPA) gives to an Environmental Management System (EMS), namely

> *"[..] a framework that helps an organization achieve its environmental goals through consistent review, evaluation, and improvement of its environmental performance. The assumption is that this consistent review and evaluation will identify opportunities for improving and implementing the environmental performance of the organization."*

The idea that the adoption of an EMS predicts future capacity to deliver pro-environmental outcomes is also in line with recent survey evidence[19] that firms with better green management practices are not only more informed and able to measure and monitor their environmental performance, but are also more likely to take action to deliver such performance. Furthermore, Lyon and Maxwell (2011) show that firms which are more informed about their environmental performance are less likely to manipulate reported outcomes. All this lends support to our assumption that a firm's propensity to take costly action is negatively related to its propensity to manipulate.

We first solve for an equilibrium where the investor is perfectly informed about the firm type k, and then solve for a signalling equilibrium in which the investor only knows the distribution of firm types, $k \sim \mathcal{U}[0, 1]$, at issuance. In light of investor's green preference, it suffices to assume that the firm has a feasible green project, i.e. $\theta < +\infty$, in order to render the vanilla contract inferior and allow us to focus on the firm's choice between the contingent and non-contingent green contracts. The full equilibrium which considers choices among all contract types as well as issuance costs is

[19] The survey, conducted by the Bank of International Settlements (BIS) can be found at `https://www.eib.org/en/publications/european-firms-and-climate-change-2020-2021`. Some key insights are that firms that implement better green management practices set clear climate targets, conduct energy audits, and invest in energy efficiency almost twice as much as firms without these priorities.

outlined in Appendix B.1.

3.1 Perfect Information

Denote the net profits from issuing the contingent green security, cg, relative to the non-contingent green security, g, for a firm of type k as

$$\Pi_{cg}(k) = \mathbb{E}[\mathcal{U}^{f}_{cg}(k)] - \mathcal{U}^{f}_{g}(k), \quad k \in [0,1], \tag{23}$$

with $\mathbb{E}[\mathcal{U}^{f}_{cg}(k)]$ and $\mathcal{U}^{f}_{g}(k)$ denoting the firm's utility in (19) and (15), respectively, evaluated at the cost of action $\theta = \theta_k$ and the cost of distortion $\psi = \psi_k$ defined in (22).

Figure 4. Green Financing Trade-Off Across Types
The left plot shows the firm's net expected profits from issuing a contingent rather than a non-contingent green contract (equation (23)) as a function of the firm type k (y-axis) for three different values of the distortion cost $\psi = 1.4$ (thick line), $\psi = 2.1$ (dotted line) and $\psi = 10$ (dashed line), respectively. The other model parameters are $\theta = 0.2$, $\sigma = 2$. The right plot shows the optimal equilibrium issuance choice as a function of uncertainty σ (x-axis) and firm type k (y-axis) for $\theta = 1.0$ and $\psi = 0.5$.

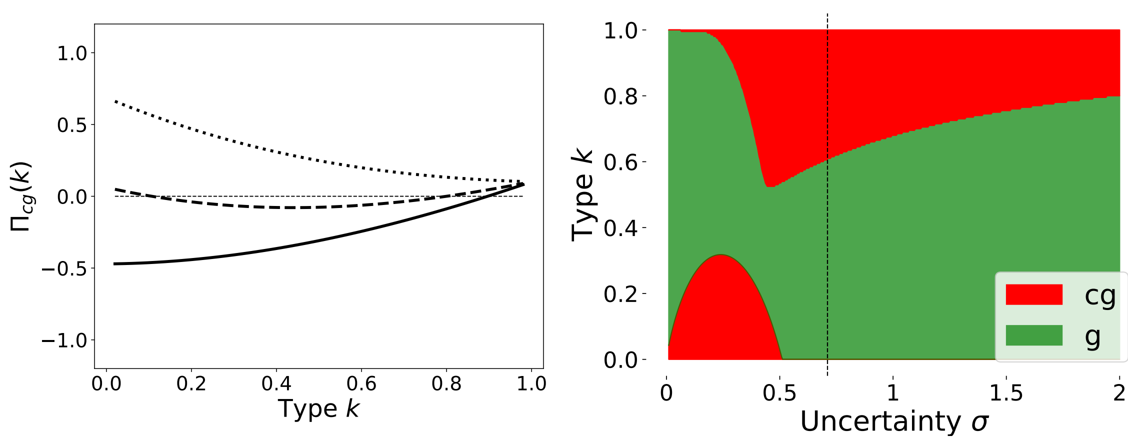


Figure 4, left plot, shows how the net profits in (23) vary as a function of the firm type k for different levels of distortion cost ψ. The net profits from, and thus preference for, issuing the contingent green contract are monotonically decreasing across firm types when the distortion cost is high, increasing when the distortion cost is low, and can be non-monotonic (u-shaped) for intermediate values of distortion cost. The intuition behind this is that when distortion is costly, the main driver behind a type-k firm's preference for the contingent contract cg is the opportunity cost of ex-ante commitment associated with the non-contingent contract g. This commitment cost decreases monotonically in the type k as the cost of action θ_k decreases, making the contingent contract cg progressively less appealing for the higher firm types. On the other hand, when the cost of distortion is low, the main driver is the distortion discount, which decreases with the firm type k as the cost of distortion ψ_k increases, making the contingent contract cg progressively more appealing for the higher firm types. For intermediate value of distortion cost, intermediate-type firms have a preference for the non-contingent green contract g, whereas low- and high-type firms prefer the contingent green contract cg because of the high distortion discount and the high opportunity cost of commitment, respectively. We prove in Appendix B the following:

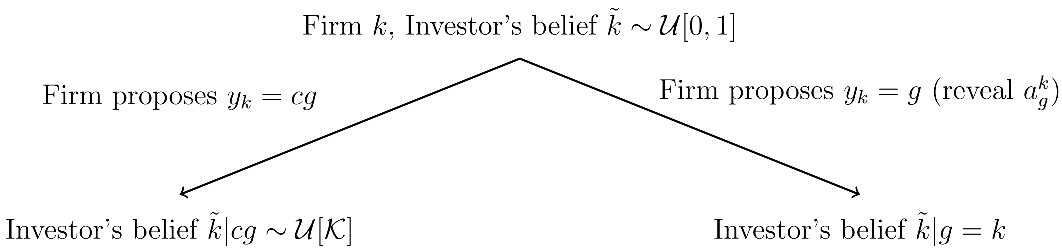
PROPOSITION 2. *For any given pair of action and distortion costs* $(\theta, \psi) \in (0, \infty)$*:*

- *if* $\sigma > \sqrt{\psi/\theta}$*, there exists a unique cutoff firm type* $\bar{k} \in [0, 1]$ *such that the types* $k \in [\bar{k}, 1]$ *issue the contingent contract* cg*, whereas the types* $k \in [0, \bar{k})$ *issue the non-contingent contract* g*.*
- *if* $\sigma < \sqrt{\psi/\theta}$*, there exist two firm types* $0 \leq \underline{k} \leq \bar{k} \leq 1$ *such that the types* $k \in [0, \underline{k}]$ *and* $k \in [\bar{k}, 1]$ *issue the contingent contract* cg*, whereas the types* $k \in (\underline{k}, \bar{k})$ *issue the non-contingent contract* g*.*

Importantly, the proposition implies that the highest firm types *always* issue the contingent contract in this equilibrium with perfect information. This is illustrated in the right plot of Figure 4, which shows the regions in which contingent contracts cg (in red) and non-contingent contracts g (in green) are optimally chosen across firm types k for different values of the project outcome uncertainty σ. The dashed black line is where the uncertainty takes the value $\sigma = \sqrt{\psi/\theta}$. In line with Proposition 2, when uncertainty is large enough then higher types are unambiguously more likely to issue the contingent contract cg. Also worth noting is that the firms' propensity to issue a contingent contract (i.e. the fraction of types $k \in [0, 1]$ issuing a contingent contract cg) is non-monotonic as a function of the uncertainty σ, which suggests that contingent green debt is more likely to be issued by firms managing green projects with an intermediate degree of green outcome uncertainty.

3.2 Asymmetric Information

We now derive the equilibrium financing choices assuming asymmetric information between the investor and the firms. Specifically, we assume that the investor cannot observe the atomistic firm type k but only knows that it is drawn from the uniform distribution $\mathcal{U}[0,1]$. In this setup, the firm's financing choice will signal information about its type to the investor. The graph below summarizes the signalling game for a firm that is evaluating the best among the available green debt contracts. The first mover is the firm, which can belong to a continuum of types $k \in [0,1]$ and has two financing strategies, namely to issue a contingent green or a non-contingent green debt contract, $y_k = \{cg, g\}$. The second mover is the investor, which has prior beliefs over the firm's type given by the distribution function $\tilde{k} \sim \mathcal{U}[0,1]$.[20]



When a firm of type k proposes a non-contingent contract, g, it also credibly commits to a costly action choice, denoted a_g^k, thus allowing the investor to perfectly infer the firm's type at issuance and update its prior belief from a distribution to an atomistic type $\tilde{k}|g = k$. On the other hand, when the firm proposes a contingent contract, cg, it does not provide any type-revealing information at issuance. In such a case, the investor can only update her prior based on the set of firms issuing the contingent green contract, denoted $\mathcal{K} := \{k \in [0,1] \; s.t. \; y_k = cg\}$. Thus, posterior beliefs about a firm's type conditional on it having issued the contingent green contract are $\tilde{k}|cg \sim \mathcal{U}[\mathcal{K}]$, with the implication that each firm $k \in \mathcal{K}$ will be charged an average, group-specific baseline interest rate of the form

$$\bar{\rho}_{cg}^{\mathcal{K}} = \mathbb{E}[\bar{\rho}_{cg}^{k} | k \in \mathcal{K}], \tag{24}$$

instead of the type-specific interest rate $\bar{\rho}_{cg}^{k}$ obtained by plugging ψ_k and θ_k into (20). With asymmetric information, the net profits from issuing a contingent rather than a non-contingent

[20] Note that in principle, the investor also has two strategies, which is to either buy or refuse the proposed contract y_k. However, since for the firm is a strictly dominant strategy to issue at least one contract among $\{g, cg\}$ (because $\min\{\mathcal{U}_g^f(k), \mathbb{E}[\mathcal{U}_{cg}^f(k)]\} \geq R - r > 0$), we can already exclude an equilibrium outcome where the investor refuses the contract and focus on the simplified signalling game described in the graph.

contract can thus be written as

$$\Pi_{cg}^{\mathcal{K}}(k) = \Pi_{cg}(k) - (\bar{\rho}_{cg}^{\mathcal{K}} - \bar{\rho}_{cg}^{k}), \tag{25}$$

with $\Pi_{cg}(k)$ the net profits in (23). From the expression in (25), one can intuitively anticipate that asymmetric information skews preferences for issuing the contingent contract towards lower firm types. This is because the baseline interest rate increases with the expected level of distortion, and the latter decreases with the firm type k. Hence, lower firm types that are below the average type in group $\mathcal{K}$ would benefit from a baseline group-specific interest rate that is lower than what they would be charged if their type was known, i.e. $\bar{\rho}_{cg}^{\mathcal{K}} < \bar{\rho}_{cg}^{k}$, resulting in higher profits. On the other hand, higher firm types that are above the average type in group $\mathcal{K}$ would be charged a higher rate than in the benchmark case with perfect information, i.e. $\bar{\rho}_{cg}^{\mathcal{K}} > \bar{\rho}_{cg}^{k}$, resulting in lower profits. By issuing the contingent green contract cg, higher types contribute to lowering the average group-specific baseline rate, $\bar{\rho}_{cg}^{\mathcal{K}}$, and are effectively subsidising lower types. Anticipating this, high-type firms will opt out of this market and it is low-type firms that are more likely to issue the contingent green contract cg.

Following this line of reasoning, we can look for an equilibrium set of issuers of the form $\mathcal{K}^* = [0, k^*)$, with $k^* \in (0, 1)$ an equilibrium cutoff type verifying $\Pi_{cg}^{\mathcal{K}^*}(k^*) = 0$. The existence of such an equilibrium relies on the verification of the *single-crossing* property

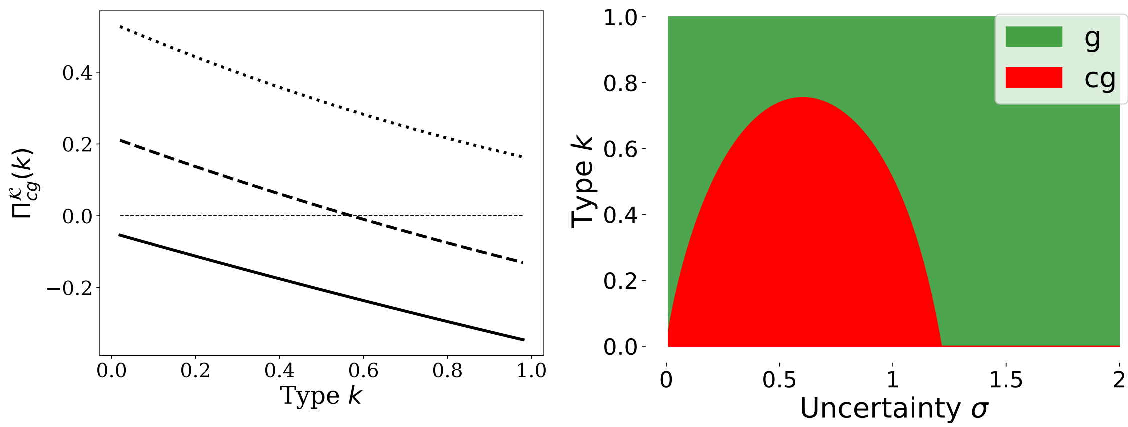
$$\frac{\partial}{\partial k}\Pi_{cg}^{\mathcal{K}}(k) < 0 \quad \text{for} \quad k \in [0, 1], \tag{26}$$

which states that the net gains from issuing the contingent green contract are monotonically decreasing in the firms' type k.[21] This is illustrated in the left plot of Figure 5, which shows how the net profits in (25) vary as a function of the type k for different levels of distortion cost ψ. Independently of the distortion cost specification, net profits monotonically decrease across types, implying that asymmetric information tilts preferences for contingent contracts towards low-type firms. Note however that when the distortion cost is are high all firms issue the contingent contract, when it is low all firms issue the non-contingent contract, while for intermediate values a separating

[21] As outlined in Mailath (1987), the single-crossing property is necessary and sufficient for the existence of a (semi-) separating Bayesian equilibrium in a case where the first mover has continuum one-dimensional types.

Figure 5. Green Financing Trade-Off Across Types

The left plot shows the firm's net expected profits from issuing a contingent rather than a non-contingent green contract (equation (25)) as a function of the firm type k for three different values of the distortion cost, namely $\psi = 1.4$ (thick line), $\psi = 2.1$ (dotted line) and $\psi = 10$ (dashed line). The other model parameters are $\theta = 0.5$, $\sigma = 1.5$. The right plot shows the optimal equilibrium issuance choice as a function of uncertainty σ (x-axis) and firm type k (y-axis) for $\theta = 1.0$ and $\psi = 1.2$.



equilibrium exists.[22] More formally, we prove in Appendix B the following

PROPOSITION 3. *For any set of model parameters* $(\psi, \theta, \sigma) \in (0, +\infty)$*, the single-crossing condition* (26) *is satisfied for any* $k \in [0, 1]$ *and the following equilibria are possible:*

- *all types* $k \in [0, 1]$ *issue a non-contingent green contract,* g*, if* $\Pi_{cg}^{\mathcal{K}^*}(0) < 0$*;*
- *all types* $k \in [0, 1]$ *issue a contingent green contract,* cg*, if* $\Pi_{cg}^{\mathcal{K}^*}(1) > 0$*;*
- *otherwise there exists a cutoff type* $k^* \in (0, 1)$ *verifying* $\Pi_{cg}^{\mathcal{K}^*}(k^*) = 0$ *such that all types* $k \in [k^*, 1]$ *issue the non-contingent green contract* g*, whereas the remainder* $k \in [0, k^*)$ *issue the contingent green contract* cg*.*

Proposition 3 states that, if there exists a separating equilibrium, then higher-type firms are the ones issuing the non-contingent contract g, whereas lower firm types are those issuing the contingent contract cg. This is because issuing a non-contingent green contract allows the high-type firms to differentiate themselves from the group of those that would be better off keeping their types private by effectively allowing them to correctly reveal their action choice through credible commitment. On the other hand, firms issuing a contingent contract internalize the fact that the

[22]The assumption that action costs are higher when manipulation costs are lower, combined with the specification of the green outcome as the sum of a measurable and manipulable component, allow for the monotonicity condition in (26) to be easily verified and for the separating equilibrium to exist.

investor will impose a group-specific distortion discount that averages across all firms issuing this type of contract, with the implication that high-type firms will exclude themselves from this market. The right plot of Figure 5 captures this intuition and depicts the equilibrium contract chosen across firm types k as a function of the project uncertainty σ, when the investor is imperfectly informed about firm types $\tilde{k} \sim \mathcal{U}[0,1]$. Similarly to the perfect information equilibrium, projects with an intermediate level of uncertainty are more likely to be financed through contingent green contracts, a first important prediction of the model that we will test in the following empirical section. From Proposition 3, we prove in Appendix B the following

COROLLARY 1. *If the investor is asymmetrically informed about the firm type and the manipulation cost ψ is sufficiently low, then for any set of model parameters $(\sigma, \theta) \in (0, +\infty)$, the following inequality holds*

$$\int_0^{k^*} (\mathbb{E}[\rho_{cg}^{\mathcal{K}^*}(k)] - \rho_v)dk > \int_{k^*}^1 (\rho_g(k) - \rho_v)dk \tag{27}$$

with $\rho_g(k) = \bar{\rho}_g - x_{cg}^k a_{cg}^k$, $\rho_{cg}^{\mathcal{K}^*}(k) = \bar{\rho}_{cg}^{\mathcal{K}^*} - x_{cg}^k g(a_{cg}^k, z_r)$, $k^* \in (0,1)$ the equilibrium cutoff type and $\mathcal{K}^* = [0, k^*]$.

The corollary provides a second testable prediction stating that, on average, the combined presence of measurement and information frictions results in the average interest rate differential between contingent green contracts and vanilla contracts being higher than that between non-contingent green contracts and vanilla contracts. Inequality (27) is generally not verified in absence of measurement or information frictions, motivating the empirical exercise in the last section, where we estimate and compare the magnitude of the so-called green premium associated with contingent bonds to that associated with non-contingent bonds.

4 Empirical Testing

In this section, we test the theoretical prediction of the model by combining securities issuance data from Bloomberg with data on issuers' characteristics and carbon emissions from S&P Trucost, as well as sustainability performance data from Sustainalytics.

4.1 Data

We compile the dataset of securities on the corporate sustainable debt market using Bloomberg's fixed income search by screening for green bonds (GB), green loans (GL), social bonds (SocB) and sustainable bonds (SustB), as well as for sustainability-linked bonds (SLB) and loans (SLL) issued between January 2013 through February 2022.[23] We jointly refer to these securities on the corporate sustainable debt market as *green securities*. Within our sample period, a total of 11,669 green securities have been issued by the corporate sector, of which 5,944 bonds (including GB, SocB, SustB and SLB), and 5,725 loans (including GL and SLL).

Table 1. Security Characteristics
The table shows summary statistics on corporate bonds (panel A) and loans (panel B) issued between January 2013 and February 2022. Non-Contingent bonds include green bonds (GB), social bonds (SocB), and sustainable bonds (SustB), Contingent bonds include sustainability-linked bonds (SLB). Non-Contingent loans include green loans (GL), Contingent loans include sustainability-linked loans (SLL). We also report for reference statistics for the entire universe of corporate bonds and loans issued over the sample period, under the column Conventional; the latter are collected from the Bloomberg terminal.

Panel A: Bonds	**Non-Contingent**	**Contingent**	**Conventional**
Variable	**Mean**	**Mean**	**Mean**
Amount Issued ($ mil)	252	478	100
Coupon Rate (%)	2.5	2.4	4.1
Maturity (years)	7.1	7.2	3.2
Is Bond Callable (%)	21.9	52.3	9.4
Private Company (%)	69.1	54.2	78.1
No. Securities	5,520	424	1,157,316

Panel B: Loans	**Non-Contingent**	**Contingent**	**Conventional**
Variable	**Mean**	**Mean**	**Mean**
Loan Tranche Size ($ mil)	131	633	330
Coupon Rate (%)	3.1	2.1	4.5
Maturity (years)	16.3	7.4	8.4
Is Loan Revolving (%)	8.9	54.0	25.9
Private Company (%)	93.3	56.4	77.9
No. Securities	4,453	1,272	119,002

Table 1 reports broad statistics on these green bonds and loans, comparing them with the universe of conventional corporate bonds and loans in Bloomberg. We find that both contingent

[23]Specifically, we consider the corporate bonds and loans for which the field "Green Instruments Indicator", "Social Instrument Indicator", "Sustainability Instrument Indicator", "Sustainability Linked Bond / Loan Indicator" is "Yes". We exclude securities with issuers for which Bloomberg Industry Classification System (BICS) is equal to "Government", as those issuers include development banks and supranational entities which qualify as corporate due to their private status but are not corporations in a traditional sense.

and non-contingent bonds (panel A) are larger in size, have a lower coupon rate, longer maturity, and are less likely to be issued by private corporations relative to conventional bonds (in line with earlier evidence by Baker et al. (2022)). Interestingly, contingent bond issuers have considerably lower credit ratings compared to both non-contingent green and conventional bond issuers, as shown in Figure 7 in Appendix A.2.

Contingent and non-contingent bonds are similar in terms of coupon rates and maturities, but contingent bonds seem larger in size and are less likely to be issued by private corporations than non-contingent bonds. Furthermore, contingent bonds are significantly more likely to be callable than their non-contingent counterparts, an aspect also stressed by Ul Haq and Doumbia (2022) who study SLBs. Moving on to loan securities (panel B), we find that non-contingent green loans are smaller in size, have longer maturities, are less likely to be of the revolving type and more likely to be issued by private corporations than both contingent green and conventional loans. On the other hand, in line with Carrizosa and Ghosh (2022), we find that contingent loans are much larger in size than both non-contingent green and conventional loans, and are more likely to be issued by public corporations and to be of the revolving type.[24] Contingent loans have the lowest interest rate and a maturity similar to that of ordinary loans.

We construct the security-issuer panel dataset by matching the security information from Bloomberg with issuers' balance sheet information from Standard & Poor (S&P) and carbon emissions data from S&P Trucost. The S&P Trucost database provides quality-checked carbon emissions data differentiating between Scope 1, Scope 2, and Scope 3 emissions as defined by the GHG Protocol Standard.[25] We are particularly interested in carbon emissions data and related environmental metrics as those are the most popular metrics to which contingent bonds and loans are linked, as reported in Table 6 in Appendix A.1.[26] We also include Environmental, Social, and Governance (ESG) performance ratings in the analysis by matching the firms in the Bloomberg/S&P Trucost

[24]Related to this fact, it is worth mentioning that approximately 20% of the SLLs included in the contingent loan category were issued as ordinary or green loans, and then later linked to a metric of sustainability performance. The issue date for these securities is the date at which they have been converted to SLLs.

[25]The GHG Protocol Corporate Accounting and Reporting Standard provides requirements and guidance for companies and other organizations preparing a corporate-level GHG emissions inventory and breaks down emissions into three categories called scopes. Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain.

[26]Table 6 in Appendix A.1 shows that 64% of the sustainability performance targets (SPTs) underlying contingent debt securities are environmental metrics, of which 44% are GHGs emissions, a clear evidence of the centrality of climate change with respect to other sustainable issues.

panel dataset with Sustainalytics data. Sustainalytics is the most popular ESG rating provider for contingent loans and bonds written in ESG scores, as reported in Table 6 in Appendix A.1. The merged dataset is an unbalanced panel of 1,197 unique firms, of which 731 with ESG ratings; out of these firms, 836 have issued non-contingent debt, 399 contingent debt and 38 have issued both. In terms of securities issued, our sample of firms has issued a total of 3,495 green securities between 2013 and 2021, where 831 are categorised as contingent and the remainder as non-contingent green securities. Appendix A.1 provides additional details about the merging process and the resulting panel dataset.

Table 2 reports summary statistics on the issuers of green securities, comparing them with the representative firm in S&P Trucost. From a financial perspective, the average issuer of green securities is larger, has higher leverage, is more profitable and more capital intensive than the average firm in S&P Trucost. From an environmental perspective, the average issuer of green securities has higher emissions (consistently with the larger size), is more likely to self-report its emissions, and has a higher ESG rating than the average firm in S&P Trucost with available ESG scores.

Focusing on the distinction between contingent and non-contingent green debt issuers, we note that the former are considerably smaller[27], are less profitable, but have a marginally higher revenue. From an environmental perspective, contingent green debt issuers have much higher absolute emissions and emission intensity, despite their smaller size. Trucost also estimates total damage costs which capture the environmental impact of a firm's activity in monetary terms, and reports impact ratios which normalize damage costs relative to revenues.[28] Consistently with their higher absolute emissions and emissions intensity, the impact ratio of contingent debt issuers is much higher than that of non-contingent issuers, which in turn is similar to that of the average firm in S&P Trucost. This evidence suggests that issuers of contingent debt are more exposed to environmental risk and therefore stand to benefit most from an improved environmental performance, but they also face a higher cost for reducing their environmental impact.

[27] The size difference is mostly driven by industry effects and specifically by the fact that large banks are popular issuers of non-contingent green securities such as GBs, as we will show later in the section. Also worth nothing is the large variability that exists in this sample, as indicated by the standard deviation of assets.

[28] The impact ratio "*quantifies the percentage of a company's annual earnings at risk should the company be held accountable for the negative environmental impacts*". It is obtained by taking a company's total damage cost and dividing it by their total revenues for the same financial year.

Table 2. Issuers Characteristics

The left and middle columns refers to green security issuers from our Bloomberg/S&P Trucost merged dataset, making a distinction between issuers of Non-Contingent debt (including GB, GL, SocB and SustB) and Contingent debt (including SLL and SLB). The right column is the universe of firms in S&P Trucost. PPE stands for property, plant and equipment. Emissions intensity measures emissions over revenues, and the Impact Ratio measures the cost of direct and indirect GHG provided over revenues. Self-Disclosure measures how much of emissions are disclosed by the firm relative to what is obtained from other sources. The variable Controversies sums the variables Operations Related Controversies, Products and Services Controversies, Customer Incidents and Controversies, Employee Related Controversies, Society & Community Controversies, Governance Related Controversies, Public Policy Related Controversies and Business Ethics Controversies reported in Sustaynalitics. All variables are winsorized between the 5^{st} and the 95^{th} percentiles of the pooled distribution. $^{+}$indicates that variables are available for a subset of the sample each year.

	Non-Contingent	**Contingent**	**Trucost**
Variable	**Mean (Std. Dev.)**	**Mean (Std. Dev.)**	**Mean (Std. Dev.)**
Total Assets ($ bn)	123.05 (228.03)	32.75 (87.49)	5.94 (11.09)
Revenues ($ bn)	9.94 (15.53)	10.68 (15.41)	1.77 (3.11)
EBIT to Revenues Ratio	0.47 (0.61)	0.22 (0.31)	0.16 (1.31)
Debt to Assets Ratio	0.35 (0.18)	0.34 (0.17)	0.25 (0.34)
PPE to Assets Ratio	0.35 (0.35)	0.37 (0.28)	0.24 (0.24)
Intangible Assets Ratio (%)	0.05 (0.10)	0.15 (0.16)	0.09 (0.15)
Emissions (mil tCO2e)	7.55 (15.25)	13.83 (20.48)	1.70 (3.59)
Emission Intensity (tCO2e/$)	786.01 (1,183.89)	1,140.89 (1,239.11)	756.59 (1,237.65)
Impact Ratio	1.74 (3.08)	2.38 (2.75)	1.23 (1.55)
ESG Score^{+}	64.86 (10.21)	67.46 (10.21)	57.18 (9.61)
Self-Disclosure Emissions^{+}	68.88 (44.62)	88.59 (29.93)	27.21 (43.72)
Environmental Fines and Sanctions^{+}	0.65 (0.27)	0.75 (0.33)	0.78 (0.33)
Environmental Supply Chain Incidents^{+}	2.00 (0.86)	2.42 (0.69)	2.43 (0.90)
Social Supply Chain Incidents^{+}	1.89 (0.79)	2.47 (1.02)	2.80 (1.31)
Controversies^{+}	32.69 (3.96)	31.65 (3.29)	32.66 (3.30)
No. Unique Firms	836	399	23,652

On the sustainability performance side, contingent debt issuers have marginally higher ESG scores and are significantly more likely to disclose their emissions, which is somehow expected given that most of the SLBs/SLLs issued are written on environmental metrics. They are less likely to experience general controversies compared to issuers of non-contingent debt, but they have more environmental fines and sanctions, as well as more environmental and supply chain incidents. Thus, despite portraying a positive ESG imagine, they experience more objective[29] negative events as far as their environmental behaviour is concerned.

Taken together, this evidence indicates the contingent debt is currently issued by firms that are in a relatively worse position to deliver green outcomes and have experienced incidents typical of irresponsible environmental behaviour despite portraying a favourable environmental imagine. While a firm's type cannot be identified with precision, the evidence is in line with an equilibrium

[29]For example, an environmental fine is a more unequivocal signal of corporate irresponsibility than an environmental controversy.

outcome with asymmetric information in which contingent debt contracts are issued by low-type firms with a high cost of action and a low cost of distortion.

It is important to note that our evidence is merely suggestive and based on descriptive statistics that do not control, for example, for industry effects. However, a number of studies provide rigorous evidence that is consistent with the idea that the corporate sustainable debt market is affected by information fictions and greenwashing. Loumioti and Serafeim (2022) document that the targets and pricing adjustments embedded in SLLs are largely independent of the ESG risk profile of the issuers.[30] Sustainability-performance pricing that is consistent with greenwashing concerns is also documented in Carrizosa and Ghosh (2022). Furthermore, Kim et al. (2022) document that by and large, SLLs are opaque and vary widely in the extent of their contractual disclosures, and borrowers with the low quality disclosures about the terms of their contacts experience a deterioration in their ESG performance. Similarly, Du et al. (2022) document that there is no improvement in the ESG performance of SLL issuers, and in fact borrowers are more likely to have negative ESG events post issuance. Evidence consistent with greenwashing concerns also comes from SLB markets. Kölbel and Lambillon (2022) focus on analysing pricing incentives and note that SLBs can be issued purely for financial optimization without a real commitment to carry out sustainability improvements. Ul Haq and Doumbia (2022) focus on structural loopholes and document that high polluters are more likely to issuer SLBs with late targets, and speculative grade issuers more likely to embed call provisions in the SLBs they issue, suggesting that at the moment there is scope for low-type issuers to tap into this market.

4.1.1 Issuance by Project Uncertainty

A first interesting equilibrium prediction of the model is that the propensity of contingent green debt issuance is hump-shaped as a function green outcome uncertainty. We proxy green outcomes using carbon emissons and conceptualize uncertainty as the degree to which they can be measured and controlled.[31] Specifically, we conceptualize green outcome uncertainty as the degree of control

[30] Specifically, they find no evidence that ESG risk is associated with target materiality and relevance, loans to borrowers with high environmental or social risk are no more likely to include an environmental or social target, or that borrower's ESG risk influences target restrictiveness.

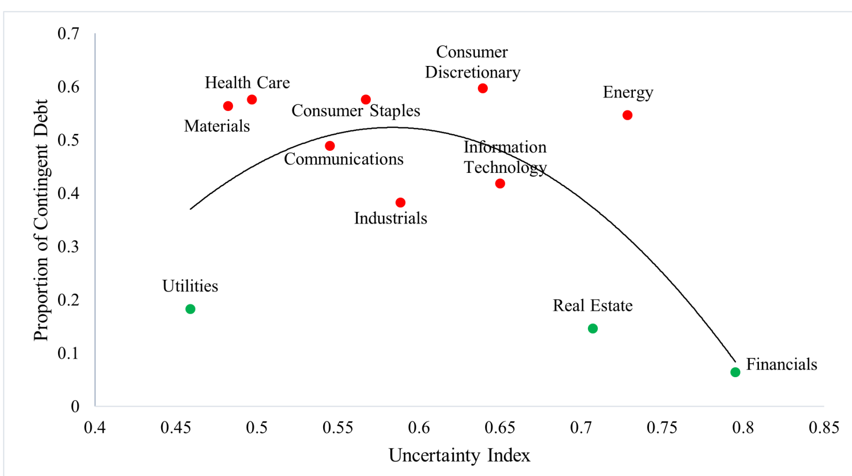
[31] GHG emissions are the single most popular metric on which sustainability-linked bonds and loans are written on. Table 6 in Appendix A.2 reports statistics on the targets underlying contingent green debt securities as collected from Bloomberg New Energy Finance (BNEF).

and measurement accuracy that a firm has over its GHG emissions, and use the emission scopes breakdown of the GHG protocol standard to quantify this uncertainty.[32] Scope 1 emissions are those produced by sources directly owned or controlled by the firm, and so they are deemed as most easy to measure and control. Scope 2^+ emissions, which we define as including scope 2 emissions and scope 3 upstream emissions, capture indirect emissions produced by the firm's suppliers or by energy input sources, and so they are deemed as having an intermediate degree of control and measurement accuracy. Scope 3 downstream emissions encompass all other indirect emissions produced by the firm's consumers or by its financial investments, and so they are deemed as the most uncertain in that they are largely outside the firm's control and are not easily measurable. We define an uncertainty index for industry j as

$$\sigma_j = \frac{1}{N_j} \sum_{i=1}^{N_j} \sigma^1 w_{i,j}^1 + \sigma^2 w_{i,j}^2 + \sigma^3 w_{i,j}^3 \tag{28}$$

where N_j is the total number of firms in industry j, $w_{i,j}^1, w_{i,j}^2, w_{i,j}^3$ are firm i's average scope 1, scope 2+, and scope 3 emissions relative to its total emissions, respectively, and $\sigma^1 = 0 < \sigma^2 = 0.5 < \sigma^3 = 1$ parameterize the uncertainty associated with the emissions scopes. Figure 6 plots

Figure 6. Issuance Choice by Industry
The plot shows the industry-level average proportion of contingent green debt securities relative to all green securities (y-axis) against the industry-level uncertainty index (x-axis). Industry sectors refer to the Global Industry Classification Standards (GICS) provided by S&P Trucost.



[32]This is similar in spirit to Kacperczyk and Peydró (2022) who make a distinction between emissions scopes in terms of the degree to which they can be measured and controlled.

the industry-level uncertainty index (x-axis) against the industry-level proportion of contingent debt securities relative to all green securities issued over our sample period (y-axis). In line with the model predictions, industries with intermediate levels of green outcome uncertainty are those more likely to issue contingent green debt, while industries that lie at the end of the uncertainty spectrum, such as utilities and financials, are the most popular issuers of non-contingent green debt. The model rationalizes this pattern by showing that the ex-ante commitment to actions associated with non-contingent contracts is less costly when firms have very good control over the green outcome, which is the case of utilities firms with a high share of Scope 1 emissions, because in such a case there is a low opportunity cost of commitment. Conversely, non-contingent debt is optimal for firms that have a very poor control over their green outcomes, such as financial firms with a high share of Scope 3 emissions, because in such case the distortion discount makes issuing the contingent contract too costly.

4.2 Green Premia and Asymmetric Information

In this last section, we compare the financial performance of contingent and non-contingent green debt securities. The model provides a testable prediction by stating that, if contingent contracts are more likely to be issued by lower firm types in equilibrium, then the expected return on those contracts should be higher than that on non-contingent debt, so as to compensate the investor for the lower expected green outcome.[33] To test this prediction, we compare the *green premia* associated with contingent and non-contingent green securities, estimated as the yield differential between a green security and an otherwise equivalent conventional one. Our model prediction, restated in terms of the green premium, is that non-contingent debt has a higher green premium than contingent debt. Our empirical estimation follows the literature analyzing the green premium associated with green bonds (Zerbib, 2019; Flammer, 2021) and that associated with sustainability-linked bonds (Kölbel and Lambillon, 2022; Ul Haq and Doumbia, 2022), but we are interested in the difference across the green premia of contingent and non-contingent green debt, rather than testing for the existence of the green premium per se.

We focus on the bond market and estimate the green premium of non-contingent bonds (GB,

[33] Alternatively stated, the rational investor anticipates contingent contracts to be issued by low-types firm that are more likely to manipulate reported outcomes rather than deliver green outcomes, and are therefore willing to forgo less returns.

SocB, SustB) and compare it to that of contingent bonds (SLB) by using a matching methodology which aims to construct pairs of securities with the same properties except for the one property the effects of which we are interested in. The matching procedure is in line with Kölbel and Lambillon (2022) who look at the green premium in the market for SLBs. The main steps are outlined below.

We start by selecting a subsample of the green securities, reported in Table 1, by restricting it to bonds that are issued after January 2018, which is the first year in which contingent bonds (i.e. SLBs) are issued. This is because we want to compare the financial performance of the two types of contracts in a time period where investors have the option to buy either of them. We then focus on contracts with a maturity type that is either callable or fixed (at maturity), and we exclude putable and convertible bonds.[34] We collect information on the contingencies embedded in contingent bonds from Bloomberg, which is available for a subset of the contracts in our sample. Summary statistics reported in Appendix A.3 show that of the 424 contingent bonds (SLBs) in our sample, 358 have detailed information on the type of contingency they embed and out of these, 311 have coupon margin adjustments linked to the firm's sustainability performance. We focus on this subset of securities, which are similar to the type of contingencies studied in our model. The selection leaves us with a total of 4,163 non-contingent bonds (GB, SocB, and SustB) and 311 contingent bonds (SLB).

For each firm that issues the selected bonds, we download from Bloomberg the universe of conventional bonds issued over in the same years (i.e., between 2018 and 2022), and complement this with data from Refinitiv to maximize coverage. We pair each green bond security with the set of conventional bonds from the same issuer and with the same bond seniority, maturity type, coupon type and currency.[35] Within this set of bonds, we exclude those with tenor difference larger than two years, and issue size difference larger than a factor of two (i.e. the selected conventional bonds are not larger than two times the green securities or not smaller than one half). This leaves us with 3,176 conventional bonds (counterfactual securities henceforth) matched to a total of 1,489 non-contingent bonds (GB, SocB, SustB) and 92 contingent bonds (SLB).

[34] At maturity bonds have a fixed maturity, meaning that the issuer must repay the bond at maturity. Callable bonds give the issuer the option redeem the bond before maturity, subject to time or other special constraints. Putable bonds offer the bondholders the right to demand early repayment of the principal from the issuer. Convertible bonds offer the possibility to convert the bond into a number of common stock or equity shares at a predetermined date.

[35] Doing so requires some adjustments to make bonds' characteristics from Refinitiv consistent with those in Bloomberg. We report the details of the adjustments in Appendix A.3.

Table 3. Summary Statistics of Bonds Pairs

Summary statistics (mean) of the pair of green-counterfactual bonds issued between January 2018 and February 2022. The columns Non-Contingent and Conterfactuals refer to pairs pairs of GBs, SocBs, SustBs and conventional bonds. The columns Contingent and Conterfactuals refer to pairs of SLBs and conventional bonds. Fixed Maturity is an indicator variable equal to 1 if the bond has a fixed term maturity, and 0 if it is callable. Unsecured Debt is an indicator variable equal to 1 if the bond is unsecured (including junior and senior unsecured) and 0 otherwise. Unique pairs refer to the number of unique green securities which are matched to one or more conventional counterfactuals. When multiple conventional bonds are matched to a green security, we report the average amount issued, maturity, and coupon rate.

	Non-Contingent and **Counterfactuals**		**Contingent** and **Counterfactuals**	
Variable				
Callable Maturity (%)	0.20		0.84	
Fixed Coupon (%)	0.92		1.00	
Unsecured Debt (%)	0.66		0.97	
Amount Issued ($ bl)	0.29	0.25	0.68	0.62
Coupon Rate (%)	1.51	1.64	2.62	2.83
Maturity (years)	6.09	6.05	8.09	7.93
No. Unique Pairs	1,489		93	

The characteristics of the bond pairs are reported in Table 3, where the left (right) column refers to the pairs of non-contingent (contingent) green and counterfactual securities. We report one set of values for the set of characteristics represented by maturity type, coupon type, and seniority because the bond pairs were formed by matching on these characteristics.[36] Comparing the non-matched characteristics indicates that the bond pairs have very similar size, tenor and coupon rates. However, the differences between the contingent and non-contingent bond pairs are notable. The most striking difference concerns the maturity type, in that contingent securities are significantly more likely to be callable than to have a fixed maturity. This is consistent with evidence in Kölbel and Lambillon (2022), as well as Ul Haq and Doumbia (2022) who emphasize that the coupon step-up penalties embedded in SLBs are likely to be accompanied by call provisions.[37] Second, contingent bonds are larger in size, have markedly lower seniority, and higher coupon rates. Part of these differences are likely due to the features of two debt contacts, such as difference is their stated purpose of financing specific projects versus being general purpose, but are also due to the fact that contingent and non-contingent bonds are issued by different firms, as indicated by evidence in Table 8 in Appendix A.3, and in line with our model predictions.

For each pair of green and counterfactual securities we obtain the current yield at the issue date,

[36]Worth noting is that the fixed coupon type in SLBs means that there is no variation in the coupon rate *other than* the step-up or step-down linked to the sustainable performance.

[37]Note that a callable SLBs means that the issuer can redeem the security before the performance against the target is assessed and the coupon step up is potentially materialized.

and when more than one counterfactual security is available for each green security, we take the average of the yield at issue.[38] Since Bloomberg does not provide yields at issue for our complete sample, we complement this data with the Refinitiv database.

Table 4. Green premium: t-test for bond pairs
The table reports the difference between the yield at issue of non-contingent bonds and that of counterfactual bonds (NC column), and between the yield at issue of contingent bonds and that of counterfactual bonds (C column). The columns Fixed and Callable Maturity refers the subset of bond pairs with fixed and callable maturity, respectively. *,**,*** indicate statistical significance at 1%, 5%, and 10% respectively.

	All		**Fixed Maturity**		**Callable Maturity**	
Variable	**NC**	**C**	**NC**	**C**	**NC**	**C**
Yield Differential	-0.09***	-0.15**	-0.03	-0.03	-0.34***	-0.17***
(Std. Err)	(0.02)	(0.06)	(0.03)	(0.12)	(0.06)	(0.07)
No. Unique Pairs	1,489	93	1,186	15	303	78

Table 4 reports the sign, magnitude and statistical significance of the difference between the yield at issue of contingent and non-contingent bonds and their conventional counterparts (the distribution of the yield differential is reported in Appendix A.3). A negative yield differential means that investors demand a lower yield for investing in green rather than otherwise equivalent conventional bonds, or in other words, they are willing to pay a green premium. The table shows that the yield differential for both non-contingent and contingent bonds is statistically significant and negative, but seems to be larger for contingent bonds (-9bp and -15bp, respectively). Thus, investors seem to be willing to pay a higher green premium for contingent securities, which is seemingly at odds with the prediction of our model. However, most contingent bonds are callable and this option feature can have an amplifying effect on the yield differential since callable bonds have typically higher coupon rates than bonds with fixed maturity. We thus make a distinction between the sub-samples of callable and fixed maturity bonds. Indeed, once controlling for the maturity type, contingent securities have a lower green premium as indicated by the results in Table 4 under the Callable Maturity heading. When excluding the callable bonds from the analysis the green premium is equal across contingent and non-contingent bonds and it is not statistically different from zero (in line with evidence in Zerbib (2019)). Worth noting is that contingent bonds with a fixed maturity date, which represent a minority of the sample, are most likely to be issued

[38]The current yield, also known as the interest yield, is defined as the ratio of the current coupon of a security to its current market price.

by firms that also issue non-contingent bonds. Taken together, this evidence is therefore consistent with our model predictions that contingent securities are affected by measurement frictions and, in the presence of asymmetric information, they will be issued by lower types and will have a lower green premium.

Table 5. Green premium: regression analysis
Linear regression of the yield differential on bond pair characteristics and issuer characteristics. Bond pair characteristics are reported in Table 3. Standard errors are clustered at the issuer level. *,**,*** indicate statistical significance at 1%, 5%, and 10% respectively.

Variables	I	II	III
SLB	0.13	0.14	0.28***
	(0.09)	(0.10)	(0.09)
Callable	-0.30***	-0.23**	-0.06
	(0.09)	(0.10)	(0.14)
Fixed Coupon		-0.01	-0.05
		(0.22)	(0.01)
Amount Issued		-0.00	-0.00
		(0.00)	(0.00)
Tenor		-0.01	-0.01
		(0.01)	(0.01)
Diff. Amount Issued		-0.00	-0.00
		(0.00)	(0.00)
Diff. Tenor		0.02	0.02
		(0.03)	(0.04)
Intercept	-0.03	0.05	0.37
	(0.05)	(0.26)	(0.21)
Industry Dummy	N	N	Y
Issue Year Dummy	N	N	Y
Currency Dummy	N	N	Y
Seniority Dummy	N	N	Y
R^2	0.02	0.02	0.09
No. Obs.	1,582	1,582	1,560

We test the robustness of our results by regressing the yield differential on a selected set of issuer and bond pair characteristics, and report the results in Table 5. As observed, once controlling for the negative effect of the callable feature on the yield at issue deferential, we find that contingent green securities have higher spreads than non-contingent green securities, as indicated by the positive coefficient on the SLB indicator. Furthermore, the difference becomes statistically significant once controlling for industry and time fixed effects, as well as for the currency and seniority of the bond pairs. This evidence is therefore consistent with the model predictions that in the presence of asymmetric information, contingent bonds are issued by lower types in equilibrium.

5 Concluding Remarks

Motivated by the development of the corporate sustainable debt market, we propose a theory of corporate financing to study firms' incentives to finance green projects using action-based non-contingent debt contracts that restrict the use of proceeds to specific green projects, or outcome-based contingent debt contracts that make the cost of debt contingent on realized green outcomes. Absent measurement frictions, contingent contracts such as SLLs/SLBs are strictly optimal and address the limitations inherent to the design of non-contingent contracts such as GBs by eliminating the need to restrict borrower's actions ex-ante and by making outcomes rather than actions the focus of green projects financing. However, when green outcomes can be manipulated, non-contingent contracts such as GBs become optimal.

Our model sheds light on the time-series evolution of the sustainable debt market and explains the initial dominance of GBs in terms of the absence of reliable measurement systems which characterised the early stages of the market. Subsequent improvements in measurement systems explain the co-existence of the two green debt contract designs, which is the result of an active trade-off between the opportunity cost of ex-ante commitment associated with non-contingent contracts such as GBs, and the distortion discount associated with contingent contracts such as SLLs/SLBs.

We extend the model to also shed light on issuance patterns across firms by introducing a continuum of firm types that are differentiated with respect to the cost of action and the cost of distortion they face. When investors are perfectly informed about firm types, the model predicts that contingent contracts such as SLLs/SLBs are issued by high-type firms that are more likely to exert costly action rather than manipulate reported outcomes. However, in the presence of asymmetric information this prediction flips and it is low-type firms that issue contingent contracts, whereas non-contingent contracts such as GBs can be used by high-type firms as a costly signalling device. We test the model predictions empirically and provide evidence that is consistent with the equilibrium outcome of our model with measurement frictions and asymmetric information.

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A Data Appendix

A.1 The Sustainable Finance Market

The market for sustainable debt started in 2007 with the issuance of the world's first green bond by the European Investment Bank, the so called Climate Awareness Bond.[39] Green bonds (GBs) are fixed income instruments which are differentiated from regular bonds by a green label, which represent a commitment to exclusively use the funds raised to finance or re-finance green projects. The financing terms depend implicitly on the expected green benefits that these projects are expected to yield, which are signalled ex-ante by the issuer and which effectively constitute a green promise, but there is no explicit commitment to delivering specific green benefits. This gives rise to a moral hazard problem since in the absence of contractual mechanism to incentivise the provision of green benefits the firm will not exert costly effort once it has obtained the funds. To mitigate this moral hazard problem issuers can obtain a green label which is essentially a verification of the commitment to deliver the promised green benefit. Issuers can obtain a green label from a number of certification providers, most of which adhere to the Green Bond Principles (GBPs).[40] The GBPs are voluntary guidelines put forward by the International Capital Market Association (ICMA) which provide issuers with high level guidance on the key components involved in launching a credible green bond. They place particular emphasis on ex-ante verification that all the necessary processes are in place to ensure that the proceeds will be used for the stated projects, but they make no reference to the outcomes delivered by the projects.[41] Alongside the development of GBs, the market has seen a proliferation of debt instruments that are similar in spirit but which are dedicated to financing other purposes, such as social bonds (SocB) and sustainability bonds (SustB). While SocBs raise funds for projects that address social issues, the proceeds obtained through the issuance of SustBs are dedicated to financing a combination of both green and social projects. Similarly to GBs, there are principles to guide the issuance of Social and Sustainability

[39]The first corporate green bond was issued in 2013 by Swedish housing company Vasakronan.

[40]The role of the external certification providers is to confirm that the bonds align with the principles, and their services or involvement range from second party opinion to rigorous verification against standardized scientific criteria and which also involve the appointment of approved 3rd party verifiers. The major certification providers include the Climate Bond Initiative (CBI), Climate Bonds Certification, MSCI Green Bond Indices, Moody's Green Bond Assessment and Standard & Poor's Green Evaluations.

[41]For example, Apple clearly states that can be no assurance that funded projects meet investors' criteria or expectations regarding sustainability performance.

Bonds, namely the Social Bond Principles (SBP) and the Sustainability Bond Guidelines (SBG), respectively.

Sustainability-linked Bonds (SLBs) and Loans (SSLs) represent new types of debt instruments which do not earmark proceeds for specific projects, but instead make the borrower's financing cost contingent on the borrower meeting specific targets, which reflect broad sustainability concerns, at predetermined dates throughout the life of the contract.[42] A firm raising capital using these state-contingent debt contracts essentially commits to making a series of interest repayments that are linked to the deviation of its realized sustainability performance from the target. The issuance of SLBs is governed by the ICMA Sustainability-Linked Bond Principles which are centred around specifying the performance targets and the ex-post reporting and verification of performance. The ex-post performance verification is mandatory for SLBs but is similar to an audit process so is less costly and less reliable compared to the ex-ante green label certification processes associated with GBs.[43] In the case of SLLs, which represent the private debt counterpart of SLBs and whose issuance is guided by the voluntary guidelines issued by the Loan Market Association (LMA), ex-post reporting and verification of performance is only recommended, and subject to negotiation between the borrower and lenders on a transaction-by-transaction basis.[44]

Table 6. Sustainability Performance Targets
The table breaks down the target performance metrics associated to SLLs and SLBs in our sample by categories: general ESG Scores, Environmental metrics, Social metrics, Governance metrics, and then by respective sub-categories. Data are collected from Bloomberg New Energy Finance (NEF). The number of targets does not correspond to the number of unique loans and bonds: some loans and bonds have unknown targets, while other loans and bonds have more than one target.

ESG Score	**Environmental**	**Social**	**Governance**	**Unknown**
220 (9%)	1278 (52%)	330 (13%)	90 (4%)	538 (22%)
• Sustainalytics 25% • GRESB 11% • EcoVadis 9% • ISS 5% • MSCI 5% • Vigeo Eiris 4% • Other/Unknown 41%	• GHGs 46% • Waste 13% • Renewable Energy 12% • Energy Efficiency 7% • Water 7% • Transport 2% • Other/Unknown 13%	• Worker Accidents 18% • Female Staff 10% • Labor Rights 9% • Education 8% • Disabilities 2% • Social Returns 1% • Other/Unknown 52%	• Female Board 49% • Other/Unknown 51%	

[42]The first SLL was issued in April 2017 by the Dutch health technology company Koninklijke Philips.

[43]For a discussion on the difference between auditing reports and certifications of green securities see also Baker et al. (2022).

[44]For example, verification of performance reports is negotiated and agreed between the borrower and lenders on a transaction-by-transaction basis, and is only recommended when reporting about KPIs is not made publicly available or otherwise accompanied by an audit/assurance statement.

A.2 Issuers Dataset

We construct a panel dataset which combines our initial sample of green securities described in Table 1 with data on issuers' balance sheet from Standard & Poor Global (S& P) and carbon emissions from S&P Trucost, as well as their sustainability performance from Sustaynalitics. Firm i's securities issuance in year t is matched with firm i's characteristics in fiscal year t from S&P Trucost.[45] Matching is performed on company tickers when possible, otherwise company names. Given that out S&P Trucost sample ends in 2021, we obtain a merged sample that runs from 2013 to 2019. The resulting unbalanced panel is reported in the second column Table 7. The number of matches per year is provided in the second column of Table 7.

We then complement the Bloomberg/S&P Trucost merged dataset with ESG ratings from Sustainalytics. Matching the Bloomberg/S&P Trucost dataset with Sustainalytics is performed on Capital IQ identifiers. We use the legacy Sustainalytics dataset which measures ESG preparedness and performance and which has been discontinued in 2019 and roll over the data for this last available year.[46] The resulting unbalanced panel is reported in the third column of Table 7.

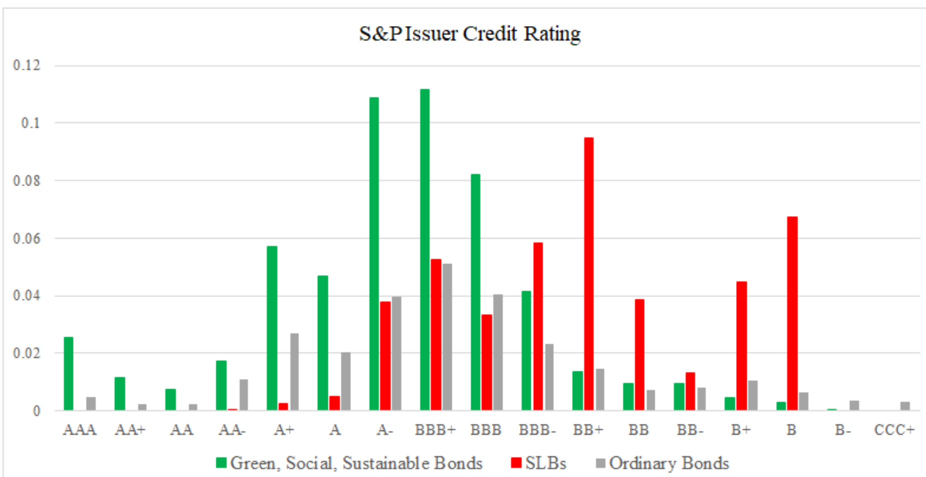
Table 7. Issuers Dataset
The Table reports the distribution of firms per year in the S&P Trucost dataset (first column), Bloomberg/S&P Trucost merged dataset (second column), and Bloomberg/S&P Trucost/Sustainalytics merged dataset (third column), respectively.

Issuance Year	Trucost	BB/Trucost	BB/Trucost/Sust.
2013	20,730	8	4
2014	21,458	30	19
2015	21,940	34	23
2016	22,355	49	32
2017	22,563	87	54
2018	22,510	137	95
2019	22,146	291	200
2020	22,513	359	243
2021	17,908	854	515
No. Unique Firms	23,652	1,197	731

[45]Note that for SLLs, the issuance year is the year in which the loan has been linked to the firm's sustainability performance, recorded in Bloomberg as the sustainability-linked start date. A large fraction of these loans were outstanding revolving credit lines that were subsequently converted into SLLs so their issuance date differs from ...

[46]While this is not ideal, the two datasets cannot be used in conjunction and using the old one insures a better coverage.

Figure 7. Issuers Credit Rating
The figure shows the distribution of the S&P credit ratings of the issuers of green, social and sustainable bonds (non-contingent bonds), sustainability-linked bonds (contingent bonds) as well as the universe of ordinary corporate bonds from Bloomberg. The sample period is January 2013 to February 2022.



A.3 Green Premium Exercise

Since yield differentials are available for bonds only, we exclude corporate loans from the green premium exercise. Furthermore, we focus on GBs, SocBs, SustBs and SLBs issued after January 2018, which is the first year in which SLBs are issued. We also focus on bond contracts whose maturity type is either callable or fixed (at maturity) while we exclude putable and convertible bonds. After this screening, we are left with 3,622 GBs, 374 SocBs, 617 SustBs and 424 SLBs. The number of issuers per year is reported in Table 8. Among the 424 SLBs, we then focus on those 311 with contingencies that are of the type discussed in the theoretical model (i.e. a coupon margin adjustment as a function of the reported performance). Details on the type of contingencies in SLBs are reported in Table 9.

Table 8. Selected Bonds Issuers
The table reports in the first and second columns the number of issuers of Non-Contingent bonds (including GBs, SocBs, SustBs) and Contingent bonds (including SLBs) by issuance year, respectively. The third column shows the number of firms issuing both contracts types.

Issuance Year	Non-Contingent	Contingent	Both
2018	233	1	0
2019	392	2	1
2020	460	19	0
2021	953	123	13
2022	162	14	1
No. Unique Firms	1,465	148	14

Table 9. Penalty Types
Summary statistics of the type of contingencies embedded in SLBs. The first column indicates the number of bonds, whereas the second column indicates the total amount issued in $ billions.

	No. Bonds	Amount ($bn)
Coupon margin adjustment	311	161.4
Step-up penalty	244	143.7
Step-up/down penalty	63	17.2
Step-down penalty	4	0.5
Other penalty types	47	13.9
Redemption premium at maturity	39	11.5
Donation	3	0.4
Purchase carbon credits	3	0.5
Other	2	1.4
No information	66	27.5

For the selected set of bonds in our sample, we download from Bloomberg the set of conventional bonds issued by the same group of firms in the same years (i.e., between 2018 and 2022). To increase coverage, we complement the Bloomberg conventional bonds dataset using the Refinitiv fixed income dataset. In order to match the pair of conventional and green securities, we standardize security characteristics across the two data providers. Specifically, we apply the following adjustments to terminology used in each dataset for referring to seniority types, coupon types and currencies:

- *Seniority.* Green securities in Bloomberg have the types of seniority listed in the left table. In contrast, the universe of conventional bonds downloaded from Refinitiv has the seniority listed in the right table. To make the bonds comparable, we denominate i) all the "Senior Secured - " types in Refinitiv as "1st Lien", ii) "Senior Unsecured" as "Sr Unsecured", iii) "Senior Subordinate Unsecured" as "Sr Unsecured", iv) "Subordinated Unsecured" as "Subordinated", v) "Senior Non-Preferred" as "Sr Non Preferred", vi) "Senior Preferred" as "Sr Preferred", and vii) "Junior Unsecured or Junior Subordinated" as "Jr Subordinated".

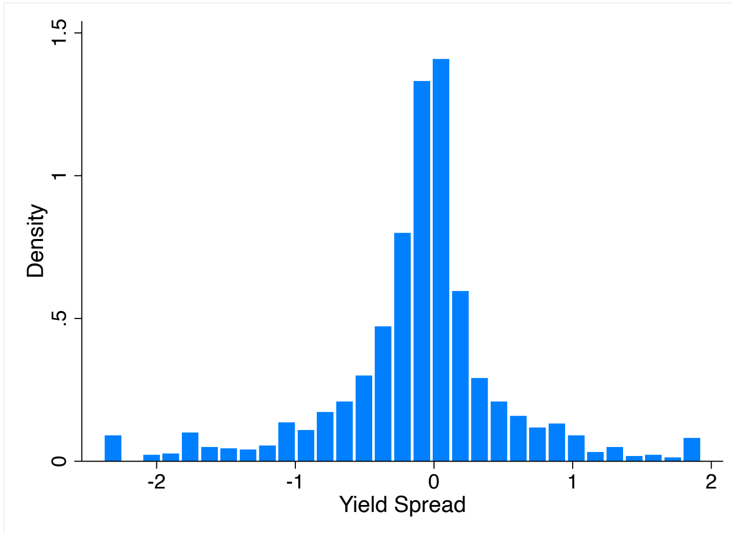
Bloomberg Seniority	**Perc.**
1st lien	5.16
2nd lien	0.08
Asset Backed	0.74
Jr Subordinated	0.93
Secured	8.34
Sr Non Preferred	6.29
Sr Preferred	4.81
Sr Unsecured	60.57
Subordinated	1.56
Unsecured	11.51

Refinitiv Seniority	**Perc.**
Junior Unsecured or Junior Subordinated	0.01
Secured	0.11
Senior Non-Preferred	1.60
Senior Preferred	5.17
Senior Secured	1.40
Senior Secured - First Lien	0.12
Senior Secured - First Mortgage	0.07
Senior Secured - First and Refunding	0.08
Senior Secured - Mortgage	0.69
Senior Subordinated Unsecured	0.03
Senior Unsecured	32.36
Subordinated Unsecured	0.65
Unsecured	57.69

- *Coupon type.* We use a broad definition of coupon type: either "Fixed" or "Not fixed". "Fixed" is the coupon denomination in Bloomberg, which corresponds to "Plain Vanilla Fixed Coupons" and "Zero Coupon" in Refinitiv. "Not fixed" is the remainder of coupon types which are not fixed (the majority of those are "Floating" and "Variable" coupons).
- *Currency.* Currencies in Bloomberg are expressed in codes whereas they are reported in full text in Refinitiv. Therefore, we simply assign the respective code to each currency name.

Figure 8. Yield differential distribution

Histogram of the yield differential between otherwise equivalent pairs of green and ordinary bond securities.



B Proofs

Proposition 1. The profits from issuing the contingent contract cg rather than the non-contingent contract g can be expressed as

$$\mathbb{E}[\mathcal{U}^f_{cg}] - \mathcal{U}^f_g = \underbrace{(\mathbb{E}[\mathcal{U}^s] - \mathcal{U}^f_g)}_{\text{commitment cost}} - \underbrace{(\mathbb{E}[\mathcal{U}^s] - \mathbb{E}[\mathcal{U}^f_{cg}])}_{\text{distortion cost}} \tag{29}$$

with $\mathbb{E}[\mathcal{U}^f_{cg}]$ and $\mathcal{U}^f_g$ the expected utility from issuing the contracts cg and g, respectively, and $\mathbb{E}[\mathcal{U}^s]$ the expected utility of the central planner as evaluated at the first-best. From the properties of the truncated normal distribution, we have

$$\begin{aligned}
\mathbb{E}[\mathcal{U}^s] &= R - r + \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z})^+] \\
&= R - r + \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z})1\{\tilde{z} > -\frac{1}{2}\frac{1}{\sigma\theta}\}] \\
&= R - r + \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z})|\tilde{z} > -\frac{1}{2}\frac{1}{\sigma\theta}]F(\frac{1}{2}\frac{1}{\sigma\theta}) \\
&= R - r + \frac{1}{2}\frac{1}{\theta}F(\frac{1}{2}\frac{1}{\sigma\theta}) + \sigma f(\frac{1}{2}\frac{1}{\sigma\theta})
\end{aligned} \tag{30}$$

with $F(\cdot)$ and $f(\cdot)$ cumulative standard normal distribution function and density function respectively. The opportunity cost of commitment in (29) is therefore

$$\begin{aligned}\mathbb{E}[\mathcal{U}^s] - \mathcal{U}_g^f &= \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z})^+] - \frac{1}{2}\frac{1}{\theta} \\ &= \frac{1}{2}\frac{1}{\theta}(F(\frac{1}{2}\frac{1}{\sigma\theta}) - 1) + \sigma f(\frac{1}{2}\frac{1}{\sigma\theta}) > 0\end{aligned} \tag{31}$$

which from Jensen's inequality is strictly positive for any $\sigma \in (0, +\infty)$ and $\theta \in (0, +\infty)$. The expected utility from issuing the contract cg reads

$$\begin{aligned}\mathbb{E}[\mathcal{U}_{cg}^f] &= R - \bar{\rho}_{cg} + \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \frac{1}{2}\frac{\sigma^2}{\psi} + \sigma\tilde{z})^+] \\ &= R - \bar{\rho}_{cg} + (\frac{1}{2}\frac{1}{\theta} + \frac{1}{2}\frac{\sigma^2}{\psi})F(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi}) + \sigma f(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi}) \\ &= R - r + (\frac{1}{2}\frac{1}{\theta} - \frac{1}{2}\frac{\sigma^2}{\psi})F(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi}) + \sigma f(\frac{1}{2}\frac{1}{\theta} + \frac{1}{2}\frac{\sigma}{\psi})\end{aligned} \tag{32}$$

since $\bar{\rho}_{cg} = r + \mathbb{E}[x_{cg}d_{cg}] = r + \frac{\sigma^2}{\psi}F(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi})$. The distortion cost in (29) therefore is

$$\mathbb{E}[\mathcal{U}^s] - \mathbb{E}[\mathcal{U}_{cg}^f] = \frac{1}{2}\frac{1}{\theta}(F(\frac{1}{2}\frac{1}{\sigma\theta}) - F(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi})) + \frac{1}{2}\frac{\sigma^2}{\psi}F(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi}) + \sigma(f(\frac{1}{2}\frac{1}{\sigma\theta}) - f(\frac{1}{2}\frac{1}{\sigma\theta} + \frac{1}{2}\frac{\sigma}{\psi})). \tag{33}$$

From (33), it follows that

$$\lim_{\psi\to+\infty} \mathbb{E}[\mathcal{U}^s] - \mathbb{E}[\mathcal{U}_{cg}^f] = 0, \tag{34}$$

while the baseline rate $\lim_{\psi\to+\infty} \bar{\rho}_{cg} = r$. On the other hand,

$$\lim_{\psi\to+0} \mathbb{E}[\mathcal{U}^s] - \mathbb{E}[\mathcal{U}_{cg}^f] = \lim_{\psi\to 0} \frac{1}{2}\frac{\sigma^2}{\psi} = +\infty, \tag{35}$$

while the baseline rate $\lim_{\psi\to 0} \bar{\rho}_{cg} = +\infty$. Subtracting the distortion costs in (34) and (35) from the commitment cost in (31) proves the result.

Proposition 2. Denote the type $k \in [0, 1]$ such that $\theta_k = \theta/k$ and $\psi_k = \psi/(1-k)$. From (32), the utility from issuing the contingent green contract cg for a firm of type k is

$$\mathbb{E}[\mathcal{U}_{cg}^f(k)] = R - r + (\frac{k}{2\theta} - \frac{1}{2}\frac{\sigma^2(1-k)}{\psi})F(k) + \sigma f(k), \tag{36}$$

where $F(k) = \mathcal{N}(\frac{1}{2}\frac{k}{\sigma\theta} + \frac{1}{2}\frac{\sigma(1-k)}{\psi})$ is the cumulative normal distribution and $f(k) = F^{'}(k)$ is the density function, whereas $\mathcal{U}_g(k) = R - r + \frac{k}{2\theta}$. So, profits from issuing the contingent contract read

$$\Pi_{cg}(k) = \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_g^f(k) = -\frac{\sigma^2}{2\psi}F(k) + kF(k)(\frac{1}{2\theta} + \frac{\sigma^2}{2\psi}) + \sigma f(k) - \frac{k}{2\theta}. \tag{37}$$

Since $\Pi_{cg}(k)$ is continuous in $k \in [0,1]$, this implies that

$$\lim_{k \to 1} \Pi_{cg}(k) > 0 \tag{38}$$

which implies that there exists a firm type $\bar{k} < 1$ such that $\Pi_{cg}(k) > 0$ for $k \in [\bar{k}, 1]$. Deriving $\Pi_{cg}(k)$ with respect to k one gets

$$\begin{aligned}
\frac{\partial}{\partial k}\Pi_{cg}(k) &= -\frac{1}{2\theta} + f(k)(\frac{1}{2\theta\sigma} - \frac{\sigma}{2\psi})(-\frac{\sigma^2}{2\psi} + k(\frac{1}{2\theta} + \frac{\sigma^2}{2\psi}) - (\frac{1}{2}\frac{k}{\theta} + \frac{1}{2}\frac{\sigma^2(1-k)}{\psi})) + F(k)(\frac{1}{2\theta} + \frac{\sigma^2}{2\psi}) \\
&= -\frac{1}{2\theta}(1 - F(k)) - \frac{\sigma^2}{\psi}f(k)(1-k)(\frac{1}{2\theta\sigma} - \frac{\sigma}{2\psi}) + \frac{\sigma^2}{2\psi}F(k) \\
&\sim -\frac{\psi}{\theta\sigma^2}(1 - F(k)) + F(k) + \frac{\sigma}{\psi}(1 - \frac{\psi}{\theta\sigma^2})f(k)(1-k),
\end{aligned}$$

where the last expression follows from dividing by $\sigma^2/2\psi$.

If $\psi < \sigma^2\theta$ (i.e. $\sigma > \sqrt{\psi/\theta}$), then the derivative $\frac{\partial}{\partial k}\Pi_{cg}(k)$ is always positive since $-\frac{\psi}{\theta\sigma^2}(1 - F(k)) + F(k) > -1 + 2F(k) > 0$ since $F(k) > 0.5$ for each $k \in [0,1]$, and the third term is positive for each $k \in [0,1]$. From the single-crossing property, it follows that $\bar{k}$ is unique and either $\Pi_{cg}(0) > 0$, in which case $\bar{k} = 0$ and all types issue the contract cg, or $\Pi_{cg}(0) < 0$, in which case $\bar{k} \in (0,1)$ and all types $k \in [0, \bar{k})$ issue the contract g.

If $\psi > \sigma^2\theta$ (i.e. $\sigma < \sqrt{\psi/\theta}$), on the other hand, the derivative $\frac{\partial}{\partial k}\Pi_{cg}(k)$ can be either positive or negative. The second derivative is

$$\begin{aligned}\frac{\partial^2}{\partial k^2}\Pi_{cg}(k) &= \frac{\partial}{\partial k}\Big(-\frac{1}{2\theta}(1-F(k)) - \frac{\sigma^2}{\psi}(1-k)f(k)(\frac{1}{2\theta\sigma}-\frac{\sigma}{2\psi}) + \frac{\sigma^2}{2\psi}F(k)\Big) \\ &= F^{'}(k)(\frac{1}{2\theta}+\frac{\sigma^2}{2\psi}+\frac{\sigma^2}{\psi}) + F^{'}(k)\frac{\sigma^2}{\psi}(1-k)(\frac{1}{2\theta\sigma}-\frac{\sigma}{2\psi})(\frac{1}{2}\frac{k}{\sigma\theta}+\frac{1}{2}\frac{\sigma(1-k)}{\psi})\end{aligned} \tag{39}$$

where the last equality follows after some rearrangement and noting that $F^{'}(k) = f(k)(\frac{1}{2\theta\sigma} - \frac{\sigma}{2\psi})$. Note that if $\psi > \sigma^2\theta$, then $(\frac{1}{2\theta\sigma} - \frac{\sigma}{2\psi}) > 0$ and $F^{'}(k) > 0$ for each $k \in [0,1]$. Therefore, one has that $\frac{\partial^2}{\partial k^2}\Pi_{cg}(k) > 0$ for each $k \in [0,1]$. Since the net profits are strictly convex in k when $\psi > \sigma^2\theta$, then either $\Pi_{cg}(0) < 0$ in which case $\bar{k} \in (0,1)$ is unique and types $k \in [0,\bar{k})$ issue the contract g, or $\Pi_{cg}(0) > 0$, in which case it may exist (at most) a second $\underline{k} \in (0,1)$ such that $k \in [0,\underline{k})$ and $k \in [\bar{k},1]$ issue the contract cg, whereas the internal types $k \in [\underline{k},\bar{k})$ issue the contract g.

Proposition 3. In the presence of asymmetric information, we solve for a perfect Bayesian equilibrium (PBE) of a signalling game where the first mover (the firm) has infinite types $k \sim \mathcal{U}[0,1]$ and two moves (issue a contingent contract cg or the non-contingent contract g) $y_k = \{cg, g\}$, whereas the second mover (investor) has one type and two moves (accept or refuse the proposed contract) and prior belief over the firm's type $\tilde{k} \sim \mathcal{U}[0,1]$. A PBE requires that the firm's issuance strategy is sequentially rational, that is, for each information set at which the firm moves, the firm maximizes its expected utility anticipating the investor's beliefs at the information set, and that the investor updates its belief in a Bayesian manner.

A first thing to note is that, independently of the issuance choice, the firm is strictly better off when the investor accepts the proposed contract instead of when it refuses it. This because it holds that $\min\{\mathbb{E}[\mathcal{U}^f_{cg}(k)], \mathcal{U}^f_g(k)\} \geq R - r > 0$. Consequentely, the firm will always propose a contract rate so as to satisfy the investor's participation constraint, meaning that the investor always buys the contract in equilibrium. We consider the optimal contracting problem from the perspective of a high-type firm k that knows that if it offers a contract cg, it will be mimicked by low type firms, so that it is always pooled with low firms in the same observable group $\mathcal{K} = [0,k)$.[47] This implies that the investor's posterior upon issuing this contract $\tilde{k}|cg = \mathcal{U}[\mathcal{K}]$. Following Mailath (1987), for

[47] The reason why low firms imitate high firms is that a different strategy would reveal that they are low firms with higher manipulation incentives.

a PBE to exist it is sufficient to prove that the single-crossing property is verified, meaning that

$$\frac{\partial}{\partial k}\Pi_{cg}^{\mathcal{K}}(k) \leq 0 \quad \forall k \in [0,1] \tag{40}$$

where

$$\Pi_{cg}^{\mathcal{K}}(k) = \Pi_{cg}(k) - (\bar{\rho}_{cg}^{\mathcal{K}} - \bar{\rho}_{cg}^{k}). \tag{41}$$

and $\bar{\rho}_{cg}^{\mathcal{K}} = \mathbb{E}[\bar{\rho}_{cg}^{k}|k \in \mathcal{K}]$ is the group-specific baseline interest rate charged to contingent debt issuers in the set $\mathcal{K}$. It can be shown that

$$\bar{\rho}_{cg}^{\mathcal{K}} - \bar{\rho}_{cg}^{k} = \frac{\sigma^2}{\psi}(\frac{1}{k}\int_0^k (1-s)F(s)ds - (1-k)F(k)) \tag{42}$$

so the derivative

$$\begin{aligned} \frac{\partial}{\partial k}(\bar{\rho}_{cg}^{\mathcal{K}} - \bar{\rho}_{cg}^{k})) &= \frac{\sigma^2}{\psi}(\frac{1}{k}(1-k)F(k) + F(k) - (1-k)f(k)(\frac{1}{2\theta\sigma} - \frac{\sigma}{2\psi})) \\ &= \frac{\sigma^2}{\psi}(\frac{1}{k}F(k) - (1-k)f(k)(\frac{1}{2\theta\sigma} - \frac{1\sigma}{2\psi})) \\ &\sim \frac{2}{k}F(k) + (1-k)f(k)\frac{\sigma}{\psi}(1 - \frac{\psi}{\theta\sigma^2}) \end{aligned} \tag{43}$$

where the last expression follows from dividing everything by $\sigma^2/2\psi$. Recalling (37) and plugging it into (41), we have that

$$\begin{aligned} \frac{\partial}{\partial k}\Pi_{cg}^{\mathcal{K}}(k) &\sim -\frac{\psi}{\theta\sigma^2}(1-F(k)) + F(k) - \frac{2}{k}F(k) \\ &< -\frac{\psi}{\theta\sigma^2}(1-F(k)) - F(k) \end{aligned} \tag{44}$$

from which it follows immediately the condition (40) since $F(k) \leq 1$ for each $k \in [0,1]$.

Corollary 1. To prove the corollary note that

$$\begin{aligned}\frac{1}{k^*}\int_0^{k^*}(\mathbb{E}[\rho_{cg}^{\mathcal{K}^*}(k)]-\rho_v)dk =&\frac{1}{k^*}\int_0^{k^*}(r+\bar{\rho}_{cg}^{\mathcal{K}^*}-\mathbb{E}[x_{cg}^k(g(a_{cg}^k,z)+\sigma d_{cg}^k)]-r)dk\\ =&\bar{\rho}_{cg}^{\mathcal{K}^*}-\frac{1}{k^*}\int_0^{k^*}\mathbb{E}[x_{cg}^k(g(a_{cg}^k,z)+\sigma d_{cg}^k)]dk\\ =&-\frac{1}{k^*}\int_0^{k^*}\mathbb{E}[x_{cg}^k g(a_{cg}^k,z)]dk\end{aligned}\tag{45}$$

where $\rho_v = r$ and the last equality follows from the definition of the distortion discount. Recalling that $x_{cg}^k = 1\{\frac{1}{2\theta_k}+\frac{\sigma}{\psi_k}+\sigma z>0\}$, if ψ is small enough then for $k<k^*$ we have that $x_{cg}^k\approx 1$, which yields

$$\begin{aligned}\frac{1}{k^*}\int_0^{k^*}(\mathbb{E}[\rho_{cg}^{\mathcal{K}^*}(k)]-\rho_v)dk \approx& -\frac{1}{k^*}\int_0^{k^*}\mathbb{E}[g(a_{cg}^k,z)]dk\\ \approx& -\frac{1}{k^*}\frac{(k^*)^2}{2\theta}=-\frac{k^*}{2\theta}.\end{aligned}\tag{46}$$

On the other hand, recalling that $\rho_g(k)=\bar{\rho}_g - x_g^k a_g^k$ and $\bar{\rho}_g = r$, we have that

$$\begin{aligned}\frac{1}{1-k^*}\int_{k^*}^1(\rho_g(k)-\rho_v)dk =&\frac{1}{1-k^*}\int_{k^*}^1(r-\frac{k}{\theta}-r)dk\\ =&-\frac{1}{1-k^*}(\frac{1}{2\theta}-\frac{(k^*)^2}{2\theta})\\ =&-\frac{1+k^*}{2\theta}<-\frac{k^*}{2\theta},\end{aligned}\tag{47}$$

which proves the result.

B.1 Introducing fixed costs for green securities issuance

A prediction of our baseline model is that, as long as investors have preferences for green outcomes and the action cost θ is finite (i.e., there exists a project which delivers a positive green outcome in expectation), the vanilla contract v should never be issued. In practice though, we know that green contracts are only a small fraction of the corporate debt universe typically issued by large firms, as the empirical analysis shows. This suggests the presence of barriers to entry in the sustainable debt market, which could be captured by the introduction of a fixed cost α associated with issuing green securities.

We assume that the cost α is paid ex-ante by the firm when issuing the non-contingent contract g

(to capture the cost of obtaining a certified green label), and paid ex-post by the firm when issuing the contingent contract cg (to capture the cost of measuring and reporting the outcome delivered by the green project), if the latter is chosen. In the presence of such cost, the firm's utility when issuing the non-contingent green contract g becomes

$$\mathcal{U}_g^f(k) = \mathcal{U}_v + \frac{k}{2\theta} - \alpha \tag{48}$$

which implies that only higher types $k > 2\theta\alpha$ prefer this contract to a vanilla contract v. The net profits from the contingent contract issuance are a piece-wise linear function of k

$$\Pi_{cg}(k) = \begin{cases} \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_v^f & \text{if } k \in [0, 2\theta\alpha] \\ \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_g^f(k) & \text{if } k \in (2\theta\alpha, 1]. \end{cases} \tag{49}$$

with

$$\mathbb{E}[\mathcal{U}_{cg}^f(k)] = \mathcal{U}_v + r - \bar{\rho}_{cg}^k + \mathbb{E}[(\frac{k}{2\theta} + \frac{1}{2}\frac{\sigma^2(1-k)}{\psi} + \sigma\tilde{z} - \alpha)^+] \tag{50}$$

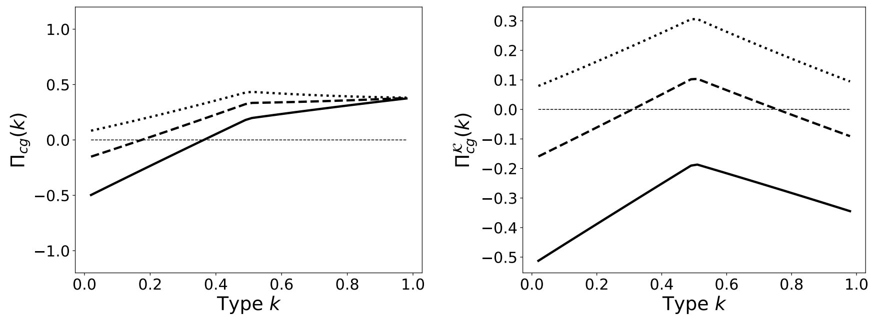
Figure 9, left plot, shows how the profits vary with the firm type for different values of the distortion cost. As observed, profits are increasing in the type k when $k < 2\theta\alpha$, and this is independent of the magnitude of the distortion cost ψ. This is because the effect of the opportunity cost of commitment vanishes and only the distortion discount drives firms' preferences for the contract cg relative to contract v.

The equilibrium with asymmetric information is complicated by the introduction of issuance costs α, in that preferences for the contingent contract, modelled as

$$\Pi_{cg}^{\mathcal{K}}(k) = \Pi_{cg}(k) - (\mathbb{E}[\bar{\rho}_{cg}^k | k \in \mathcal{K}] - \bar{\rho}_{cg}^k) \tag{51}$$

are non-monotonic across types k although still tilted towards lower types, as shown in the right plot of Figure 9. This in turn implies that the single-crossing property is not verified for any $k \in [0, 2\alpha\theta]$, which in turn implies that a separating equilibrium as the one defined in the previous sections may not exists. However, a separating equilibrium exists if we assume that the investor

Figure 9. Net Profits From Issuing a Contingent Green Contract
The left (right) plot show the firm's expected profits from issuing a contingent green contract under perfect information (49) and asymmetric information (51), as a function of the firm type k for three different values of the distortion cost $\psi = 1.0$ (thick line), $\psi = 1.4$ (dotted line) and $\psi = 10$ (dashed line). The other model parameters are $\theta = 0.5$, $\alpha = 0.5$, $\sigma = 1.5$.



has a refined information set about the firm's type at issuance. That is, the investor knows whether $\tilde{k} \sim \mathcal{U}[0, 2\theta\alpha]$ or $\tilde{k} \sim \mathcal{U}[2\theta\alpha, 1]$. This amounts to assuming that the investor knows if the firm type is high enough so that it can afford the issuance of a green bond, although it does not know whether such issuance would be optimal if its type was perfectly revealed. In such a case, one can prove the following

PROPOSITION 4. *For any set of model parameters* $(\psi, \theta, \sigma\alpha) \in (0, +\infty)$ *such that the single crossing-property in* (40) *is verified for* $k \in [2\alpha\theta, 1]$*, the following equilibria are possible:*

- *profits in* (51) *are negative for each* $k \in [0, 2\theta\alpha)$*, in which case types* $k \in [0, 2\alpha\theta]$ *issue a non-contingent vanilla contract* v*, whereas the remainder of types* $k \in [2\alpha\theta, 1]$ *issue a non-contingent green contract* g*.*
- *profits in* (51) *are positive for each* $k \in [0, 2\theta\alpha)$*, in which case it exists a cutoff type* $k^* \in (2\theta\alpha, 1]$ *such that all types* $k \in [0, k^*)$ *issue a contingent green contract* cg*, whereas the remainder of types* $k \in [k^*, 1]$ *issue a non-contingent green contract* g*.*

The extended proposition confirms that for the range of model parameters which admit an equilibrium, non-contingent contracts g are unambiguously more likely to be issued by higher types. This is because if all types $k \in [0, 2\theta\alpha]$ issue the contingent contract cg, then it must be that types $k \in [2\theta\alpha, k^*)$ also issue the contract cg, whereas the remainder issue the non-contingent green contract g. On the other hand, if all types $k \in [0, 2\theta\alpha]$ issue the vanilla contract v, then necessarily all types $k \in [2\theta\alpha, 1]$ issue the non-contingent contract g. Hence, the main prediction of the model does not vary. The additional prediction of the model is that the lowest types only, i.e. those whose $k \in [0, 2\theta\alpha]$, should be the ones issuing vanilla contracts.

C Robustness

C.1 Specification of the green outcome

We specify the green outcome as the sum of a measurable and an uncertain component, $g(a, \tilde{z}) = a + \sigma\tilde{z}$. The specification implies that the relative degree of uncertainty in the green outcome reduces as the predictable component a (i.e. the scale of the investment) increases. The latter can be expressed as

$$Var(\frac{g(a,\tilde{z}) - \mathbb{E}[g(a,\tilde{z})]}{c(a)}) = \frac{\sigma^2}{c(a)}, \tag{52}$$

with $c(a) = \frac{1}{2}\theta a^2$ the cost of action i.e. investment. The feature in (52) implies that value of the option to wait to learn the realization of the uncertain state, z, decreases as the action cost θ decreases, and plays an important role when solving for the equilibrium issuance choices across firm types in presence of asymmetric information.

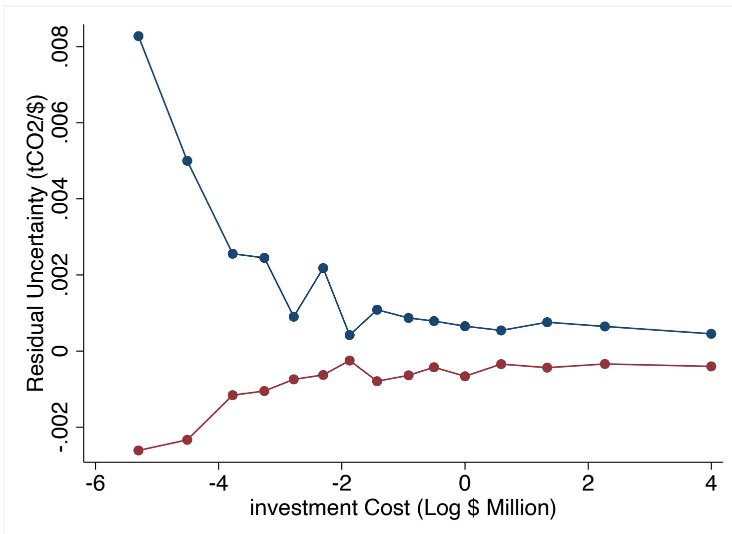
We micro-found the specification choice of the green outcome using firms' disclosures from the Carbon Disclosure Project (CDP). CDP is a not-for-profit charity that runs the global disclosure system for investors and companies to manage their environmental impacts. Firms that participate in CDP report voluntarily their current actions to mitigate carbon emissions. The reports include investment costs and realized environmental benefits in terms of emissions reduction, allowing us to test the assumption in (52). We focus on European and US firms reporting in 2017, the year after the Paris agreement announcement and before the global pandemic shock, obtaining a total of 2,635 pairs of investment costs and realized environmental benefits, denoted as c_j and g_j, respectively. Using the joint distribution $\{(c_j, g_j)\}_{j=1,...2,365}$, we create $b = 20$ equally sized bins sorting by investment costs, and for each bin we measure the residual uncertainty as

$$\sigma_b^2 = Var(\frac{g_j - \mathbb{E}[g_j | j \in b]}{c_j}) \tag{53}$$

Figure 10 show that the standard deviation in the mitigation project outcome (i.e. the emissions reduction) shrinks as the investment scale (i.e. level of action) increases, consistently with our model assumption.

Figure 10. Residual Uncertainty in the Outcome of Mitigation Technologies

The plot shows the distribution of the residual uncertainty in the outcome of carbon mitigation projects across equally sized bins of investment cost. The x-axis reports the average investment in \$ millions for each equally sized bin, in logarithmic scale. The y-axis reports the residual efficiency, measured as in (52) using the de-meaned CO2 savings per \$ invested. The red and blue lines show the 40th and 60th percentiles of the distribution within each bin respectively. Mitigation projects and relative CO2 savings are reported by firms participating in the 2017 CDP questionnaire.



C.2 Optimal Contract

In the model, we present two given types of green debt contracts, the outcome-based contingent contract, $y = cg$, which has an interest rate that is contingent on the reported outcome, and the action-based non-contingent green debt contract, $y = g$, which has a fixed interest rate that depends on ex-ante commitment to and verification of projects and action choices. We show below that a piece-wise linear contract which combines the outcome-based contingency with verification of actions can be strictly optimal in that it can replicate the first-best outcome while avoiding manipulation. However, as we argue below, these types of contracts are not yet seen in the market as they may be too costly to implement.

Optimal contract. *Define a step-wise linear contingent contract with interest rate*

$$\rho = \begin{cases} r & \text{if } x = 0 \\ r + \frac{1}{2\theta} - xa & \text{if } xg(a, z_r) \geq \bar{g} \\ \infty & \text{if } xg(a, z_r) < \bar{g} \end{cases} \tag{54}$$

with $\bar{g} = \frac{1}{2\theta}$ *the net expected green outcome. Then for each realization of the uncertain state* z*, the contract achieves the first-best project and action choices* $x^s(z)$ *and* a^s*, independently of the magnitude of the manipulation cost* ψ*.*

Proof. Recall that the first-best level of action is equal to $a^s = \frac{1}{\theta}$ if $x^s(z) = 1$, that is if $\frac{1}{2\theta} + \sigma z \geq 0$ (i.e. if $g(a^s, z) = \frac{1}{\theta} + \sigma z \geq \frac{1}{2\theta}$), and $a^s = 0$ otherwise. Suppose first that $\sigma z \geq -\frac{1}{2\theta}$. Then the firm implements the green project $x = 1$ and exerts action $a = \frac{1}{\theta}$, and its utility is $\mathcal{U}^f = R - r - \frac{1}{2\theta} - \frac{1}{2\theta} + xa = R - r = \mathcal{U}_v^f$. In such a case, the firm makes the same profits as if it was implementing the business-as-usual project $x = 0$, and we can assume that it goes for $x = 1$[48]. If, on the other hand, $\sigma z < -\frac{1}{2\theta}$, then the firm either chooses $x = 0$, or has to distort the outcome such that $g(a, z_r) = \frac{1}{2\theta}$ (that is $d = |z| - \frac{1}{2\theta}$). Doing so would cost an additional $\frac{1}{2}\psi(|z| - \frac{1}{2\theta})^2$, resulting in utility $\mathcal{U}^f = \mathcal{U}_v^f - \frac{1}{2}\psi(|z| - \frac{1}{2\theta})^2 < \mathcal{U}_v^f$, and thus making the distortion sub-optimal with respect to the choice of implementing the business-as-usual project. We therefore obtain $a = a^s$ and $x(z) = x^s(z)$ and $d_{cg} = 0$ for each realization of z.

The interest rate in (54) is step-wise linear in the level of exerted effort with the adjustment depending on the realized state z. This in turn means that the interest rate includes both ex-post reporting of outcomes but also verification of investment costs, and is therefore a combination of the two contracts studied in our model. Furthermore, for the threshold $\bar{g}$ to be correctly set ex-ante, it must be that the firm reports its cost of action θ at issuance. Hence, a security of this kind would request the firm i) to disclose ex-ante a plan for delivering the green outcome, and then ii) to report the achieved outcome together with balance-sheet data that would reveal the investment choices actually implemented. These types of contracts are not prevalent in the market. In practice, they may be too costly as they require a considerable level of ex-ante effort in discovering investment opportunities, as well as high monitoring costs throughout the lifetime of the contract.

[48] Similarly, we can assume an infinitesimally lower interest rate $\rho = r + \frac{1}{2\theta} - xa - \epsilon$, with ϵ arbitrarily small.