

# The Optimal Design of Green Securities <sup>\*</sup>

Adelina Barbalau<sup>†</sup> and Federica Zeni<sup>‡</sup>

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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 green 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' type, non-contingent debt can be used as an expensive signalling device, and we find empirically that contingent green debt securities have lower credit ratings, higher yields and are issued by more emissions intensive firms.

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<sup>†</sup>University of Alberta.

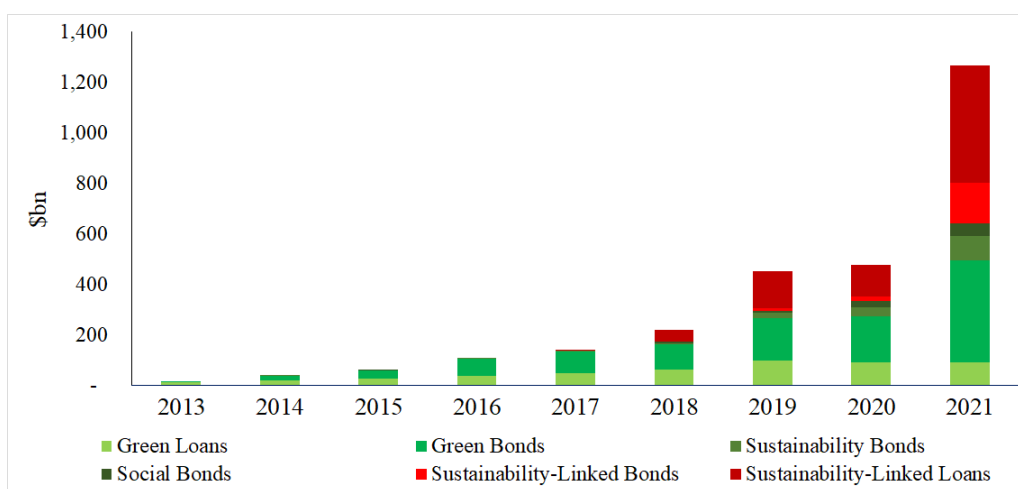
<sup>‡</sup>The World Bank.

# 1 Introduction

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 positive environmental and social benefits. The corporate sustainable debt market opened slowly about a decade ago and has grown exponentially in recent years, reaching a cumulative volume of approximately 2.5\$tn as of the third quarter of 2021.

**Figure 1.** Corporate Sustainable Debt Market

The figure shows cumulative issuance volume of corporate sustainable debt securities in \$ billions across years. Institutional details about the securities are reported in Section 3 and Appendix A.



The first and most predominant type of debt contract issued is the green bond (see Figure 1). Green bonds (GBs) are fixed income instruments 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 or re-finance green projects. The contract focuses solely on specifying ex-ante the projects that the borrower can allocate the proceeds to, but does not embed the mechanisms needed to ensure commitment to green outcomes. In contrast, the newly emerging class of sustainability-linked loans (SLLs) and bonds (SLBs), now making up about 45% of the market, does not impose ex-ante constraints on the projects that the proceeds can be allocated to, but instead makes interest payments contingent on realized green outcomes, such as carbon emission reductions.

The introduction of contingencies in securities' payoff addresses the limitations inherent to the design of project-based non-contingent securities such as green bonds by eliminating the need to

restrict borrower’s actions ex-ante and by making outcomes rather than intentions the focus of green projects 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.

In this paper, we propose a model of firm financing which embeds verifiable moral hazard, manipulation and asymmetric information, and which rationalizes the observed debt issuance patterns. 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. In the first time period or at an interim date before the second time period, the firm can decide to upgrade to a green project. The green project yields the same monetary return as the business-as-usual project and, at some further cost, an *uncertain* green outcome, which can be interpreted as a reduction in carbon emissions.

The investor is risk-neutral and has green preferences, in the sense that she equally values monetary and green outcomes.<sup>1</sup> We specify the green outcome delivered by the green project as the sum of a measurable and an uncertain component. The measurable component represents the firm’s costly action, and can be perfectly verified by the investor at a cost. The uncertain component of the green outcome can only be observed by the firm at an interim date, and its reported value can be manipulated at a cost.<sup>2</sup> The firm seeks to maximize profits by choosing to finance its investment through the issuance of one of the following three debt contract categories: a plain vanilla non-contingent contract, a project-based non-contingent green contract which involves ex-ante verification of action choices (similar in spirit to GBs), or an outcome-based contingent green contract which involves ex-post monitoring of green outcomes (similar in spirit to SLLs/SLBs).<sup>3</sup> The investor accepts the

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<sup>1</sup>We take as given the existence of a market that deploys capital to fund green projects (a similar assumption is also outlined in Pastor, Stambaugh, and Taylor [2020]) and focus solely on the firm’s optimal debt financing choice. As far as the risk-neutrality assumption is concerned, we show in Appendix B that introducing risk-aversion does not alter the baseline predictions of the model.

<sup>2</sup>The measurable component can be conceptualized as the expected level of carbon emissions reduction which can be inferred from the scale of investment in the green technology. The uncertain component can be interpreted, for example, as a piece of information about the true potential of the green technology to reduce carbon emissions, that becomes subsequently known to the firm, and which the firm can manipulate.

<sup>3</sup>The plain vanilla non-contingent contract is the most basic form of corporate debt whereby the investor lends the money in the first time period and receives the principal plus a predefined interest rate in the second time period. Note that we focus solely on the firm debt financing problem and disregard capital structure considerations. In

debt contract provided it generates at least zero return in expectation.

In the baseline single firm model, we show 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 as they involve costly verification of actions (in the spirit of Townsend [1979]), but give rise to an opportunity cost of committing to project and action choices before learning the outcome potential of these green projects. Contingent 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 green bonds in terms of the fact that the measurement of green outcomes was particularly difficult in the early stages of the market. On the other hand, subsequent improvements in measurement systems explain the co-existence of the two contract categories, 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 manipulation discount that comes with contingent contracts such as SLLs/SLBs (which arises because of measurement frictions).

Importantly, this trade-off 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 debt to finance it, which sheds light on observed issuance patterns across industries. The magnitude of the uncertain, manipulable component of the green outcome relative to the total green outcome delivered by the project, captures the degree to which a firm can control and measure green outcomes.<sup>4</sup> According to the model, projects which are more likely to be financed using non-contingent

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Appendix B we analyse the role of equity in a simple model extension which allows for uncertain monetary returns.

<sup>4</sup>We capture uncertainty about green outcomes using the emission intensity 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 a firm's emissions increases. 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 a firm. A similar ordering of carbon emissions' scopes according to their level of control can be found in a recent work by Kacperczyk and Peydro

green debt are those with very high or very low levels of green outcome uncertainty. We verify these predictions empirically when we proxy green outcomes using carbon emissions, as we see that non-contingent debt such as GBs is more prevalent in industries with either very high degree of control/measurability over carbon emissions such as utilities (because here the cost of commitment is low) or very low carbon emissions control/measurability such as financials (because here the distortion discount is very high).<sup>5</sup>

Next, we extend the model along the firm type dimension to explain issuance patterns within industries. Firm types are differentiated with respect to the cost of action and the cost of distortion that they face. Specifically, high type firms have a higher ability to invest in green projects and do not manipulate reported outcomes, while low type firms have a higher ability to manipulate outcomes and a lower ability to take costly action to deliver green outcomes.<sup>6</sup> The extended model provides testable predictions in terms of issuance choices across firm types which depend importantly on the degree of information available to the investor. When investors are perfectly informed about the firm type, the model predicts that, across possible choices of the model parameters, high firm types should always issue contingent green debt, intermediate types issue either contingent or non-contingent green debt, whereas low firm types issue vanilla debt. On the other hand, when there is asymmetric information over firm types, the model's prediction flips in that high firm types are expected to issue non-contingent green debt, whereas intermediate types unambiguously issue contingent green debt, and low firm types continue to prefer vanilla debt. The intuition is that when there is asymmetric information, the investor learns something about the firm type from the financing contract proposed, and non-contingent contracts such as GBs become signalling devices which allow high types to credibly reveal their ability to commit ex-ante. Since the cost of manipulation increases with firm type, high type firms will not find it advantageous to issue a contingent contract because by doing so they would effectively end up subsidizing low type firms.<sup>7</sup> Importantly, as a result of the combined presence of measurement and information frictions, the model predicts that holding an contingent green debt security should yield higher financial returns than holding a non-contingent green debt security in equilibrium, a prediction that we verify empirically.

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(2021).

<sup>5</sup>The focus on carbon emissions as a sensible proxy for green outcome is motivated by evidence that carbon emissions represent the most common metric underlying sustainability-linked debt targets (see appendix A).

<sup>6</sup>We borrow this assumption from a work related to ours by Allen and Gale [1992], discussed in extent in the literature section, and test the validity of this assumption in the empirical section.

<sup>7</sup>As we clarify in the paper, such flip in the equilibrium predictions relies, among other factors, on the assumption that action and distortion costs are negatively correlated across types.

As a first step to test the hypothesis of perfect information in the sustainable debt market, we search for ex-ante proxies of the firms' manipulation and distortion costs by merging security-level data from Bloomberg with issuer-level data from S&P Trucost and Sustainalytics. The argument is that if those proxies allow for a precise identification of firms' types within industry, then we should see that the best types are the ones innovating by issuing contingent contracts such as SLLs and SLBs. On the other hand if those proxies are only weakly correlated with unobservable characteristics of firms' types, then we should observe a negative correlation between contingent debt issuance choice and good firm types as captured by those noisy proxies. We measure the cost of action to deliver green outcomes using the physical cost of abating emissions as reflected in the firm's historical emissions intensity, defined as a firm's total emissions relative to assets from S&P Trucost. On the other hand, we borrow from the greenwashing literature [Netto, Sobral, Ribeiro, and Soares, 2020, Yang, 2020] and measure the cost of manipulation using the historical discrepancy between the firm's overall corporate sustainability image, as measured by the aggregate ESG score provided by Sustainalytics, and a credible signal of environmental commitment captured by the firm's actual adoption of an Environmental Management System (EMS).<sup>8</sup> Regression results indicate that within industries, issuers of contingent green debt have significantly higher cost of action and significantly lower cost of manipulation, and therefore do not classify as best types following the ordering provided by our proxies. This result indicates the presence of asymmetric information.

Finally, we test for the presence of asymmetric information by measuring yield differentials across contingent and non-contingent green debt securities after issuance. We follow the methodology in Zerbib [2017] and estimate green premia as the negative yield differential between a green security and a virtually identical conventional security from the same issuer. Specifically, we pair each GB, social and sustainability bond (non-contingent green debt) and SLB (contingent green debt) in our sample with a set of conventional bonds from the same issuer and with same coupon type, maturity type, currency, nearest maturity, and nearest coupon rate. After controlling for further effects due to differences in liquidity and credit ratings, we find that the green premium on non-

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<sup>8</sup>The EMS is a standardized framework that helps an organization achieve its environmental goals through consistent review, evaluation, and improvement of its environmental performance. A well functioning EMS both increases the firm's likelihood to achieve positive environmental outcomes and also makes it more difficult for the firm to manipulate the measurement system which monitors those outcomes (see also Lyon and Maxwell [2011]).

contingent green debt is higher than the green premium on contingent green debt, although those differences are not statistically significant. This evidence is in line with the model equilibrium prediction that contingent securities are issued by lower environmental types, and should therefore compensate the investor with higher financial returns than non-contingent securities. Put together, these empirical exercises support the joint presence of measurement and information frictions in the sustainable finance market, leading us to conclude that addressing such frictions should be a matter of first-order importance to support the transition to a green economy.

## 2 Related Literature

Our paper is related to the literature on sustainable investing,<sup>9</sup> which explores the condition under and channels through which financial markets can catalyze the transition to a sustainable economy. Notable papers in this literature stream include Heinkel, Kraus, and Zechner [2001] who study how exclusionary ethical investing impacts corporate behavior, Pastor et al. [2020] who study how shifts in customers' tastes for green products and investors' tastes for green holdings produce positive social impact, Oehmke and Opp [2020] who study the conditions 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. A paper 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<sup>10</sup> and an important role is played by the existence and behavior of groups of investors with heterogeneous beliefs and tastes regarding non-pecuniary motives. Our paper also relates to the literature on corporate green bonds, which aims at rationalizing the existence of these securities as a way to increase the firm's value by either lowering its cost of capital (Zerbib [2017]) or by signalling credible environmental commitment to investors (Flammer [2021]). We contribute to this literature by being the first to formally study

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<sup>9</sup>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.

<sup>10</sup>Among the few works that take a firm perspective there is Ramadorai and Zeni [2019] who document and rationalize corporate commitment in reducing carbon emissions around a regulatory announcement with a strategic model of reputation, and Bolton and Kacperczyk [2021] who provide an empirical analysis voluntary disclosure initiatives driven by institutional investors, and show that while institutional pressure matters, firms that respond the most are the ones that are already less carbon intensive.

corporate green bonds along with the newly emerging class of sustainability linked bonds, interpreting their co-existence as a result of measurement and information frictions.

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. 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. 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 at an interim date after issuance of the security. Thus, it is not only private information, but also flexibility that plays a key role in driving the results.

Finally, this paper also relates to the literature on financial innovation, which has explored a large number of reasons behind agents' incentives to innovate such as completing markets, addressing information asymmetries, responding to regulatory and economic changes, or capitalizing on investment opportunities (see Tufano [2003] for a survey). In a similar spirit to the work of Allen and Gale [1988], in our model incentives to innovate come from changes in the value of pre-existing assets or firm value.<sup>11</sup> In our paper, monetizing investors' green preferences depends importantly on the possibility to measure green benefits, so it is the interaction between demand for green investing and advances in measurement systems that allow firms to innovate by incorporating contingencies in their green debt contracts. A paper related to ours is Manso, Strulovici, and Tchisty [2010] who study performance sensitive debt (PSD), an innovative debt instrument whereby the interest rate

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<sup>11</sup>The firm innovates to maximize its value by capitalizing on the fact that investors value the green benefit that the project under management has the potential to deliver and are willing to pay for it. This is in line with the evidence that the market for sustainable financed has had a bottom up development, being driven by investor demand.

varies ex-post with some performance metric of the borrower. Despite sharing the same security payoff structure, there is a model of risky debt valuation with endogenous costly bankruptcy which differs essentially from ours in that their performance metric is perfectly measurable by the investor and cannot be manipulated. Under perfect information their model predicts that PSD is sub-optimal, but when there is asymmetric information between investors and the borrowing firm, PSD can be used as a screening device and so it is optimally issued by the best firm types.

### 3 Institutional Details

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.<sup>12</sup> Green bonds (GBs) are fixed income instruments which are differentiated from regular bonds by a green label, which signifies a commitment to exclusively use the funds raised to finance or re-finance green projects. Insofar as GBs finance projects that are expected to yield green benefits, the capital raised depends on these expected green benefits, which are signalled ex-ante by the issuer and which effectively constitute a green promise that is monetised through the issuance of this security. Put differently, a firm issuing a green bond is basically receiving an upfront subsidy, which gives rise to an agency problem since the firm has no incentive to commit to delivering the promised green benefit once it has obtained the funds, given that it is costly to do so.

An effective tool to mitigate this moral hazard problem is represented by the verification process associated with obtaining a green label, which is aimed at ensuring that ex-ante green promises are followed through. Issuers can obtain a green label from a number of certification providers, most of which adhere to the Green Bond Principles (GBPs).<sup>13</sup> The GBPs provide issuers with high level guidance on the key components involved in launching a credible green bond, and 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, while making no reference to outcomes delivered by

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<sup>12</sup>The first corporate green bond was issued in 2013 by Swedish housing company Vasakronan.

<sup>13</sup>The GBPs, which were introduced in January 2014 by the International Capital Market Association (ICMA), are voluntary process guidelines for issuing green bonds that were put together by a consortium of some of the largest investment banks worldwide. 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.

the projects.<sup>14</sup> 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 and Sustainability Bonds. While Social Bonds raise funds for projects that address social issues and/or seek to achieve positive social outcomes, the proceeds obtained through the issuance of Sustainability Bonds 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 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.<sup>15</sup> 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 component is mandatory 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 green bonds.<sup>16</sup> In the case of SSLs, 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.

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<sup>14</sup>For example, Apple clearly states that there can be no assurance "that funded projects meet investor criteria or expectations regarding sustainability performance".

<sup>15</sup>The first SLL was issued in April 2017 by the Dutch health technology company Koninklijke Philips.

<sup>16</sup>For a discussion about the difference between auditing reports and proper certifications of green securities see also Baker, Bergstresser, Serafeim, and Wurgler [2018].

## 4 Model

The baseline economy features two time periods, an investor, and one firm in the market. At time  $t = 0$ , the firm has access to a project which costs 1\$ and yields a certain monetary return of  $\$1+R$  at time  $t = 1$ . At time  $t = 0$  or at an interim date before  $t = 1$ , the firm can decide to upgrade to a green technology by investing in a green project. The green project delivers, at time  $t = 1$ , the same monetary return and an uncertain green outcome  $g(\tilde{z}, a)$  which can be conceptualized as a reduction in carbon emissions. The green outcome is the sum of two components

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

The first component  $a$  denotes the firm's costly action choice, which can be thought of as the scale of investment in the green technology, whereas the second component  $\tilde{z} \sim \mathcal{N}(0, 1)$  is an uncertain state capturing the true environmental quality of the technology, that is revealed only to the firm at an interim date between  $t = 0$  and  $t = 1$ . The action  $a$  encompasses the portion of the outcome that can be perfectly verified by the investor. The interpretation of this component is that based on ex-ante information about the scale of the investment in the technology, the investor can form a meaningful expectation about the average emission savings delivered by the project i.e. the action can be backed out from the cost of action, which is expressed in monetary terms and thus measurable. The uncertain state  $\tilde{z}$  is the component of the outcome that cannot be observed nor verified by the investor, and whose reported value can be manipulated by the firm ex-post. The interpretation is that for a given scale of investment, there is residual uncertainty with respect to the emissions savings delivered by the project, which can for instance depend on hidden technology fundamentals that are privately revealed to the firm. The parameter  $\sigma$  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. In other words, a high degree of uncertainty regarding the green outcome stands for a harder to assess and control green outcome.

The investor has a linear utility which equally values consumption (i.e. the monetary outcome) and the green outcome. Denoting  $x = \{0, 1\}$  the firm's binary choice of whether to implement the

green project, the investor's utility reads

$$\mathcal{U}^I = \mathcal{C}_0^I + \mathcal{C}_1^I + xg(\tilde{z}, a), \quad (2)$$

and the investor's endowments are  $n_0^I \gg 1$  and  $n_1^I = 0$  at time  $t = 0$  and  $t = 1$ , respectively.

The firm, on the other hand, has monetary preferences only and pays a quadratic cost of action to deliver the green outcome

$$\mathcal{U}^f = \mathcal{C}_0^f + \mathcal{C}_1^f - x\frac{1}{2}\theta a^2 \quad (3)$$

with  $\theta$  the action cost parameter, and endowments  $n_0^f = n_1^f = 0$  at time  $t = 0$  and  $t = 1$ , respectively.

Before introducing the details of the financing problem, it is useful to derive an efficient benchmark for the project and investment choices of a perfectly informed social planner.

#### 4.1 Central Planner Problem

The first-best project and action choices,  $x$  and  $a$  respectively, are obtained by solving the problem of a social planner, indexed by  $s$ , which is perfectly informed about the realization of the uncertain state (e.g.  $\tilde{z} = z$ ), and maximizes the aggregate utility

$$\max_{a,x} \mathcal{U}^I + \mathcal{U}^f = R + \max_{a,x} x(g(z, a) - \frac{1}{2}\theta a^2). \quad (4)$$

The Euler conditions yield the following project and action choices

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

Thus, the social planner finds it optimal to implement the green project provided that the realization of the uncertain state  $z$  is such that the green outcome delivered by the project is higher than the cost. The optimal action, interpreted as the level of investment, is conditional on the project implementation and can be thought of as the intensive margin of investment. Clearly, if the project is not implemented the optimal action is zero. Importantly, note that the social planner's choices are state dependent.

#### 4.2 Decentralized Problem

In the decentralized market, the firm seeks to maximize utility (3) by proposing a debt contract  $y$  to the investor. The generic structure of the debt contract is as follows: at date  $t = 0$ , the investor

lends  $b_0^y = \$1$  to the firm, so that the latter can afford the implementation of (at least) the baseline project yielding a positive and certain monetary return.<sup>17</sup> Depending on the design of the contract  $y$  and its associated characteristics, the firm will then decide the green project and action choices,  $x^y$  and  $a^y$  respectively, which depend on the realization  $z$  of the uncertain state variable  $\tilde{z}$  in ways that will be detailed below. At date  $t = 1$ , the firm will repay the investor an amount  $b_1^y = \$1 + \rho^y$ , with  $\rho^y$  denoting the interest rate associated with the debt contract. The investor's participation constraint, which features the optimal project specific project and action choices,  $x^y$  and  $a^y$ , is<sup>18</sup>

$$-b_0^y + \mathbb{E}[b_1^y + x^y g(\tilde{z}, a^y)] \geq 0. \quad (6)$$

In what follows, we take a positive approach to studying green project financing in that we analyse the welfare implications of firm's issuance choices using a given set of debt contracts whose design is similar to that of securities currently observed in the market. Formally, we assume that the firm can choose one among a specified set of securities  $y \in \{v, g, cg\}$  which differ in term of the interest rate specification, where  $v$  stands for a plain vanilla debt contract,  $g$  stands for a project-based non-contingent green debt contract, and  $cg$  stands for an outcome-based contingent green debt contract.

The *vanilla* contract, indexed by  $v$ , is a simple form of debt contract which repays the investor at date  $t = 1$  a fixed interest rate  $\rho^v$ .

The *project-based non-contingent* green debt contract, indexed by  $g$ , involves ex-ante commitment to a project  $x^g = 1$  and action  $a^g$  at the moment of issuing the security. This contract specifies an interest rate  $\rho^g$  that will remain fixed throughout the life of the contract. At issuance, the firm also pays a verification cost  $\alpha$  to certify its commitment to the project and action choices, and which can be thought of as the cost needed to allow the investor to observe the action choice  $a^g$  conditional on implementing the green project  $x^g = 1$ . The verification cost maps into the green bond label that certifies the firm's commitment to dedicate the proceeds to green projects, i.e. the ex-ante certification of the firm's compliance with the Green Bond Principles.

The *outcome-based contingent* green debt contract, indexed by  $cg$ , does not involve ex-ante se-

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<sup>17</sup>The positive certain monetary return and the fact that the firm has zero endowments ensures that external financing is always profitable in equilibrium, i.e. there are no equilibrium outcomes where no contract  $y$  is chosen.

<sup>18</sup>The participation constraint comes from the investor's zero return requirement  $C_{0,y}^I + \mathbb{E}[C_{1,y}^I + xg(\tilde{z}, a^y)] \geq n_0^I$  where time 0 and time 1 consumption are given by  $C_{0,y}^I = n_0^I - b_0^y$  and  $C_{1,y}^I = b_1^y$ , respectively.

lection of projects nor commitment to actions, but incentivize commitment to outcomes through the introduction of a state-dependent interest rate  $\rho^{cg}$  which is contingent on the realization of the uncertain green outcome:

$$\rho^{cg} = \bar{\rho}^{cg} - x^{cg} g(z_r^{cg}, a^{cg}), \quad (7)$$

where  $\bar{\rho}^{cg}$  is a base interest rate set at date  $t = 0$ ,  $x^{cg}$  and  $a^{cg}$  are the firm's optimal project and action choices decided at a later date after the security issuance, and  $z_r^{cg}$  is the *reported* uncertain component of the green outcome. The specification (7) implies that the firm will pay the base interest rate  $\bar{\rho}^{cg}$  if it reports no green outcome, and it will be rewarded with a lower interest rate if it reports a positive green outcome. The firm pays an auditing cost  $\alpha$  in order to produce the report about the green outcome  $g(z_r^{cg}, a^{cg})$  and let the investor observe it.<sup>19</sup> Notwithstanding auditing, the reported uncertain state  $z_r^{cg}$  can differ from the true realized state  $z$ , so this specification creates an incentive for ex-post manipulation, in that by reporting a state  $z_r^{cg} \geq z$ , the firm can repay the debt at a lower interest rate than in the case of truthful reporting. The reported uncertain state is a function of an optimal level of distortion as follows:

$$z_r^{cg} = z + d^{cg}, \quad (8)$$

where the distortion choice  $d$  comes at quadratic cost  $\frac{1}{2}\psi d^2$ , with  $\psi$  the distortion cost parameter (in the spirit of the literature on strategic communication with lying costs by Kartik [2009]).

## 5 Single Firm

This section considers a single firm model to highlight the key mechanisms that drive a firm's preference for issuing a non-contingent or a contingent debt contract. The extended model with multiple firm types, as well as its equilibrium predictions in presence of asymmetric information are considered in the next section.

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<sup>19</sup>For simplicity, we assume that auditing costs in outcome-based contingent contracts are comparable to verification costs in project-based non-contingent contracts. However, one can also show that, with exception of predictions across industries, all of the predictions outlined in this paper are the same if auditing costs are assumed strictly smaller than verification costs.

## 5.1 Vanilla security

It is trivial to observe that the vanilla contract is affected by a standard moral hazard problem in that costly actions to deliver the green outcome are not verified, and the contract payoff does not embed a contingency to incentivize commitment to the green outcome. As a result, any attempt to finance the green project with this security will fail, the investor will anticipate that the firm has no incentive to implement the green project upon the issuance of this contract (e.g.  $x^v = 0$  independently of the realized state  $z$ ), and will demand a minimum contract interest rate  $\rho^v \geq 0$ . Conditional on issuing this contract, the firm's utility reads

$$\mathcal{U}_v^f = R. \tag{9}$$

## 5.2 Project-based, non-contingent security

Project-based non-contingent green debt contracts are those whereby project selection takes place ex-ante, 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.

We capture this in the context of our model by making the firm choose the project  $x^g$  and commit to an action choice  $a^g$  at the moment of issuing the security and thus *prior* to the realization of the random state  $\tilde{z}$ . Importantly, the firm pays a verification cost  $\alpha$  to make the commitment credible. This is interpreted as the cost that the firm incurs to set up the processes by which the investor will be able to verify ex-post that the action it has committed to is effectively the same as the one actually implemented. This mechanism is again in line with the green bond principles which revolve around setting up the processes and mechanisms necessary to facilitate verification, such as placing the bond proceeds in a separate account that the investor can verify to make sure that they are used for projects aligned with the security purpose.

Conditional on the issuance of a debt contract  $g$ , the firm problem can be simplified as follows

$$\mathcal{U}_g^f = \max_{a,x} R - \rho^g - x \frac{1}{2} \theta a^2. \tag{10}$$

subject to the investor participation constraint, which features the contract specific optimal project and action choices,  $x^g$  and  $a^g$ , respectively

$$\mathbb{E}[\rho^g + x^g g(\tilde{z}, a^g)] \geq 0. \quad (11)$$

Recalling that with this security there is credible commitment, meaning that the project and action choices revealed at the time of issuing the security are the same as those actually implemented by the firm, i.e.  $x^g = x$  and  $a^g = a$ , and substituting the binding participation constraint (11) into (10), the firm problem becomes

$$\mathcal{U}_g^f = R + \max_{a,x} x(\mathbb{E}[g(\tilde{z}, a)] - \frac{1}{2}\theta a^2 - \alpha) \quad (12)$$

from which we obtain optimal project and action choices

$$x^g = 1\{\frac{1}{2}a^g - \alpha > 0\} \quad \text{with} \quad a^g = \frac{1}{\theta}. \quad (13)$$

From (11), one notes that the contract rate  $\rho^g = -\mathbb{E}[x^g g(\tilde{z}, a^g)]$ , from which follows that the interest rate on the project-based non-contingent contract is  $\rho^g = -\frac{1}{\theta}$  if  $x^g = 1$ , and is  $\rho^g = 0$  if  $x^g = 0$ . Importantly, note that

$$\mathcal{U}_g^f > \mathcal{U}_v^f \quad \text{iff} \quad x^g = 1 \quad (14)$$

meaning that the firm has a strict preference for contract  $g$  relative to contract  $v$  if and only if it commits to the implementation of a green project.<sup>20</sup> If this non-contingent green contract  $g$  is issued, the interest rate  $\rho^g = -\frac{1}{\theta}$  is *lower* than the rate associated with the vanilla contract,  $\rho^v \geq 0$ , meaning that the investor is willing to pay a green premium by accepting a negative interest rate. 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., 2018, Kapraun and Scheins, 2019]. Thus, ex-ante commitment is important because insofar as it is credible, it provides a sufficient alignment of the firm's and the investor's incentives so as to make possible the implementation of the green project. Importantly though, since the project choice is determined at issuance and therefore independent of the realisation of the random state  $z$ , ex-ante commitment is also costly as the firm gives up the opportunity to wait and learn more about the green technology. This is a first important implication of the model stating that, when resolving the moral hazard problem intrinsic in the vanilla contract by means

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<sup>20</sup>This follows from the fact that the firm's utility if  $x^g = 1$  is  $\mathcal{U}_g^f = R + \frac{1}{2\theta} - \alpha$  and this is greater than  $\mathcal{U}_v^f$  if  $2\alpha\theta < 1$ , which is exactly the condition for  $x^g = 1$ . On the other hand, if  $x^g = 0$  the firm utility is  $\mathcal{U}_g^f = R = \mathcal{U}_v^f$ .

of a green non-contingent contract with verifiable commitment, gives rise to an opportunity cost of commitment as the firm is forced to make green promises at issuance.

### 5.3 Outcome-based, contingent security

With contingent green debt contracts, the firm does not commit to projects ex-ante, but chooses them ex-post after the issuance of the security and after the observation of the random state  $\tilde{z}$ . With this security, instead of ex-ante commitment we have ex-post reporting of realised green outcomes, which can be manipulated.

The firm problem upon issuance of this contract can be simplified to

$$\mathcal{U}_{cg}^f = R - \bar{\rho}^{cg} + \max_{a,x,d} x(g(z_r, a) - \frac{1}{2}\theta a^2 - \frac{1}{2}\psi d^2 - \alpha) \quad (15)$$

where  $\psi$  is a distortion cost parameter,  $\alpha$  is the cost of auditing, and the base interest rate is now subject to the participation constraint

$$\bar{\rho}^{cg} \geq \mathbb{E}[x^{cg}g(\tilde{z}_r^{cg}, a^{cg}) - x^{cg}g(\tilde{z}, a^{cg})]. \quad (16)$$

The participation constraint tells us that the base rate  $\bar{\rho}^{cg}$  is at least as high as the expected distortion imposed by the firm. Specifically, the minimum acceptable base interest rate  $\bar{\rho}^{cg}$  reflects the expected deviation of reported green outcome from the actual green outcome of the project, such that the investor effectively imposes a *distortion discount* in the pricing of this contract by raising the expected cost of financing for the firm.

When the cost of distortion is prohibitively high, i.e.  $\psi = +\infty$  such that  $d^{cg} = 0$ , the green outcome is truthfully reported for each realization  $z$  of the uncertain state  $\tilde{z}$ , i.e.  $z_r^{cg} = z$ . The minimum required interest rate  $\bar{\rho}^{cg}$  is thus zero and the variable, state-contingent interest rate  $\rho^{cg}$  in (7) will depend on the reported green outcome. Specifically, it will be set so as to perfectly offset the reported green performance in every state, i.e.  $\rho^{cg} = -x^{cg}(z_r^{cg}, a^{cg})$ . Making explicit the dependence on the realised state  $z$ , first-order conditions yield optimal choices

$$x^{cg}(z) = 1\{\frac{1}{2}a^{cg} + \sigma z - \alpha > 0\} \text{ with } a^{cg} = \frac{1}{\theta}. \quad (17)$$

The firm's utility in this case is

$$\mathcal{U}_{cg}^f = \mathcal{U}_v^f + \left( \frac{1}{2} \frac{1}{\theta} + \sigma \tilde{z} - \alpha \right)^+ \quad (18)$$

and its expected value is unambiguously higher than  $\mathcal{U}_v^f$ , as well as unambiguously higher than  $\mathcal{U}_g^f$ , as formalized in Appendix B. In fact, note that if manipulation is prohibitively costly and auditing costs are low, the optimal state-dependent choices equate the first best in (5).

On the other hand, when the distortion cost is not sufficiently high to deter manipulation  $\psi \ll +\infty$ , meaning when the contingency depends on a measurement system which can be manipulated, optimal action and distortion choices read

$$x^{cg}(z) = 1_{\left\{ \frac{1}{2} a^{cg} + \frac{\sigma}{2} d^{cg} + \sigma z - \alpha > 0 \right\}} \text{ with } a^{cg} = \frac{1}{\theta} \text{ and } d^{cg} = \frac{\sigma}{\psi}. \quad (19)$$

Result (19) states that when manipulation is possible, the firm's optimal distortion  $d^{cg}$  increases with the uncertainty surrounding the project green outcome  $\sigma$  and decreases with the distortion cost  $\psi$ .<sup>21</sup> Importantly, note that the firm may optimally devote more effort towards manipulating reported outcomes rather than taking costly action to deliver green outcomes if the model parameters satisfy  $\theta > \frac{\psi}{\sigma}$ . This prediction implies that firms can achieve a higher 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 model feature 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.

Equation (19) also indicates that because of a state-independent gain that comes from manipulation, a green project is unambiguously *more* likely to be implemented when manipulation is possible than it is in the case of no manipulation. This is an important feature of the model which implies that, for high levels of manipulation, the benefit of waiting to learn the realization of uncertain state  $z$  is eroded by the possibility of manipulation. On the other hand, as reported in Appendix B, the optimal expected green outcome under manipulation is lower than that obtained using the contingent green security  $cg$  with no manipulation, but higher than the outcome obtained

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<sup>21</sup>This come from the fact that the cost of distortion is independent of  $\sigma$ , hence distortion benefits increase with  $\sigma$ . A different specification where the distortion costs increase linearly in  $\sigma$  does not affect qualitatively any of the predictions in the paper.

using the non-contingent green security  $g$ .

Plugging in optimal choices into the firm utility we have

$$\mathcal{U}_{cg}^f = \mathcal{U}_v^f + \left(\frac{1}{2} \frac{1}{\theta} + \frac{1}{2} \frac{\sigma^2}{\psi} + \sigma \tilde{z} - \alpha\right)^+ - \bar{\rho}^{cg}. \quad (20)$$

Note that if the minimum required rate  $\bar{\rho}^{cg}$  was set to zero, then the firm would have a higher expected return relative to the case of no manipulation. However, we assume that the investor is aware that the reported green outcome is different from the actual green outcome, and so will require a higher base interest rate

$$\bar{\rho}^{cg} = \mathbb{E}\left[\frac{\sigma^2}{\psi} 1\left\{\frac{1}{2} \frac{1}{\theta} + \frac{1}{2} \frac{\sigma^2}{\psi} + \sigma \tilde{z} - \alpha > 0\right\}\right] \quad (21)$$

which is obtained by plugging in the optimal distortion choice in (19) into (16). In other words, we assume that the investor is perfectly internalizing the distortion imposed by the firm by setting the base rate to satisfy the participation constraint outlined in (16) or, in other words, demands a distortion premium.

As we show next, when the green outcome is manipulable and the investor correctly internalizes this, the firm's expected utility when financing is done using the contingent security is no longer unambiguously higher than that obtained when issuing non-contingent contracts.

#### 5.4 Optimal security choice

Formally, the firm's contract choice can be written as

$$y = \operatorname{argmax}_{v,g,cg} \{\mathcal{U}_v^f, \mathcal{U}_g^f, \mathbb{E}[\mathcal{U}_{cg}^f]\} \quad (22)$$

where  $\mathcal{U}_v^f, \mathcal{U}_g^f$  and  $\mathbb{E}[\mathcal{U}_{cg}^f]$  denote the firm's expected utility upon issuance of the vanilla contract  $v$ , the non-contingent green contract  $g$ , and the contingent green contract  $cg$ , respectively.

#### **Trade-off driving choice between contingent and non-contingent green debt contracts.**

Let us assume for a moment that the verification cost  $\alpha = 0$ , which has the implication that the firm is strictly better off issuing one of the proposed green debt contracts and not the vanilla one. There are two competing forces which drive the firm's preference for a contingent green contract

relative to a non-contingent green contract: the *opportunity cost* of committing to projects ex-ante associated with the non-contingent contract, and the *distortion discount* associated with the contingent contract which is generated by the fact that reported outcomes can be manipulated. We define a synthetic *project-based contingent green* contract  $pcg$ , involves ex-ante selection of the green project at issuance as in  $g$ , thus giving rise to an opportunity cost of commitment, and which also embeds contingencies by making the cost of capital dependent on reported outcomes, thus giving rise to an incentive to manipulate as in  $cg$ .<sup>22</sup> We can identify these competing forces in equation (23), by adding and subtracting the firm's utility from the issuance of this synthetic project-based contingent contract, indexed by  $scg$ , from the firm's net profits yielding

$$\mathbb{E}[U_{cg}^f] - U_g^f = \underbrace{(\mathbb{E}[U_{cg}^f] - \mathbb{E}[U_{pcg}^f])}_{\text{opportunity cost} \geq 0} - \underbrace{(U_g^f - \mathbb{E}[U_{pcg}^f])}_{\text{distortion discount} \geq 0}. \quad (23)$$

It is therefore immediate to see that, if the *opportunity cost* of committing ex-ante to the green project is lower than the *distortion discount* generated by manipulation, then the firm should opt for the non-contingent green security  $g$ , whereas if the opposite is true than the firm should opt for the contingent green security  $cg$ .

**Figure 2.** Comparative Statics of the Trade-Off - Single Firm

The plots show the firm's expected net profits in (23) (black line) as well as the opportunity cost component (green line) and distortion cost component (red line) as a function of the parameter  $\sigma \in [0, 2]$  (left plot),  $\theta \in [0.5, 10]$  (mid plot), and  $\psi \in [1, 50]$  (right plot) respectively. Other model parameters are  $\alpha = 0.0$ ,  $\theta = 1.5$ ,  $\psi = 1.8$  (left plot),  $\alpha = 0.0$ ,  $\psi = 2.0$ ,  $\sigma = 0.5$  (mid plot),  $\alpha = 0.0$ ,  $\theta = 1.0$ ,  $\sigma = 0.5$  (right plot), respectively.

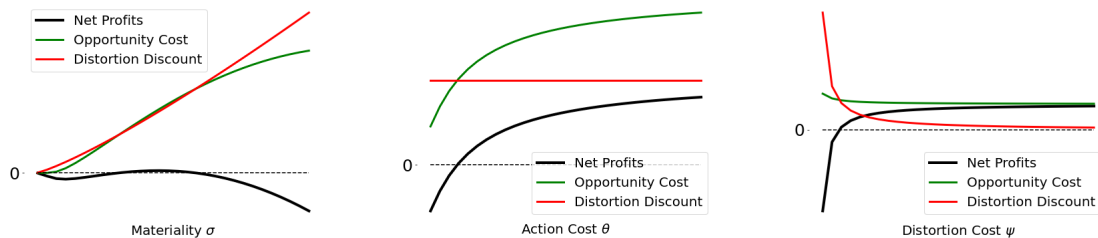


Figure 2 shows how the trade-off in (23) varies with the uncertainty of the project green outcome  $\sigma$  (left-hand plot), the action cost  $\theta$  (mid plot), and the distortion cost  $\psi$  (right-hand plot) respectively. The left-hand plot shows that issuance choices are non-monotonic as a function of the

<sup>22</sup>It can be shown that  $\mathbb{E}[U_{pcg}^f] = U_v^f + \frac{1}{2} \frac{1}{\theta} - \frac{\sigma^2}{2} \frac{1}{\psi}$ .

uncertainty parameter  $\sigma$ . As  $\sigma$  increases, both the opportunity cost of commitment (in green) as well as the distortion discount (in red) increase as a function of  $\sigma$ .<sup>23</sup> However, one notes that the distortion discount is convex in  $\sigma$ , whereas the opportunity cost of commitment is first convex and then concave in  $\sigma$ . The convexity of the distortion discount comes from the fact that the expected level of distortion in a green project (or equivalently the base rate in (21)) is quadratic in  $\sigma$ . On the other hand, the convexity and then concavity of the opportunity cost of commitment requires more explanation: for small values of  $\sigma$ , expected benefits from manipulation are low and the firm's compensation is largely dependent on the *true* outcome state  $z$ . In such a case, an increase in  $\sigma$  increases the “value of the option to wait” in the standard quadratic manner<sup>24</sup>, generating the observed convexity. On the other hand, when  $\sigma$  becomes larger, expected benefits from manipulation become a predominant portion of the firm's compensation, therefore inducing the firm to undertake the green project independently of the realized outcome state  $z$ . As a result of these combined nonlinearities, the firm tends to prefer non-contingent green contracts when  $\sigma$  is low, contingent green contracts for intermediate values of  $\sigma$ , and it eventually opts for the non-contingent green contracts when  $\sigma$  is large. As we show later in the empirical section, this interesting non-monotonicity result is in line with observed issuance patterns across industries.

The mid plot shows that net profits from the issuance of the contingent contract increase monotonically with the action cost  $\theta$  and are uniquely driven by the opportunity cost component. Specifically, the opportunity cost of foregoing information about the green outcome increases as the predictable component of the green outcome (i.e. the inverse of the cost of action  $\theta$ ) decreases. As we argue later when introducing firm types, this feature is relevant in generating equilibrium results that vary considerably depending on the investor's information set. Similarly, the right-hand plot shows that net profits from the issuance of the contingent contract increase monotonically with the distortion cost  $\psi$  and they are (almost) uniquely driven by the distortion discount component. Importantly as formalized by the proposition below, for extreme values of the distortion discount  $\psi$ , the firm has a strict preference for the non-contingent contract or for the contingent contract, in the sense that it is a strictly dominant strategy for the firm to finance the green project via one or the other type of contract independently of the other model parameters.

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<sup>23</sup>Note that for projects with no uncertainty (i.e.  $\sigma = 0$ ) the firm is always indifferent between a contingent and a non-contingent contract because the opportunity cost of committing to a project ex-ante is equal to the ex-post distortion discount, and both are equal to zero.

<sup>24</sup>See, for example, Kandel and Pearson [2002].

**Proposition 1.** *Let  $y$  denote the optimal contract choice in (20). For each couple of parameters  $(\sigma, \theta) \in (0, +\infty)$  and  $\alpha \geq 0$ , it always exists a pair  $(\underline{\psi}, \overline{\psi})$  such that:*

- *if the distortion cost  $\psi > \overline{\psi}$ , then  $y = cg$  and the firm always issues a contingent contract.*
- *if the distortion cost  $\psi < \underline{\psi}$ , then  $y \neq cg$  and the firm never issues a contingent contract. In such a case, if  $2\alpha\theta > 1$ , then  $y = v$  and the firm issues a vanilla contract, whereas if  $2\alpha\theta \leq 1$ , then  $y = g$  and the firm issues a non-contingent green contract.*

This baseline proposition sheds light on the time-series evolution of the sustainable debt market and explains the initial dominance of green bonds in terms of the fact that the measurement of green outcomes was particularly difficult in the early stages of the market (e.g. when  $\psi < \underline{\psi}$ ). On the other hand, when green outcomes becomes measurable with great precision (e.g. when  $\psi > \overline{\psi}$ ), then the model predicts that the outcome-contingent contract is unambiguously optimal.

## 6 Multiple Firm Types

So far we have focused on optimal security issuance from the point of view of a single firm, deriving predictions in a general setting which depends on three independent state variables: the cost of action, the cost of distortion, and the uncertainty surrounding the project outcome. In this section we aim to impose restrictions on the firm's action and distortion ability so as to reduce the number of state variables at play and derive more refined, testable predictions from the model.

We assume that there is a continuum of firm types  $k$  drawn from a uniform distribution  $k \sim \mathcal{U}[0, 1]$ . The firm type  $k$  is related depends on the cost of action and the cost of distortion parameters as follows:

$$\theta_k = \theta \frac{1}{k}, \quad \psi_k = \psi \frac{1}{1-k}, \quad (24)$$

meaning that the highest type firm,  $k = 1$ , has infinite distortion cost and action cost equal to  $\theta$ , while the lowest type firm,  $k = 0$ , has infinite action cost and distortion cost equal to  $\psi$ . The pair  $(\theta_k, \psi_k)$  identifies the firm type and is independent of the parameter  $\sigma$ , which now uniquely identifies the project type in terms of green outcome uncertainty.

Condition (24) states that the ability to distort the green outcome is *negatively correlated* with the ability to produce the outcome in the first place. Intuitively, the assumption implies that

it is often companies that do not have systems in place to measure negative externalities/green outcomes that both: 1) have leeway to misreport or manipulate, i.e. have low cost of distortion; and 2) do not take action to reduce negative externalities/deliver green outcomes, i.e. have high cost of action. This assumption is also supported by 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”. In addition to the fact that adoption of an EMS stands for commitment to environmental performance, Lyon and Maxwell [2011] find that corporate adoption of an EMS also makes it more difficult for the firm to manipulate the measurement system which monitors those outcomes. These lend support to the idea that the propensity to take costly action is negatively related to the propensity to manipulate.

In deriving the predictions that follow, we assume that the verification cost  $\alpha$  satisfies  $0 < 2\alpha\theta < 1$  for a given action cost  $\theta$ , so that the issuance of the project-based non-contingent green contract has positive (negative) net present value for the highest (lowest) type  $k = 1$  ( $k = 0$ ).<sup>25</sup>

## 6.1 Perfect Information

We first analyse the baseline case where the investor is perfectly informed about the firm type  $k$ , that is, the continuum of firm types  $k$  can be perfectly observed by the investor who knows the mapping between the cost of action and distortion faced by a firm  $k$ .

### 6.1.1 Optimal security choice

A firm  $k$ 's contract choice is

$$y_k = \operatorname{argmax}_{v,g,cg} \{U_v^f, U_g^f(k), \mathbb{E}[U_{cg}^f(k)]\} \quad (25)$$

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<sup>25</sup>The condition  $0 < 2\alpha\theta < 1$  comes from the firm utility associated with the non-contingent green contract which for the firm type  $k$  reads  $U_g^f(k) = U_v^f + \frac{k}{2\theta} - \alpha$ , such that the non-contingent green contract is strictly preferred if and only if  $k > 2\alpha\theta$ . Thus, there is an internal type  $k = 2\alpha\theta \in (0, 1)$  which is indifferent between issuing the plain vanilla and the green non-contingent contract.

where  $\mathcal{U}_g^f(k)$  and  $\mathbb{E}[\mathcal{U}_{cg}^f(k)]$  are type-specific utilities from issuing the non-contingent green contract  $g$  and the contingent green contract  $cg$  obtained by substituting the expressions for  $\theta_k$  and  $\psi_k$  in (24) into the utility functions (12) and (20), respectively.<sup>26</sup>

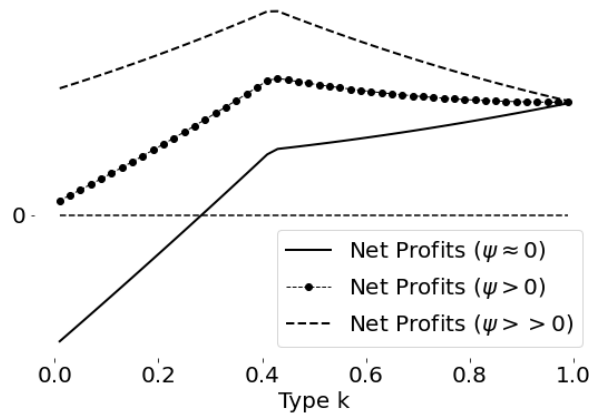
The expected net profits from issuing the contingent contract  $cg$  are defined as

$$\begin{cases} \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_v^f & \text{if } k \in [0, 2\alpha\theta] \\ \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_g^f(k) & \text{if } k \in (2\alpha\theta, 1]. \end{cases} \quad (26)$$

Figure 3 shows that if  $k \in [0, 2\alpha\theta]$ , then the net profits in (26) are strictly increasing as a function of the type  $k$ . This is because when the alternative to a contingent green contract is a vanilla contract, higher types are better off issuing contingent contracts because of their combined lower action costs and higher distortion costs. On the other hand, when  $k \in (2\alpha\theta, 1]$ , then the net profits in (26) can be non-monotonic as a function of  $k$  depending on the magnitude of the type-specific opportunity cost of ex-ante commitment relative to the distortion discount. Specifically, the op-

**Figure 3.** Comparative Statics of the Trade-Off - Multiple Firm Types

The plot shows the firm's net expected profits from issuance of a contingent green contract in (26) as a function of the firm type  $k$  for three different values of the distortion cost  $\psi = 0.7$  (thick line)  $\psi = 1.2$  (dotted line) and  $\psi = 9$  (dashed line) respectively. Other model parameters are  $\theta = 0.7$ ,  $\alpha = 0.3$ ,  $\sigma = 1.0$ .



portunity cost of ex-ante commitment decreases monotonically in  $k$  as the action cost  $\theta_k$  decreases, making contingent contracts progressively *less* appealing for the higher type. On the other hand, the distortion discount also decreases monotonically in the type  $k$  as the cost of distortion  $\psi_k$  increases, making contingent contracts progressively *more* appealing for the higher type. Depending

<sup>26</sup>Explicit expressions for these utilities can be found in Appendix B.

on the magnitude of  $\psi$  relative to  $\theta$ , either of the terms prevails making net profits from issuance of the contingent contract increasing, decreasing, or non-monotonic as a function of the firm's type. Importantly though, as long as  $\sigma \in (0, +\infty)$ , the highest types *always* issue the contingent contract across all values of distortion cost  $\psi \in (0, +\infty)$  and action cost  $\theta \in (0, +\infty)$ ,<sup>27</sup> the lowest types can either issue contingent contracts or vanilla contracts,<sup>28</sup> whereas intermediate types can issue a combination of contingent and non-contingent green debt. More formally, we prove in Appendix B the following

**Proposition 2.** *Let  $y_k$  denote the optimal contract choice that maximizes the firm problem in (26) for a type  $k \in [0, 1]$  with action and distortion costs that vary as in (24). Then for a given triple of parameters  $(\theta, \sigma, \psi) \in (0, \infty)$  and verification cost  $\alpha$  such that  $0 < 2\alpha\theta < 1$ , there exist two types  $\underline{k} \leq \bar{k}$  such that*

- *if  $k \geq \bar{k}$  then  $y_k = cg$  and the firm issues a contingent green contract.*
- *if  $k \leq \underline{k}$  then  $y_k = v$  and the firm issues a vanilla contract.*
- *if  $\underline{k} < k < \bar{k}$  then either  $y_k = g$  and the firm issues a non-contingent green contract, or there exists an intermediate cutoff type  $k'$  such that if  $\underline{k} < k < k'$  then  $y_k = cg$ , whereas if  $k' < k < \bar{k}$  then  $y_k = g$ .*

Figure 4 shows how the optimal issuance strategies vary as a function of the distortion cost  $\psi$ , the action cost  $\theta$ , the verification cost  $\alpha$  and the project uncertainty  $\sigma$ . The figure illustrates that on average, across possible choices of the parameters, higher types are more likely to issue the contingent green contract (red region), intermediate types are more likely to issue the non-contingent green contract (green region), whereas lower types are more likely to issue the plain vanilla non-contingent contract (grey region).<sup>29</sup> It is interesting to note that, as discussed earlier for the single-firm case, preferences for the contingent contract are on average higher for projects with intermediate level of uncertainty (bottom right-hand plot in Figure 4).

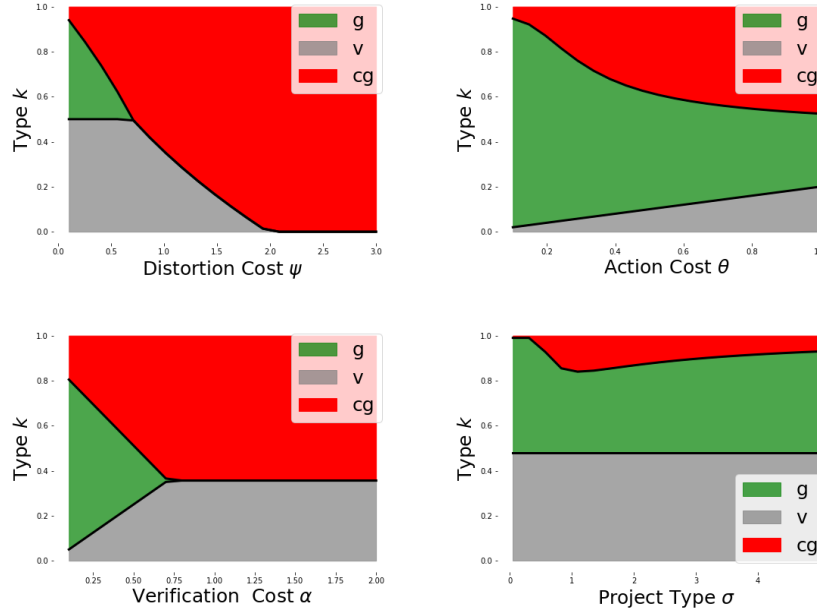
<sup>27</sup>This follows from Proposition 1 and from the specification of the distortion cost function across types.

<sup>28</sup>This follows from the assumption that  $0 < 2\alpha\theta < 1$ .

<sup>29</sup>As we outline in detail in Appendix B, it may exist a region of the model parameters where the issuance strategy  $y_k = cg$  is non-monotonic in  $k$ . However, such region is very small and not attained for any of the parameters choices reported in Figure 4.

**Figure 4.** Equilibrium Contract Choice - Perfect Information

The plots show the firm’s optimal contract choice as a function of the type  $k$  (y-axis) and the parameters  $\psi$ ,  $\theta$ ,  $\alpha$ , and  $\sigma$ , respectively. Model parameters are  $\theta = 0.25$ ,  $\alpha = 1.0$ ,  $\sigma = 2.0$  (top left plot),  $\alpha = 0.1$ ,  $\psi = 1.0$ ,  $\sigma = 2.0$  (top right plot),  $\theta = 0.25$ ,  $\psi = 1.0$ ,  $\sigma = 2.0$  (bottom left plot), and  $\theta = 0.4$ ,  $\alpha = 0.6$ ,  $\psi = 0.3$  (bottom right plot), respectively.

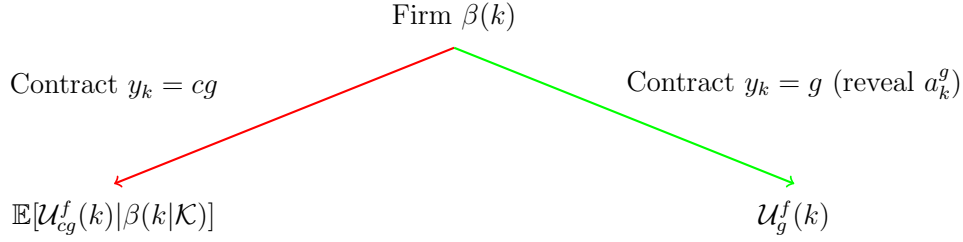


## 6.2 Asymmetric Information

In this section we extend the model further in that we assume that there is asymmetric information over the firm’s type  $k$ , meaning that the investor cannot observe the atomistic type  $k$  but only knows whether the firm is “good enough” so that it could afford issuing a green debt contract of either the contingent or non-contingent type (i.e.  $k \in (2\alpha\theta, 1]$ ), or if it can only opt for the vanilla contract as an alternative to contingent green debt (i.e.  $k \in [0, 2\alpha\theta]$ ). We choose this specification as it allows for an intuitive and tractable equilibrium result. Furthermore, we believe that it is plausible to assume that the investor holds a certain degree of information about the environmental quality of the firm, though the information is imperfect. In Appendix B, we also consider the case of full asymmetric information where the investor only knows that  $k \sim \mathcal{U}[0, 1]$ .

The game tree 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  $k \in (2\alpha\theta, 1]$  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  $\beta(k) \sim \mathcal{U}(2\theta\alpha, 1]$ .<sup>30</sup>



The right branch of the tree shows that if the firm proposes a non-contingent contract  $g$ , then it will attain the type-specific utility  $\mathcal{U}_g^f(k)$ . Specifically, through ex-ante commitment to actions  $a_k^g$ , the non-contingent green contract  $g$  allows the investor to perfectly infer the firm's type  $k$  at issuance, and therefore to update its prior belief  $\beta(k)$  from a distribution function to the atomistic type  $k$ . On the other hand, the left branch shows that, if the firm proposes a non-contingent contract  $cg$ , then it will attain an expected utility which is conditional to the group of firms that are issuing this contract, denoted  $\mathcal{K} := \{k \in (2\alpha\theta, 1] \text{ s.t. } y_k = cg\}$ . More specifically, the investor's posterior belief after observing this issuance choice follows the distribution function  $\beta(k|\mathcal{K}) \sim \mathcal{U}[\mathcal{K}]$ , and each firm  $k \in \mathcal{K}$  receives a group-specific interest rate

$$\bar{\rho}_{\mathcal{K}}^{cg} = \int_{2\alpha\theta}^1 \bar{\rho}_k^{cg} \beta(k|\mathcal{K}) dk \quad (27)$$

which differs from the type-specific rate  $\bar{\rho}_k^{cg}$  obtained by plugging  $\psi_k$  and  $\theta_k$  into (21). A firm  $k$ 's expected utility from issuing the contract  $cg$  conditional on the investor's posterior belief can then be expressed as

$$\mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})] = \mathbb{E}[\mathcal{U}_{cg}^f(k)] + \bar{\rho}_{\mathcal{K}}^{cg} - \bar{\rho}_k^{cg}. \quad (28)$$

From the expression in (28), one can intuitively anticipate that asymmetric information skews the firm's preferences for issuing contingent contracts towards lower types  $k$ . This is because the minimum required interest rate increases with expected distortion, and the latter decreases with firm type  $k$ . Consequently, lower types (those below the average type in group  $\mathcal{K}$ ) are receiving a lower rate than the benchmark case with perfect information, i.e.  $\bar{\rho}_{\mathcal{K}}^{cg} < \bar{\rho}_k^{cg}$  such that  $\mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})] > \mathbb{E}[\mathcal{U}_{cg}^f(k)]$ , whereas higher types (those  $k$  above the average type in group  $\mathcal{K}$ ) are

<sup>30</sup>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  $\{v, g, cg\}$  (this because  $\min\{\mathcal{U}_v^f, \mathcal{U}_g^f(k), \mathbb{E}[\mathcal{U}_{cg}^f(k)]\} \geq R > 0$ ), we can already exclude an equilibrium outcome where the investor refuses the contract and focus on the simplified signalling game described in the graph.

receiving a higher rate than the benchmark case with perfect information, i.e.  $\bar{\rho}_{\mathcal{K}}^{cg} > \bar{\rho}_k^{cg}$  such that  $\mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})] < \mathbb{E}[\mathcal{U}_{cg}^f(k)]$ . Effectively, by issuing the contingent green contract, higher types contribute to lowering the average group-specific rate and thus end up subsidising lower types.

We first introduce the following

**Perfect Bayes Equilibrium (PBE)** For a given  $\mathcal{K}$ , the pair  $(y_k, \beta(k|\mathcal{K}))$  such that

$$y_k : \begin{cases} = cg & \text{if } k \in \mathcal{K} \\ = g & \text{if } k \notin \mathcal{K} \end{cases} \quad (29)$$

and the investor's posterior belief  $\beta(k|\mathcal{K}) \sim \mathcal{U}[\mathcal{K}]$  is a PBE if it verifies

$$y_k = \operatorname{argmax}_{v,g,cg} \{\mathcal{U}_v^f, \mathcal{U}_g^f(k), \mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})]\} \quad (30)$$

for each  $k \in (2\alpha\theta, 1]$ .

Then, we prove in Appendix B the following

**Proposition 3.** *If  $\theta < \frac{\psi}{\sigma^2}$  is verified, then for each  $k \in (2\alpha\theta, 1]$ , it holds that*

$$\frac{\partial}{\partial k} \mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})] - \mathcal{U}_g^f(k) \leq 0 \quad (31)$$

where  $\mathcal{K} = [2\alpha\theta, k)$  and the following PBE are possible

- $\mathcal{K} = \emptyset$ , in which case  $y_k = g$  for each  $k \in (2\alpha\theta, 1]$ .
- $\mathcal{K} = (2\alpha\theta, 1]$ , in which case  $y_k = cg$  for each  $k \in (2\alpha\theta, 1]$ .
- $\mathcal{K} = [2\alpha\theta, e]$  for  $e < 1$ , in which case  $y_k = cg$  for  $k \in [2\alpha\theta, e]$ , whereas  $y_k = g$  for  $k \in (e, 1]$ .

Proposition 3 states that, if it exists a (semi-) separating equilibrium, then necessarily higher types are those ones issuing the non-contingent contract  $g$ , whereas lower types are those issuing the contingent contract  $cg$ . This is because issuing a non-contingent green contract allows the good types to differentiate themselves from the group of those that would be better off keeping their types private. The existence of such equilibrium relies on the verification of the *single-crossing* property outlined in (31), which states that the net gains from issuing the contingent contract are monotonically decreasing in the firm's type  $k$ .<sup>31</sup> This happens because when the investor is

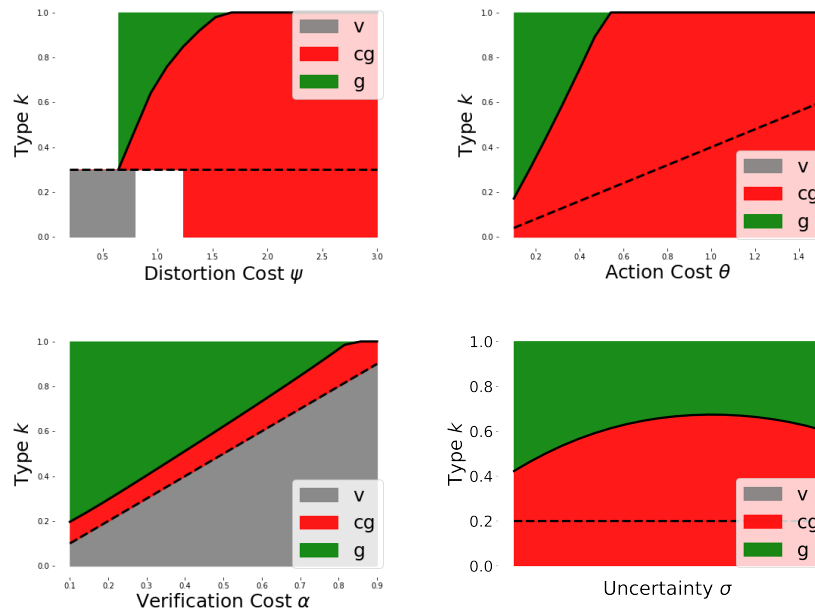
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<sup>31</sup>As outlined in Mailath [1987], the single-crossing property is necessary and sufficient for the existence of a (semi-) separating PBE in case the first mover has continuum one-dimensional types.

poorly informed about the firm’s type, the marginal effect of the type-specific distortion cost on the firm’s preference for issuing a contingent contract is *diluted* by the fact that the investor averages distortion costs across the set of types that are issuing the contingent contract. On the other hand, type-specific action costs continue to play a central role in driving firm’s preferences given that those costs can be correctly signalled when issuing a green bond. Proposition 3 states that in the case where  $\theta < \frac{\psi}{\sigma^2}$ , meaning when the action cost for the average type is sufficiently small relative to its distortion cost, then the role played by type-specific distortion costs becomes negligible and the marginal benefits from issuing a contingent contract decrease monotonically in the type  $k$  and are uniquely driven by their action costs (i.e. by their opportunity cost of commitment illustrated in Figure 2), and therefore condition (31) is satisfied.

**Figure 5.** Equilibrium Contract Choice - Asymmetric Information

The plots show the firm’s optimal contract choice as a function of the type  $k$  (y-axis) and the parameters  $\psi$ ,  $\theta$ ,  $\alpha$ , and  $\sigma$ , respectively. Model parameters are  $\theta = 0.5$ ,  $\alpha = 0.3$ ,  $\sigma = 1.0$  (top left plot),  $\alpha = 0.5$ ,  $\psi = 2$ ,  $\sigma = 1.0$  (top right plot),  $\theta = 0.5$ ,  $\psi = 0.1$ ,  $\sigma = 0.5$  (bottom left plot), and  $\theta = 0.2$ ,  $\alpha = 0.5$ ,  $\psi = 2.5$  (bottom right plot), respectively.



Following this line of reasoning, one can also show that a semi-separating equilibrium with signalling cannot exist for types  $k \in [0, 2\theta\alpha)$ . Specifically, as discussed formally in Appendix B, condition (31) is never satisfied when the alternative to a contingent contract is a vanilla contract  $v$ , because action and distortion costs cannot be disentangled and preferences for contingent contracts are

u-shaped as a function of firm types. As a consequence, the only possible equilibria are corner solutions in which either all firms pool at a contingent green contract, or all firms pool at a vanilla contract. The dashed line in Figure 5 indicates the cutoff type  $k = 2\theta\alpha$  and delimits the possible equilibria for these lower firm types.

Importantly, by focusing on the conditional set of types that issue contingent or non-contingent green contracts in equilibrium (i.e. red and green regions in Figure 5), we find that non-contingent green contracts are unambiguously more likely to be issued by higher types. Specifically, Figure 5 shows how firm’s issuance preferences vary across possible choices of the parameters  $\psi, \theta, \alpha$  and  $\sigma$ . Note that with asymmetric information, we obtain that across all possible choices of the model parameters that admit an equilibrium, non-contingent green debt contracts are more likely to be issued by higher types compared to contingent green debt contracts. Such prediction is markedly different from that obtained under perfect information, whereby the best types would always issue the contingent green debt, and motivates the empirical section that follows.

## 7 Empirical Testing

In what follows, we test the predictions outlined in the theoretical sections combining green securities data with issuers characteristics.

### 7.1 Data

We first compile the universe of sustainable corporate debt securities, by screening for Green loans and bonds, Social and Sustainable bonds, as well as for Sustainability-linked bonds and loans in the Bloomberg fixed income database between January 2013 through February 2022 (details are provided in Appendix A). We jointly refer to these securities on the sustainable finance market as green debt securities. We find a total of 12,372 green debt securities, of which 7,349 bonds (including Green, Social, Sustainable and Sustainability-linked), and 5,023 loans (including Green and Sustainability-linked). Appendix A reports broad statistics on sub-samples of these green securities, comparing them with the universe of conventional corporate bonds and loans in Bloomberg.

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.<sup>32</sup> 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.<sup>33</sup> We also include Environmental, Social, and Governance (ESG) performance ratings in the analysis by matching the firms in the Bloomberg/S&P Trucost panel dataset with Sustainalytics data.<sup>34</sup> The final dataset is an unbalanced panel of 1,215 unique firms, of which 430 with ESG ratings, which have issued a total of 3,571 green debt securities between 2013 and 2022, where 852 are categorised as contingent green debt and the remainder as non-contingent green debt.

Table 1 reports summary statistics on our selected firms (column Issuers) comparing them with the universe of firms in Trucost (column S&P Trucost Universe). From a financial perspective, the average green issuer is larger, has higher leverage, and is more profitable than the average firm in S&P Trucost. From an environmental perspective, the average green issuer is more likely to self-report its emissions (and consistently with its larger size, reports higher emissions levels than the average firm in S&P Trucost), as well as more likely to be tracked by the ESG rating provider. These statistics suggest that size and the availability of emissions/sustainability related performance metrics are barriers to entry in the sustainable debt market, consistent with the model prediction that the lowest types are more likely to issue ordinary debt contracts. What is interesting though is that, notwithstanding the green financing choice, green issuers receive only marginally better ESG ratings than the universe of ESG-tracked firms in S&P Trucost, suggesting that there is still significant variation in the environmental quality of firms that issue green securities.

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<sup>32</sup>Matching is performed at the issuer level and is based on company tickers when possible, otherwise company names. Firm  $i$ ’s securities issuance in year  $t$  is matched with firm  $i$ ’s characteristics in fiscal year  $t - 1$  from S&P Trucost. The number of matches each year is provided in Appendix A.2.

<sup>33</sup>The GHG Protocol Corporate Accounting and Reporting Standard provides requirements and guidance for companies and other organizations preparing a corporate-level GHG emissions inventory. 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. Source: <https://ghgprotocol.org/corporate-standard>

<sup>34</sup>Sustainalytics is a Morningstar rating company which measures a company’s exposure to industry-specific ESG risks and how well a company is managing those risks. Table A.7 in the appendix shows that Sustainalytics is the most popular rating provider on which contingent green debt securities are written on. Matching the Bloomberg/S&P Trucost dataset with Sustainalytics is done using the company ticker symbol where possible and using the name for the remainder.

**Table 1**  
Summary Statistics

Data are from the Bloomberg/S&P Trucost/Sustainalytics merged panel dataset. The left column (Issuers) refers to the selected panel of green issuers (Table A.8 in Appendix A). The right column (S&P Trucost Universe) is the universe of firms in S&P Trucost (Table A.8 in Appendix A). \*indicates that variables are winsorized between the 5<sup>st</sup> and the 95<sup>th</sup> percentiles of the pooled distribution. + indicates that variables are available for a subset of the sample each year.

Variable	Issuers		S&P Trucost Universe	
	Mean	(Std.)	Mean	(Std.)
Total Assets*(\$ bl)	92.6	(195.2)	5.86	(10.9)
Total Revenues*(\$ bl)	9.36	(14.3)	1.76	(3.09)
EBIT to Revenues Ratio*	0.36	(0.37)	0.15	(0.26)
Debt to Assets Ratio*	0.35	(0.18)	0.25	(0.20)
Self-Disclosure of Emissions	0.68	(0.45)	0.27	(0.44)
Emissions* (ml tCO <sub>2</sub> e)	9.32	(17.8)	1.93	(4.12)
Sustainalytics ESG Score <sup>+</sup>	66.3	(10.9)	55.60	(10.17)
Unique Firms	1,215		23,716	

## 7.2 Issuance by Project Type

A first interesting equilibrium prediction of the model is that the propensity of contingent green debt issuance (as opposed to non-contingent green debt) is hump-shaped as a function green outcome uncertainty, as can be inferred from the bottom-right plots in figures 4 and 5. We proxy green outcomes using GHG emissions<sup>35</sup> and define industries as having a high (low) degree of green outcome uncertainty if firms operating in these industries can be characterized as having a low (high) degree of control and measurement accuracy over their GHG emissions. Heterogeneity within GHG emissions is provided by the scopes breakdown of the GHG protocol standard. Specifically, 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<sup>+</sup> 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

<sup>35</sup>GHG emissions are the single most popular metric on which sustainability-linked bonds and loans are written on. In Table A.7 in the appendix reports statistics on the targets underlying contingent green debt securities as collected from Bloomberg New Energy Finance (BNEF).

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.

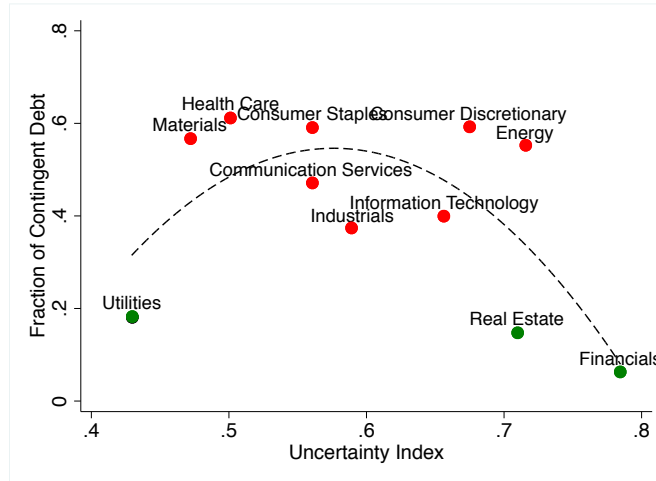
We define an industry-level uncertainty index as

$$\sigma_j = \frac{1}{N_j} \sum_{i=1}^{N_j} \sigma^1 w_{i,j}^1 + \sigma^2 w_{i,j}^2 + \sigma^3 w_{i,j}^3 \quad (32)$$

where  $N_j$  is the total number of firms in industry  $j$ , the weights  $w_{i,j}^1, w_{i,j}^2, w_{i,j}^3$  are firm  $i$ ’s proportions of scope 1, scope 2+, and scope 3 emissions out of total emissions, respectively, averaged across the observation period in the dataset, and  $\sigma^1 = 0 < \sigma^2 = 0.5 < \sigma^3 = 1$  parameterize the uncertainty associated with the emissions scopes. Figure 6 plots the industry-level uncertainty index (x-axis)

**Figure 6.** Issuance Choice by Industry

The plot shows the industry-level average proportion of outcome-based contingent green debt 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.



against the industry-level proportion of contingent debt securities (y-axis) defined as

$$p_j^{cg} = \frac{1}{N_j} \sum_{i=1}^{N_j} \left( \frac{1}{K_{i,j}} \sum_{k=0}^{K_{i,j}} \delta_{i,j,k}^{cg} \right) \quad (33)$$

with  $K_{i,j}$  the total number of green securities issued by firm  $i$  during the observation period in the dataset and  $\delta_{i,j,k}^{cg}$  is an indicator equal to one if the green security is contingent. In line with the model predictions, industries with intermediate levels of uncertainty are those more likely to issue

the contingent green debt. Indeed one observes that both utilities and financial firms, which lie at the end of the uncertainty spectrum, having the lowest and largest share of scope 1 and scope 3 downstream emissions, respectively, 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 the firm has either very good control over the green outcome (such that there is a low opportunity cost of foregoing more profitable investments), or when it has very poor control over the green outcome (such that issuing a contingent contract is too costly because of the distortion discount).

### 7.3 Issuance by Firm Types

We look for the presence of information frictions by regressing firms' green securities issuance choices on observable characteristics that should proxy for their environmental types. In line with the model predictions, if firms' types are correctly identified by the proxies, then we should expect a positive or insignificant correlation between contingent debt issuance and firms' types. On the other hand, if the proxies are only weakly correlated with firms' environmental types (i.e., there is residual uncertainty about the true ordering of firms' types after controlling for the proxies), then we should expect a negative correlation between contingent debt issuance and the noisy proxies.

In the model, good types are those that have a better ability to deliver the green outcome (i.e. a *lower* action cost) as well as a worse ability to distort the green outcome in reports (i.e. a *higher* distortion cost). Given that we focus on GHG emission as the green outcome metric, we proxy for the cost of action using the historical emissions intensity of the firm, measured as the logarithm of the firm's total emissions scopes per unit of total assets. The idea is that after controlling for location and industry effects, a higher historical emissions intensity is an endogenous outcome of higher historical abatement costs, in turn predicting a lower abatement capacity in the next period. Therefore, we proxy for action cost as

$$actioncost_{i,j,t} = \log(emissions_{i,j,t-1}) - \log(assets_{i,j,t-1}) \quad (34)$$

where for each firm  $i$ , industry  $j$ , and issuance year  $t$ ,  $emissions_{i,j,t-1}$  are lagged total emissions measured as the sum of scope 1, scope 2+, and scope 3 emissions in millions metric tons of carbon dioxide equivalent (mtCO<sub>2e</sub>)<sup>36</sup> and  $assets_{i,j,t-1}$  are lagged total assets in million dollars. Finding

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<sup>36</sup>Carbon dioxide equivalent or CO<sub>2e</sub> is a term for describing different greenhouse gases in a common unit. For

a distortion cost proxy using realized manipulation of emissions is challenging because one cannot disentangle reported from actual carbon emissions data. To circumvent this challenge, we conceptualize manipulation as *greenwashing*, and define it as selective disclosure of information about a company’s environmental or social performance so as to create an overly positive corporate image [Netto et al., 2020]. Following this definition, we measure manipulation propensity as the historical *discrepancy* between the firm’s overall corporate sustainability image, as measured by the aggregate ESG score provided by Sustainalytics, and a credible signal of environmental commitment embedded in these scores, captured the firm’s actual adoption of an Environmental Management System (EMS), and whether the adopted EMS is certified by a third party. In defining an EMS, the Environmental Protection Agency (EPA) explicitly ties the adoption of environmental information systems to a firms’ positive environmental performance.<sup>37</sup> Furthermore, Lyon and Maxwell [2011] provide evidence that corporate adoption of a high-quality EMS reduces incentives for greenwash, in that a well functioning EMS not only increases the firm’s information about green outcomes but it also makes it more difficult for the firm to manipulate the measurement system which monitors these outcomes. Therefore, we proxy for distortion cost as

$$distortioncost_{i,j,t} = ems_{i,j,t-1} - esg_{i,j,t-1} \quad (35)$$

where  $esg_{i,j,t-1}$  is the historical weighted ESG score as provided by Sustainalytics and  $ems_{i,j,t-1}$  is the sub-component of the score that indicates whether the firm has adopted an EMS and whether the EMS has been externally certified.

Table 2 reports panel regressions of firm’s issuance choice on the selected proxies for firm types. The dependent variable is the proportion of contingent debt securities out of all securities issued by firm  $i$  in industry  $j$  and year  $t$ , that is  $p_{i,j,t}^{cg} = \frac{1}{K_{i,j}} \sum_{k=0}^{K_{i,j}} \delta_{i,j,t,k}^{cg}$ . The regressors are the firm’s action and distortion costs proxies, as well as other controls for the firm’s financial conditions, as observed in fiscal year  $t - 1$ . The column Regression I refers to the entire sample of firms, while

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any quantity and type of greenhouse gas, CO<sub>2</sub>e signifies the amount of CO<sub>2</sub> which would have the equivalent global warming impact.

<sup>37</sup>Specifically, the Environmental Protection Agency (EPA) defines an environmental management system (EMS) as [...] 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. See <https://www.epa.gov/ems/learn-about-environmental-management-systems-what-is-an-EMS>. The most widely used EMS standard is the International Organization for Standardization (ISO) 14001 developed by the Environmental Protection Agency (EPA) and the Eco-Management and Audit Scheme (EMAS) developed by the European Commission.

**Table 2**  
Security Choice - Panel Regressions

Panel regressions of green debt security choice on issuers characteristics. The dependent variable is the annual fraction of contingent green securities out of total green securities issued by firm  $i$  in industry  $j$  and year  $t$ . Regressors are collected from Bloomberg/Sustainalytics/S&P Trucost merged dataset and refer to the fiscal year  $t - 1$ . \*, \*\*, \*\*\* indicate statistical significance at the 10%, 5% and 1% level respectively. Standard errors in parenthesis are clustered at the firm level.

Regressor	Regression I			Regression II		
Cost of Action	0.09*** (0.01)	0.04** (0.02)	0.05*** (0.02)	0.09*** (0.02)	0.02 (0.02)	0.03* (0.02)
Cost of Distortion				-0.07** (0.03)	-0.08** (0.03)	-0.06** (0.03)
Log Revenues		-0.03* (0.02)	-0.02 (0.02)		-0.02 (0.03)	-0.01 (0.02)
EBIT to Revenues Ratio		-0.20*** (0.08)	-0.24*** (0.08)		0.04 (0.05)	0.02 (0.11)
Debt to Assets Ratio		0.36* (0.19)	0.37** (0.19)		-0.09 (0.29)	0.01 (0.29)
Self-Disclosure of Emissions		0.21*** (0.06)	0.03 (0.04)		0.16* (0.08)	0.09 (0.09)
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
Industry Dummy	No	Yes	Yes	No	Yes	Yes
Location Dummy	No	No	Yes	No	No	Yes
$\mathcal{R}^2$	0.07	0.11	0.15	0.09	0.13	0.15
Unique Firms	1,109	1,075	1,075	409	398	398

column Regression II refers to the subsample of firms tracked by Sustainalytics. Standard errors are clustered at the firm level. The first thing to note is that the cost of action, as proxied by the firm's historical emissions intensity, is strongly positively correlated with the propensity to issue a contingent green debt contract. Importantly, the correlation remains statistically significant across both sample choices and when controlling for industry fixed effects, financial characteristics, as well as for location fixed effects. Also worth noting is that firms issuing contingent securities have lower profitability relative to non-contingent securities issuers in the same sector; if interpreted in light of the recent finding of De Haas, Martin, Muûls, and Schweiger [2021] that financial constraints inhibit corporate investment in green technologies, this evidence provides further support to the model prediction that contingent green debt issuers are not the best environmental types. Interestingly, contingent green issuers are more likely to self-disclose emissions voluntarily than the remainder of green issuers in the same sector, but the significance seems to be mostly driven by location

dummies.<sup>38</sup> Moving on to the subsample of firms tracked by Sustainalytics, one finally notes that issuers of contingent green debt contracts also have significantly lower distortion costs relative to the remainder of green issuers in our dataset, as proxied by our metrics of greenwashing, an effect that remains statistically significant after controlling for industry dummies, financial characteristics, as well as for location dummies.

## 7.4 Ex-post Debt Performance

In this last section, we compare the ex-post financial performance of contingent and non-contingent green debt securities. The model provides a testable implication by stating that, if contingent contracts are more likely to be issued by lower firm types in equilibrium, then those contracts should on average yield higher monetary returns than non-contingent green contracts, so as to compensate the investor for the lower green outcome.<sup>39</sup> To test this implication, we look at differences in the *green premia* across the two types of green bond securities, namely contingent and non-contingent green bonds, where the green premium is estimated as the negative yield difference between a green bond and an otherwise equivalent conventional bond. Our empirical estimation follows the methodology in Zerbib [2017], but we are interested in the difference across green premia of contingent and non-contingent green debt, rather than estimating the magnitude of the green premium per se.

We estimate the green premium of non-contingent green bonds (green, social, and sustainable bonds) and compare it to that of contingent green bonds (sustainability-linked bonds) 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. We first pair contingent and non-contingent green bonds in our initial Bloomberg dataset (summarized in Table A.6, panel A) with the set of conventional bonds issued by the same firm in the same year. For data limitations, we perform the matching on a subset of the entire Bloomberg dataset (i.e., we restrict the entire universe of corporate bonds in Bloomberg to those with an amount issued and tenor that lie

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<sup>38</sup>It is worth noting that in the empirical literature on corporate environmental disclosure, there are sharply conflicting results regarding the relationship between the firm environmental performance and its disclosure propensity. For example, Cho and Patten [2007] find that firms with worse environmental records have higher levels of environmental disclosures, while Clarkson, Li, Richardson, and Vasvari [2008] find that firms with better environmental records have higher level of disclosure. In their theoretical study, Lyon and Maxwell [2011] argue that one should expect a non-monotonic relationship between expected environmental performance and disclosure propensity.

<sup>39</sup>This is because a binding investor participation constraint implies that all securities issued are expected to yield zero total returns in equilibrium (on average or across states, depending on the contract). Therefore, monetary returns should offset environmental returns that derive from the issuance of the security in such a way that total returns sum to zero.

between the 10th and 90th percentile observed in our sample of green securities). We find a total of 14,615 conventional bonds, 3,135 contingent and 341 non-contingent green bonds respectively, issued between January 2018 and February 2022.<sup>40</sup> Statistics associated with these three sets of securities are reported in Table 3. As observed, non-contingent green bonds are fairly similar to conventional bonds – although slightly larger in terms of amount issued, with longer maturity, and lower coupon rates than conventional bonds (consistent with evidence in Baker et al. [2018]). On the other hand, contingent green bonds are notably different as they have a significantly higher amount issued, a higher coupon rate, and a different type of maturity (callable or convertible rather than fixed term).

**Table 3**  
Summary Statistics

Summary statistics (mean and standard deviation) of the pair of green-conventional bonds securities issued between January 2018 and February 2022. The column Non-Contingent refers to Green, Social, and Sustainable bonds. The column Contingent refers to Sustainability-linked bonds. The column Conventional refers to the set of conventional bonds from the same issuer and the same issue year as the corresponding green securities. Maturity Type is an indicator variables equal to one if the bond’s term maturity is fixed, and 0 otherwise (i.e., if it is of callable or puttable type). S&P (Issuer) Rating is an indicator variable equal to 1 if the bond’s (issuer’s) credit worthiness according to the S&P scale is above or equal to A-, and 0 otherwise. + indicates that the statistics are computed on the subset of securities for which ratings are available.

Variable	Non-Contingent		Contingent		Conventional	
	Mean	(Std.)	Mean	(Std.)	Mean	(Std.)
Issue Amount (\$ bl)	0.29	(0.32)	0.45	(0.33)	0.22	(0.38)
Tenor (years)	5.94	(2.60)	6.64	(2.49)	5.52	(2.81)
Coupon rate (%)	1.94	(1.88)	2.50	(1.88)	1.95	(2.24)
Maturity Type (Term 1/Callable or other 0)	0.71	(0.45)	0.47	(0.50)	0.71	(0.45)
S&P Rating <sup>+</sup> (above or equal to A-)	0.43	(0.49)	0.09	(0.28)	0.70	(0.46)
S&P Issuer Rating <sup>+</sup> (above or equal to A-)	0.41	(0.49)	0.22	(0.42)	0.36	(0.47)
Unique Securities	3,135		341		14,615	

In the attempt to control for these remaining differences, we apply other filters and keep only the conventional bonds that have the same maturity type, coupon type, and currency as the corresponding green bond. Moreover, we drop conventional bonds whose maturity differs more than two years from that one of the green bond or whose amount issued differs more than half the amount of

<sup>40</sup>2018 is the first year in which sustainability-linked bonds are issued and dictates the start date of this sample.

the corresponding green bond. Unlike Zerbib [2017], we do not match securities by credit ratings given that only half of the conventional securities are rated. This may raise a concern given that contingent green bonds display significantly lower credit ratings than the subset of conventional bonds for which ratings are available.<sup>41</sup> However, large part of the difference in credit ratings across securities disappears once accounting for differences in ratings at the issuer level (Table 3), which reduces the concern given our matching strategy. This exercise leaves us with a dataset of 1,591 pairs of green-conventional bonds, of which only 55 are contingent bonds. For each pair of green-conventional bonds, we collect daily ask yields from the issuance date of the securities until May 2022, and measure the daily yield spread as the difference between the daily ask yield of the green security and the *average* daily ask yield of the paired set of conventional securities.<sup>42</sup> We control for liquidity in estimating the green premium by following the methodology in Zerbib [2017], which involves using average differentials in bid-ask spreads as a liquidity bias proxy (see also Beber, Brandt, and Kavajecz [2009]). The green premium is defined as the unobserved fixed effect in the panel regression of the yields spread on the liquidity spread

$$\Delta y_{k,t} = b_k + \beta \Delta Liquidity_{k,t} + \tilde{\epsilon}_{k,t} \quad (36)$$

with  $\Delta y_{k,t}$  pair  $k$ 's yield spread at date  $t$ , and  $\Delta Liquidity_{k,t}$  the liquidity bias proxy. To determine the coefficient of interest, we then perform a cross-sectional regression of the estimated green premium on the type of green security

$$\hat{b}_k = \alpha_0 \delta_k^{cg} + [\alpha_1, \dots, \alpha_n]^T X_k + \tilde{\eta}_k \quad (37)$$

with  $\hat{b}_k$  the security-level premium,  $\delta_k^{cg}$  an indicator variable equal to one if the pair  $k$  is composed of a contingent green bond, and  $X_k$  a vector of  $n$  characteristics of the green security.

Table 4 reports the panel regression in (36) along with cross-sectional regressions of the estimated premium in (37) for different sets of controls  $X_k$ . Regression I shows that, in contrast with the primary finding in Zerbib [2017], there is a positive yield differential (i.e., a green discount) of approximately 5 basis points between green securities and otherwise equivalent conventional securities in our sample. However, regression II shows that such result is uniquely driven by pairs of securities for which S&P credit ratings of the issuer are not available, whereas in line with the findings in

<sup>41</sup>This feature is more pronounced when looking at the universe of corporate bond issuances (Figure A.7).

<sup>42</sup>We select ask yields following the methodology in Zerbib [2017] with the difference that averages across the ask yields of conventional bonds are equally weighted. If, on a specific day, the green or the (average) conventional ask yields are not available, we remove that observation from the dataset.

**Table 4**  
Yield Spreads

The first column is the fixed-effect panel regression of the yield spread  $\Delta y_{k,t}$  on the liquidity bias proxy in (36). The second column are OLS regressions of the estimated green premium  $\hat{b}_k$  (i.e., the unobserved fixed effect in regression (36)) on security characteristics. The columns No Rating, Rating BBB+ or lower, and Rating AA or higher, are dummy variables that indicate the S&P credit rating of the issuer. Log(Issue Amount) is the logarithm of the issued amount of the green security in \$ billions. Tenor is the maturity of the green securities in years. Maturity and Currency Type are dummy variables that indicate the type of maturity and currency of the pair of green-conventional bonds. \*,\*\*,\*\*\* indicate statistical significance at the 10%, 5% and 1% level respectively. Standard errors in parenthesis are clustered at the security level (first column) and at the firm level (second column), respectively.

Regressors	Dep. Var. $\Delta y_{k,t}$	Dep. Var. $\hat{b}_k$				
		(I)	(II)	(III)	(IV)	(V)
Liquidity bias	-0.96*** (0.06)					
Contingent				0.08 (0.05)	0.11** (0.05)	0.10* (0.05)
Intercept		0.05** (0.02)				
No Rating			0.07*** (0.01)	0.07*** (0.01)	0.02 (0.03)	0.03 (0.03)
Rating BBB+ or lower			0.05 (0.03)	0.05 (0.03)	-0.00 (0.04)	-0.01 (0.04)
Rating AA or higher			-0.04 (0.07)	-0.04 (0.07)	-0.09 (0.08)	-0.09 (0.08)
Log(Issue Amount)						0.01 (0.01)
Tenor						0.00 (0.01)
Maturity Type Dummy		No	No	No	Yes	Yes
Currency Dummy		No	No	No	Yes	Yes
$\mathcal{R}^2$	0.62	0.01	0.02	0.02	0.07	0.08
Observations	495,956	1,356	1,356	1,356	1,356	1,356

Zerbib [2017], securities whose issuers have higher credit rating have a negative yield differential (i.e., a green premium) of approximately 4 basis points (although not statistically significant).<sup>43</sup> Regressions III, IV, and V show that, in line with the model predictions under asymmetric information, yield spreads between contingent green and equivalent conventional bonds are systematically

<sup>43</sup>Issuer's credit rating is one of the strongest determinants of cross-sectional variation in green bond premia as reported by Zerbib [2017] and more recently by Larcker and Watts [2020].

*higher* than yield spreads between non-contingent green and equivalent conventional bonds. Such a positive difference, which averages around 10 basis points, is statistically significant when accounting for other controls at the security level. Figure A.8 in Appendix A.2 plots the unconditional distribution of the estimated premium  $\hat{b}_k$  across contingent green and non-contingent green securities. As observed, the estimated 10 basis point spread is due to a shift of the entire distribution rather than a change in the tails.

Taken together, the reduced-form evidence reported in Table 2 and Table 4 supports the presence of information frictions causing adverse selection in the sustainable finance market, implying that financial markets are not yet channelling funds efficiently to support the transition to a sustainable economy.

## 8 Concluding Remarks

This paper takes account of recent market developments, and develops the first theoretical model that formally captures the key features of the two types of debt contracts on the growing market for sustainable finance. The most prevalent type of green debt contract in the sustainable finance market is the green bond, a fixed income debt instrument which earmarks proceeds for specific green projects, but makes no commitment to deliver green outcomes. In contrast, the newly emerging class of sustainability-linked bonds and loans does not impose ex-ante constraints on the use of proceeds, but instead embeds contingencies that ensure commitment to outcomes. These contingent green debt securities should address the limitations inherent in the design of green bonds by eliminating the need to restrict borrower's actions ex-ante and by making outcomes rather than intentions the focus of green projects financing, yet the observed market outcome points to the co-existence of project-based non-contingent contracts and outcome-based contingent contracts, with some firms employing both. We develop a model of firm financing which incorporates an investor with green preferences into an otherwise standard framework of corporate financing with asymmetric information. Firms seek to finance green projects whose outcome embeds an uncertain, non-measurable component that is revealed only to the firm and can be manipulated. We demonstrate that the co-existence of the two green debt contracts is an equilibrium result when green outcomes are manipulable and firm types differ in their ability to manipulate. In presence of asymmetric information about firms' type, green bonds can be used as an expensive screening

device, and we find empirically that contingent green debt securities have lower green premium and are issued by more emissions intensive firms.

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## A Data Appendix

### A.1 Securities data

Guidelines on the issuance of green/social/sustainability bonds as well as sustainability-linked bonds is provided by the principles put forth by the International Capital Market Association (ICMA), summarized in Table A.5. Guidance regarding the issuance of green loans and sustainability-linked loans is provided by the Loan Market Association (LMA), although it is generally less stringent and more customized than that provided by ICMA.<sup>44</sup>

**Table A.5**  
The Principles by ICMA

The Table reports the key components of the Green Bond Principles (GBPs), Social Bond Principles (SBPs), Sustainability Bond Guidelines (SBGs), and Sustainability-Linked Bonds Principles (SLBPs) respectively as issued by ICMA. Further details can be found at <https://www.icmagroup.org/sustainable-finance/>.

GBPs/SBPs/SBGs	SLBPs
1) Use of proceeds for green/social/sustainable projects	1) Selection of Key Performance Indicators (KPIs)
2) Process for project evaluation and selection	2) Calibration of Sustainability Performance Target (SPTs)
3) Management of proceeds	3) Bond characteristics (contingency)
4) Reporting of proceeds	4) Reporting performance on the KPI
	5) Verification of KPI performance against the SPT

We compile the dataset of sustainable corporate debt using Bloomberg’s fixed income database. We extract all 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 whose issuer’s Bloomberg Industry Classification System (BICS) is “Government”.<sup>45</sup> Bloomberg applies a green/social/sustainability indicator if the issuer self-reports (and/or if relevant documentation is available) that 100% of the proceeds of the debt instrument are devoted to predetermined environmental/social/sustainability-oriented activities. Bloomberg therefore follows loosely the reference guidelines issued by the ICMA, in that only the component 1) out of the four key components in Table A.5, left column, is captured by the

<sup>44</sup>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.

<sup>45</sup>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.

indicator.<sup>46</sup> In a similar manner, Bloomberg labels the bond or loan as sustainability-linked if the issuer self-reports (and/or if relevant documentation is available) that the debt instrument is linked to a sustainability performance metric, which is again only component 1) of the five summarized in Table A.5, right column. Statistics on the universe are summarized in Table A.6.

**Table A.6**  
Corporate Sustainable Bonds and Loans

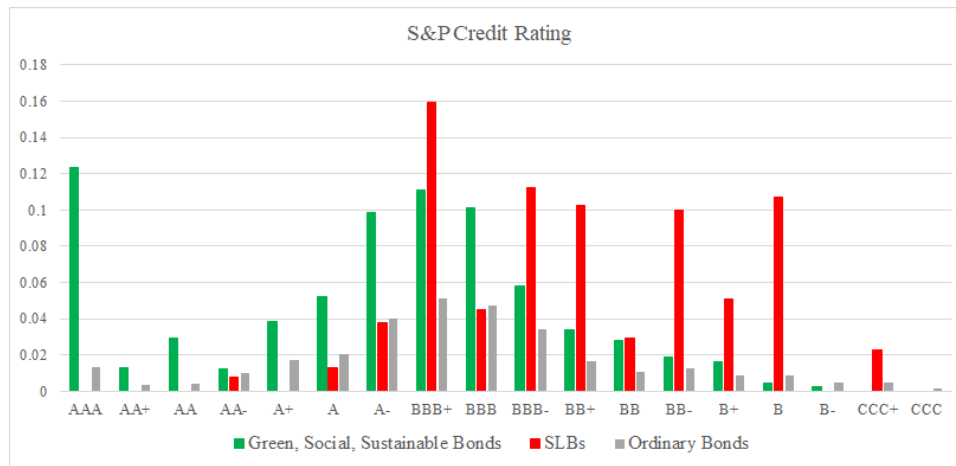
The Table shows summary statistics on corporate bonds (panel A) and loans (panel B) issued between January 2013 and February 2022 as collected from the Bloomberg fixed income search. The first column refers to the selected sample of green, social, sustainable, and sustainability-linked securities. The second column refers to the sub-sample of sustainability-linked securities. The third column refers to the entire universe of corporate bonds and loans. The variables Use of Proceeds, Project Selection, Management and Reporting are dummy variables referring to compliance with the four principles issued by ICMA (as observed from ESG reports or other available sources), whether the variable assurance is an indicator equal to 1 if there is third-party assurance of compliance with the principles.

<b>Panel A: Bonds</b>	<b>Green/Social/Sustainable/Sustainability-linked</b>	<b>Sustainability-linked</b>	<b>Ordinary</b>
<b>Variable</b>	<b>Mean</b>	<b>Mean</b>	<b>Mean</b>
Amount Issued (\$ mil)	295	476	100
Coupon Rate (%)	2.5	2.4	4.1
Maturity (years)	8.0	8.3	3.2
Private Company (%)	63.6	55.6	78.1
Project Selection (%)	98.2	1.6	0.5
Management (%)	97.3	1.6	0.5
Reporting (%)	97.3	1.6	0.5
Assurance (%)	87.8	27.9	0.5
<hr/>			
Securities	7,349	444	1,157,316
<hr/>			
<b>Panel B: Loans</b>	<b>Green/Sustainability-linked</b>	<b>Sustainability-linked</b>	<b>Ordinary</b>
<b>Variable</b>	<b>Mean</b>	<b>Mean</b>	<b>Mean</b>
Loan Tranche Size (\$ mil)	245	625	330
Is Loan Revolving (%)	21.2	54.6	25.9
Coupon Rate (%)	2.6	2.1	4.5
Maturity (years)	14.3	7.6	8.4
Private Company (%)	83.1	56.2	77.9
Project Selection (%)	6.7	0.5	0.3
Management (%)	5.7	0.7	0.2
Reporting (%)	4.5	0.7	0.2
Assurance (%)	2.5	1.1	0.1
<hr/>			
Securities	5,023	1,331	119,002

<sup>46</sup>See <https://www.icmagroup.org/sustainable-finance/the-principles/> for a complete list of the ICMA reference guidelines, and Shurey (2016) for a *Guide to Green Bonds on the Bloomberg Terminal*.

**Figure A.7.** Bonds Credit Ratings

The histogram shows the distribution of Standard & Poor (S&P) credit ratings of corporate bond securities summarized in the first panel of Table A.6. Grey bars refer to the entire universe of corporate bonds, green bars refer to the subset of corporate bonds which are labelled as Green, Social, or Sustainable, whereas red bars refer to the subset of corporate bonds which are labelled as Sustainability-linked.



**Table A.7**  
Sustainability Performance Targets (SPTs)

The table breaks down the target performance metrics associated to sustainability-linked loans and bonds in our sample by categories: general ESG Scores, Environmental metrics, Social metrics, Governance metrics, and then by respective sub-categories. 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%)
<ul style="list-style-type: none"> <li>• Sustainalytics 25%</li> <li>• GRESB 11%</li> <li>• EcoVadis 9%</li> <li>• ISS 5%</li> <li>• MSCI 5%</li> <li>• Vigeo Eiris 4%</li> <li>• Other/Unknown 41%</li> </ul>	<ul style="list-style-type: none"> <li>• GHGs 46%</li> <li>• Waste 13%</li> <li>• Renewable Energy 12%</li> <li>• Energy Efficiency 7%</li> <li>• Water 7%</li> <li>• Transport 2%</li> <li>• Other/Unknown 13%</li> </ul>	<ul style="list-style-type: none"> <li>• Worker Accidents 18%</li> <li>• Female Staff 10%</li> <li>• Labor Rights 9%</li> <li>• Education 8%</li> <li>• Disabilities 2%</li> <li>• Social Returns 1%</li> <li>• Other/Unknown 52%</li> </ul>	<ul style="list-style-type: none"> <li>• Female Board 49%</li> <li>• Other/Unknown 51%</li> </ul>	

## A.2 Issuer data

We construct a panel dataset by matching firm  $i$ 's issuances of sustainable debt securities in year  $t$  (from Bloomberg) with firm  $i$ 's characteristics in year  $t - 1$  from Standard & Poor (S&P) Trucost. For sustainability-linked loans, the issuance year is really the year in which the loan has been linked to the firm's sustainability performance. Matching is performed on company tickers when possible, otherwise on company names. S&P data is available up to 2021. We drop observations each year in which total revenues are not available. The resulting unbalanced panel is reported in the second column Table A.8. We then complement the Bloomberg/S&P Trucost merged dataset with ESG ratings from Sustainalytics, which are only available up to 2019 so we roll forward this last available year. Matching between Bloomberg/S&P Trucost and Sustainalytics is performed on Capital IQ identifiers. The resulting unbalanced panel is reported in the third column of Table A.8.

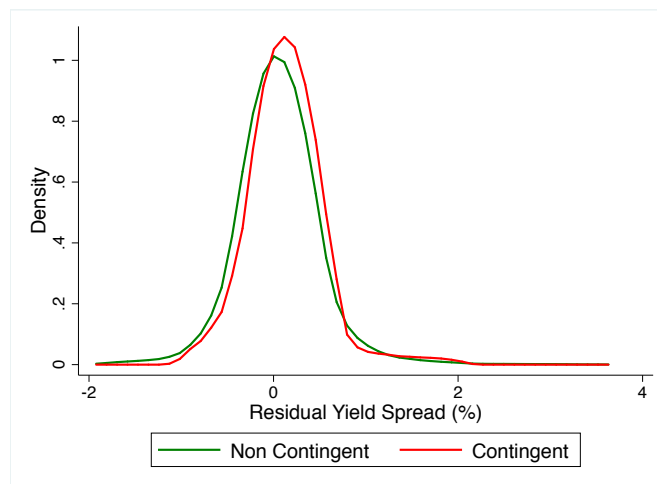
**Table A.8**  
Issuer Dataset

The Table reports the number of unique firms 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	S&P	BB/S&P	BB/S&P/Sustainalytics
2013	19,475	8	
2014	20,730	29	
2015	21,458	34	21
2016	21,940	48	30
2017	22,355	87	54
2018	22,563	136	98
2019	22,510	288	199
2020	22,146	357	242
2021	22,513	843	218
2022	17,908	85	29
Unique Firms	23,716	1,215	430

**Figure A.8.** Yield Spread - Contingent and Non Contingent Debt

The plot shows the distribution of green premia as estimated from the fixed-effect panel regression in section 7.4 grouped by type of green security (e.g. contingent green bonds in red and non-contingent green bonds in green).



## B Model Appendix

**Proposition 1.** The financing choice can be expressed as

$$y^* = cg \text{ iff } \mathbb{E}[\mathcal{U}_{cg}^f] > \mathcal{U}_v^f + \max\{0, \frac{1}{2\theta} - \alpha\}. \quad (38)$$

If  $\psi = +\infty$ , then

$$\mathbb{E}[\mathcal{U}_{cg}^f] = \mathcal{U}_v^f + \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z} - \alpha)^+] \quad (39)$$

rewriting condition (38) and applying the Jensen's inequality

$$\begin{aligned} \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z} - \alpha)^+] - \max\{0, \frac{1}{2\theta} - \alpha\} &\geq \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z} - \alpha)^+] - \frac{1}{2\theta} + \alpha \\ &> \frac{1}{2\theta} + \sigma\mathbb{E}[\tilde{z}] - \frac{1}{2\theta} = 0 \end{aligned} \quad (40)$$

from which the proof follows. If  $\psi < +\infty$ , then

$$\mathbb{E}[\mathcal{U}_{cg}^f] = \mathcal{U}_v^f + \mathbb{E}[(\frac{1}{2\theta} - \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha)1\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha > 0\}] \quad (41)$$

For any  $(\sigma, \theta, \alpha)$ , it holds that

$$\lim_{\psi \rightarrow 0} \mathbb{E}[(\frac{1}{2\theta} - \frac{\sigma^2}{2\psi} + \sigma\tilde{z})1\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} > 0\}] = -\infty \quad (42)$$

since the project will be picked with probability one whereas the distortion discount will approach infinite. This implies that for any  $(\sigma, \theta, \alpha)$

$$\lim_{\psi \rightarrow 0} \mathbb{E}[\mathcal{U}_{cg}^f] < 0 < \max\{0, \frac{1}{2\theta} - \alpha\} \quad (43)$$

which by definition of the limit proves the result. On the other hand for any  $(\sigma, \theta, \alpha)$  one has

$$\lim_{\psi \rightarrow +\infty} \mathbb{E}[(\frac{1}{2\theta} - \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha)1\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha > 0\}] = \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z} - \alpha)^+] \quad (44)$$

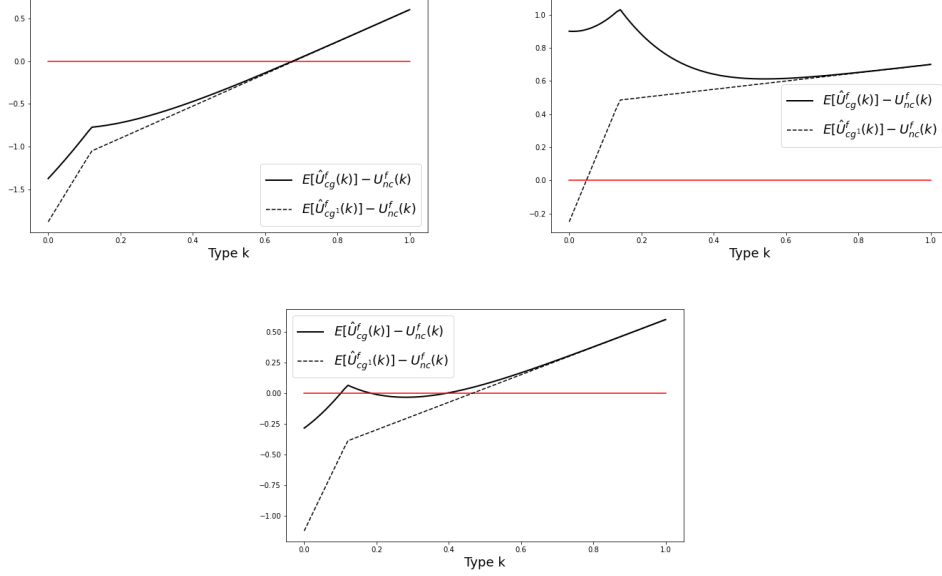
which by definition of the limit and the result stated in (40) proves the result.

**Proposition 2.** Denote the type  $k \in [0, 1]$  such that  $\theta_k = \theta/k$  and  $\psi_k = \psi/(1 - k)$ , with  $0 < 2\theta\alpha < 1$ ,  $\psi > 0$  and  $\sigma > 0$ . The utility from issuance of a non-contingent contract reads

$$\mathcal{U}_v^f + \max\{\mathcal{U}_g^f(k) - \mathcal{U}_v^f, 0\} = \mathcal{U}_v^f + \max\{\frac{k}{2\theta} - \alpha, 0\} \quad (45)$$

**Figure B.9.** Net Profits From Issuance of Contingent Contract - Perfect Information

The plots show the net profits in (47) (black thick line) and the second component in (47) (black dashed line) as a function of the type  $k$  for different values of the model parameters. The red line defines the region below (above) which the firm has strict preference for the contingent contract  $cg$ . Parameters  $\theta = 0.1$  and  $\alpha = 0.6$  and  $\sigma = 1.5$ , whereas  $\psi = 0.6$  (left plot),  $\psi = 4.5$  (right plot), and  $\psi = 1.6$  (mid plot) respectively.



which is a piecewise function of  $k$ , whereas

$$\begin{aligned} \mathbb{E}[U_{cg}^f(k)] &= U_v^f + \mathbb{E}\left[\left(\frac{k}{2\theta} - \frac{1}{2} \frac{\sigma^2(1-k)}{\psi} + \sigma\tilde{z} - \alpha\right) 1\left\{\frac{k}{2\theta} + \frac{1}{2} \frac{\sigma^2(1-k)}{\psi} + \sigma\tilde{z} - \alpha > 0\right\}\right] \\ &= U_v^f + \left(\frac{k}{2\theta} - \frac{1}{2} \frac{\sigma^2(1-k)}{\psi} - \alpha\right) F(k, \sigma, \theta, \psi, \alpha) + \sigma f(k, \sigma, \theta, \psi, \alpha) \end{aligned} \quad (46)$$

where  $F(k, \sigma, \theta, \psi, \alpha) = \mathcal{N}\left(\frac{1}{2} \frac{k}{\sigma\theta} + \frac{1}{2} \frac{\sigma(1-k)}{\psi} - \alpha\right)$  is the cumulative normal distribution and  $f(k, \sigma, \theta, \psi, \alpha) = F'(k, \sigma, \theta, \psi, \alpha)$  is the density function. Simplifying, the net-profits from issuance of the contingent contract read

$$\begin{cases} kF_k \frac{1}{2\theta} - (1-k)F_k \frac{\sigma^2}{2\psi} - \alpha F_k + \sigma f_k & \text{if } k \in [0, 2\alpha\theta] \\ k(F_k - 1) \frac{1}{2\theta} - (1-k)F_k \frac{\sigma^2}{2\psi} - \alpha(F_k - 1) + \sigma f_k & \text{if } k \in (2\alpha\theta, 1] \end{cases} \quad (47)$$

Figure B.9 shows how the net profits in (47) vary across types  $k$  for low, intermediate, and high values of the distortion cost  $\psi \in (0, +\infty)$ . When the distortion cost  $\psi$  is low (left-hand plot), preferences for the contingent contracts are strictly increasing in  $k$ . This is because the net profits in (47) are approx  $-(1-k)F_k \frac{\sigma^2}{2\psi}$ , whose derivative  $-F'_k(1-k) \frac{\sigma^2}{2\psi} + F_k \frac{\sigma^2}{2\psi} > 0$  since  $F'_k < 0$  for each  $k \leq 1$  when  $\psi$  is low. In such a scenario, it exists a  $\bar{k}$  and  $\underline{k}$  such that if  $k > \bar{k}$  then  $y_k = cg$ , if

$k \in [\underline{k}, \bar{k}]$  then  $y_k = g$ , whereas if  $k < \underline{k}$  then  $y_k = v$ , which proves the result. When the distortion cost  $\psi$  is high (right-hand plot), then the profits in (47) are strictly increasing in  $k$  for  $k \leq 2\alpha\theta$ , whereas they are strictly decreasing in  $k$  for  $k \geq 2\alpha\theta$ . This because the expression in (47) simplifies to

$$\approx \begin{cases} kF_k \frac{1}{2\theta} - \alpha F_k + \sigma f_k & \text{if } k \in [0, 2\alpha\theta] \\ k(F_k - 1) \frac{1}{2\theta} - \alpha(F_k - 1) + \sigma f_k & \text{if } k \in (2\alpha\theta, 1] \end{cases} \quad (48)$$

deriving the first term with respect to  $k$ , one gets

$$\begin{aligned} \frac{\partial}{\partial k} (kF_k \frac{1}{2\theta} - \alpha F_k + \sigma f_k) &= F_k \frac{1}{2\theta} + F'_k (\frac{k}{2\theta} - \alpha) + \sigma f'_k \\ &= F_k \frac{1}{2\theta} + \frac{1}{\sigma} f_k (\frac{k}{2\theta} - \alpha) \frac{1}{2\theta} (\frac{k}{2\theta} - \alpha) - \sigma f_k \frac{1}{\sigma} (\frac{k}{2\theta} - \alpha) \frac{1}{2\theta} \\ &= F_k \frac{1}{2\theta} > 0 \end{aligned} \quad (49)$$

which is strictly positive, whereas deriving the second term with respect to  $k$ , one gets

$$\begin{aligned} \frac{\partial}{\partial k} (k(F_k - 1) \frac{1}{2\theta} - \alpha(F_k - 1) + \sigma f_k) &= \frac{\partial}{\partial k} (kF_k \frac{1}{2\theta} - \alpha F_k + \sigma f_k) - \frac{1}{2\theta} \\ &= F_k \frac{1}{2\theta} - \frac{1}{2\theta} < 0 \end{aligned} \quad (50)$$

which is strictly negative. Importantly though, given that manipulation is negligible, net profits are overall above zero (e.g. Proposition 1 applies) and therefore such that all firms issue the contingent contract. In such a scenario,  $k = \bar{k} = 0$ , which again proves the result. On the other hand, when the distortion cost is neither high nor low (mid-plot), following the previous discussion, net profits in (47) are strictly increasing in  $k$  for  $k \in [0, 2\alpha\theta]$ , whereas they can be decreasing, increasing, or non-monotonic as a function of  $k$  for  $k \in (2\alpha\theta, 1]$ . Specifically, there is a region of other model parameters under which preferences for the contingent contract are u-shaped in  $k$ . In such a case, it exists a  $\underline{k} < \bar{k}$  such that if  $k < \underline{k}$  then  $y_k = v$  whereas if  $k > \bar{k}$  then  $y_k = cg$ , it may exist a  $k' < \bar{k}$  such that if  $k \in [\underline{k}, k']$  then  $y_k = cg$  whereas if  $k \in [k', \bar{k}]$  then  $y_k = g$ .

**Proposition 3.** In presence of asymmetric information, we solve for a semi-separating Perfect Bayes 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 or the best of the non-contingent contract)  $y(k) = \{\max(g, v), cg\}$ , whereas the second mover (investor) has one type and two moves (accept or refuse the proposed contract)  $b = \{1, 0\}$  and belief over the firm's type  $\beta(k) \sim \mathcal{U}[2\alpha\theta, 1]$  if  $g > v$ ,

and  $\beta(k) \sim \mathcal{U}[0, 2\theta\alpha]$  if  $g < v$ . A PBE requires that the firm's issuance strategy is sequentially rational – that is at each information set in 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  $\min\{\mathbb{E}[\mathcal{U}_{cg}^f(k)], \mathcal{U}_g^f(k), \mathcal{U}_v^f\} \geq R > 0$ . Consequently, 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  $b = 1$  in equilibrium.

We consider the optimal contracting problem from the perspective of a high type firm 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  $\mathcal{K} = [2\alpha\theta, k]$  if  $k > 2\theta\alpha$  or  $\mathcal{K} = [0, k]$  if  $k < 2\theta\alpha$ . The reason why low firms imitate high firms is that a different strategy would reveal that they are low firms with higher manipulation incentives. Let us first focus on the case where  $k > 2\alpha\theta$ . Following the discussion in Mailath [1987], for  $(y(k), \beta(k))$  as defined in the main text to be a PBE it is sufficient to prove that the single-crossing property is verified, meaning that

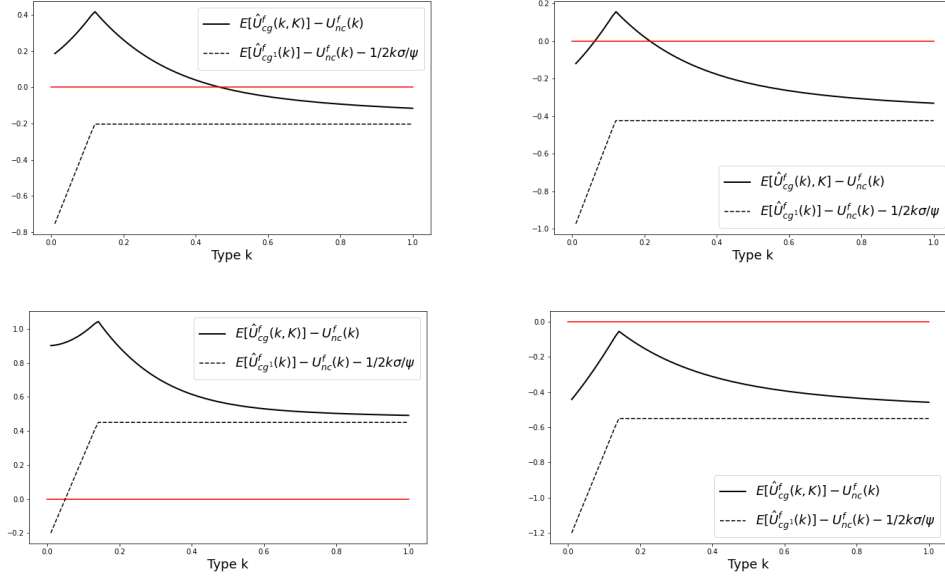
$$\frac{\partial}{\partial k}(\mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})] - \mathcal{U}_g^f(k)) \leq 0 \quad (51)$$

Let us first decompose the expected utility upon issuance of  $cg$  in presence of asymmetric information

$$\begin{aligned} \mathbb{E}[\mathcal{U}_{cg}^f(k)|\beta(k|\mathcal{K})] &= \mathbb{E}[\mathcal{U}_{cg}^f(k)] + \bar{\rho}_k^{cg} - \int_{2\alpha\theta}^k \bar{\rho}_k^{cg} dk \\ &= \left(\frac{k}{2\theta} - \alpha\right)F_k - \frac{1}{2} \frac{\sigma^2(1-k)}{\psi} F_k + \sigma f_k + \frac{\sigma^2(1-k)}{\psi} F_k - \frac{1}{k-2\alpha\theta} \int_{2\alpha\theta}^k \frac{\sigma^2(1-k)}{\psi} F_k dk \\ &= \left(\frac{k}{2\theta} - \alpha\right)F_k - \frac{1}{2} \frac{\sigma^2}{\psi} F_k (1-2\theta\alpha) + \sigma f_k \end{aligned} \quad (52)$$

**Figure B.10.** Net Profits From Issuance of Contingent Contract - Asymmetric Information

The plots show the net profits in (48) (black thick line) and the second component in (48) (black dashed line) as a function of the type  $k$  for different values of the model parameters. The red line defines the region below (above) which the firm has strict preference for the contingent contract  $cg$ . Parameters  $\theta = 0.1$  and  $\alpha = 0.6$  and  $\sigma = 1.5$ , whereas  $\psi = 1.4$  (top left plot),  $\psi = 1.1$  (top right plot),  $\psi = 4.5$  (bottom left plot), and  $\psi = 0.9$  (bottom right plot) respectively.



therefore taking the derivative of (51) with respect to  $k$ , one gets

$$\begin{aligned}
 \frac{\partial}{\partial k} (\mathbb{E}[U_{cg}^f(k)|\beta(k|\mathcal{K})] - U_g^f(k)) &= -\frac{1}{2} \frac{1}{\theta} (1 - F_k) + F_k' \left( \frac{k}{2\theta} - \alpha - \frac{\sigma^2}{2\psi} (1 - 2\theta\alpha) \right) + \sigma f_k' \\
 &= -\frac{1}{2} \frac{1}{\theta} (1 - F_k) + f_k \left( \frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi} \right) \left( \frac{k}{2\theta} - \alpha - \frac{\sigma^2}{2\psi} (1 - 2\theta\alpha) \right) + \\
 &\quad - f_k \left( \frac{k}{2\theta} + \frac{(1-k)\sigma^2}{2\psi} - \alpha \right) \left( \frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi} \right) \tag{53} \\
 &= -\frac{1}{2} \frac{1}{\theta} (1 - F_k) + f_k \left( \frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi} \right) \left( \frac{(1-k)\sigma^2}{2\psi} - \frac{\sigma^2}{2\psi} (1 - 2\theta\alpha) \right) \\
 &= -\frac{1}{2} \frac{1}{\theta} (1 - F_k) - f_k \left( \frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi} \right) \frac{\sigma^2}{2\psi} (k - 2\theta\alpha)
 \end{aligned}$$

noting that  $(1 - F_k) > 0$  and that  $k - 2\alpha\theta > 0$ , it derives that a sufficient condition for (51) to be negative is that  $\left(\frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi}\right) > 0$ , or that  $\theta < \frac{\psi}{\sigma^2}$ , which in turn means that  $a^{cg} > \sigma d^{cg}$ , proving the result. Following the same line of reasoning and recalling Proposition 2, it is simple to show that

$$\frac{\partial}{\partial k} (\mathbb{E}[U_{cg}^f(k)|\beta(k|\mathcal{K})] - U_v^f) \leq 0 \tag{54}$$

is never verified for  $k \in [0, 2\alpha\theta]$ , meaning that only corner solutions are possible.

## Robustness

**Risk-neutrality.** In what follows we show that introducing risk-aversion does not alter the baseline prediction of the model.<sup>47</sup> Specifically, assume an otherwise equivalent model with a risk-averse investor, denote  $\Lambda$  the investor's discount factor, with  $\mathbb{E}[\Lambda] = 1$  and  $Cov(\Lambda, \tilde{z}) < 0$ , then recalling the firm's problem in (10), the new investor participation constraint reads

$$\begin{aligned}
 -b_0^y + \mathbb{E}[\Lambda(b_1^y + x^y g(\tilde{z}, a^y))] &\geq 0 \\
 -1 + \mathbb{E}[\Lambda(1 + \rho^y + x^y g(\tilde{z}, a^y))] &\geq 0 \\
 \mathbb{E}[\Lambda(\rho^y + x^y g(\tilde{z}, a^y))] &\geq 0 \\
 \mathbb{E}[\rho^y + x^y g(\tilde{z}, a^y)] + Cov(\Lambda, \rho^y + x^y g(\tilde{z}, a^y)) &\geq 0
 \end{aligned} \tag{55}$$

therefore, taking count of risk-aversion amounts to introducing a covariance term in the participation constraint on the contract-specific rate. Such constrained rate therefore becomes

$$\rho^g \geq -\mathbb{E}[g(\tilde{z}, a^g)] - Cov(\Lambda, g(\tilde{z}, a^g)) \tag{56}$$

for the project-based non-contingent green debt, whereas it becomes

$$\bar{\rho}^{cg} \geq \mathbb{E}[\sigma x^{cg}(\tilde{z}) d^{cg}(\tilde{z})] - Cov(\Lambda, \sigma x^{cg}(\tilde{z}) d^{cg}(\tilde{z})) \tag{57}$$

for the outcome-based contingent contract. Now recalling that  $Cov(\Lambda, g(\tilde{z}, a^g)) = Cov(\Lambda, \sigma \tilde{z})$  and that  $Cov(x^{cg}(\tilde{z}) d^{cg}(\tilde{z}), \tilde{z}) \geq 0$ , it derives that the new covariance term increases the minimum acceptable rate on both the green debt contracts. Notably though, the magnitude of the covariance term in (57) depends on the level of manipulation in the contract. Specifically in absence of manipulation, the covariance term in (57) disappears and the firm has a further reason to issue the contingent contract, in that by doing so it would avoid the risk-premium required by the investor for holding a contract that delivers an uncertain green outcome. Viceversa if the level of manipulation is high (e.g. the distortion cost  $\psi$  is low), then the risk-premium required by the investor for holding the contingent contract would be greater than that required for holding the non-contingent green debt, in turn making this contract less appealing, everything else equal. In summary, introducing risk-aversion does not alter the baseline theoretical prediction outlined in the risk-neutral model.

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<sup>47</sup>Similarly, one can show that under the current model specification, a risk-averse firm would have the same utility function across all contract choices.

**Certain monetary return and firm capital structure.** In the model, we assume that monetary returns are certain and therefore we abstract from any analysis regarding the firm's capital structure and how it relates to the investor's green preferences. We show below that in a simple extension of the model which allows for uncertain monetary returns, equity acts as a perfect substitute to vanilla non-contingent debt, and that high firm types should therefore hold more debt relative to low firm types. Specifically, denote  $R(\tilde{\epsilon})$  as the uncertain project cashflow with  $\mathbb{E}[R(\tilde{\epsilon})] = \bar{R}$  and  $Cov(\tilde{\epsilon}, \tilde{z}) = 0$ . Assume that the firm can issue equity at the competitive price  $e_0 = \$1 + \bar{R}$  at date  $t = 0$  which delivers  $e_1 = \$1 + R(\tilde{\epsilon})$  at date  $t = 1$ , and denote  $w$  as the equity ratio of the firm. Then the firm's utility for a given financing choice  $w, y$  becomes

$$\mathcal{U}_{y,w} = \max_{a,x} \mathcal{C}_{0,y,w}^f + \mathcal{C}_{1,y,w}^f - xc(a) \quad (58)$$

where

$$\begin{aligned} \mathcal{C}_{0,y,w}^f &= we_0 + (1-w)b_0^y - 1 = w\bar{R} \\ \mathcal{C}_{1,y,w}^f &= 1 + R(\tilde{\epsilon}) - we_1 - (1-w)b_1^y = (1-w)(R(\tilde{\epsilon}) - \rho^y) \end{aligned} \quad (59)$$

such that

$$\begin{aligned} -we_0 - (1-w)b_0^y + \mathbb{E}[(1-w)(b_1^y + x^y g(\tilde{z}, a^y)) + w(1 + R(\tilde{\epsilon}))] &\geq 0 \\ -w\bar{R} + \mathbb{E}[(1-w)(\rho^y + x^y g(\tilde{z}, a^y)) + wR(\tilde{\epsilon})] &\geq 0 \\ (1-w)\mathbb{E}[(\rho^y + x^y g(\tilde{z}, a^y))] &\geq 0 \end{aligned} \quad (60)$$

substituting budget and participation constraints into the firm's problem, one gets that the expected utility reads

$$\mathbb{E}[\mathcal{U}_{y,w}] = w\bar{R} + (1-w)\mathbb{E}[R(\tilde{\epsilon})] + \mathbb{E}[x^y g(\tilde{z}, a^y)] = \bar{R} + (1-w)\mathbb{E}[x^y g(\tilde{z}, a^y)] \quad (61)$$

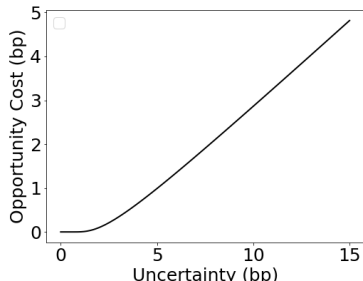
from which derives that the firm is indifferent between debt and equity whenever the expected compensation for the green outcome is zero, whereas has a strict preference for debt when the expected compensation for the green outcome is positive.

**Magnitude of the trade-off between contingent and non-contingent green debt contracts.** As reported in the text, the trade-off can be expressed as

$$\mathbb{E}[\mathcal{U}_{cg}^f] - \mathcal{U}_g^f = \underbrace{\mathbb{E}[\mathcal{U}_{cg}^f] - \mathcal{U}_{scg}^f}_{\text{opportunity cost of commitment}} - \underbrace{(\mathcal{U}_g^f - \mathcal{U}_{scg}^f)}_{\text{distortion discount}} \quad (62)$$

**Figure B.11.** Net Profits From Issuance of Contingent Contract - Asymmetric Information

The plot show the opportunity cost of commitment in (63) as a function of the uncertainty  $\sigma$  when the action cost  $\theta$  is calibrated to match an average green premium of 10 basis points (bp).



where  $\mathcal{U}_{scg}^f$  is the firm's utility from issuance of a synthetic contract which embeds manipulation of the green outcome and ex-ante commitment to the green project. The discussion outlined in Section xx shows that, as specified in (62), the opportunity cost of commitment is roughly independent of the distortion cost  $\psi$ , and so disregarding of the verification costs, the first term in (62) can be approximated by

$$\mathbb{E}[\mathcal{U}_{cg}^f] - \mathcal{U}_{scg}^f \approx \mathbb{E}\left[\left(\frac{1}{2\theta} + \sigma\tilde{z}\right)^+\right] - \frac{1}{2\theta} = \frac{1}{2\theta}(F(\sigma, \theta) - 1) + \sigma f(\sigma, \theta) \quad (63)$$

where  $F(\sigma, \theta) = \mathcal{N}\left(\frac{1}{\sigma 2\theta}\right)$  is the cumulative normal distribution and  $f(\sigma, \theta) = \mathcal{N}'\left(\frac{1}{\sigma 2\theta}\right)$  is the density function. One recalls that the *green premium* on the non-contingent green debt contract  $g$ , defined as the negative difference between the interest rate on the contract  $g$  and the plain vanilla contract  $v$ , is given by

$$-(\rho^g - \rho^v) = \mathbb{E}[g(a^g, \tilde{z})] = \frac{1}{\theta}. \quad (64)$$

The expression in (64) allows us to calibrate the green action cost  $\theta$  using extensive empirical literature that estimates the green premium on green bonds. Specifically, the literature finds a green premium of 20-30 bp in the primary market (see Kapraun, Latino, Scheins, and Schlag [2021]) and a green premium of 1-9bp in the secondary market (see Zerbib [2019] and Flammer [2021]). We therefore fix the parameter  $\theta$  to match an average 10bp. The graph below then quantifies the opportunity cost of commitment as a function of the uncertainty  $\sigma$ . As noted, the flexibility feature of the contingent contract becomes more valuable for larger values of  $\sigma$ , as acquiring more information may substantially shape the firm's profits at maturity.<sup>48</sup>

<sup>48</sup>Note that this estimate is an upperbound with respect to the case outlined in Section XX as we removed the interaction of the manipulation incentives on the firm's decision to implement the green project.

Assuming that  $\sigma$  is approximately one half of the average green outcome that can be predicted by the firm's actions, this would mean that the distortion discount would need to increase the firm's borrowing costs of roughly 3 bp to make the trade-off comparable (i.e., 30% of the average 10bp premium). While there is scarce empirical literature that quantifies the effects of greenwashing on the firm's borrowing costs, a recent paper by Attig, Rahaman, and Trabelsi [2021] on bank loans shows that greenwashing decreases the firm's borrowing benefits from environmental reporting of roughly 30%. These magnitudes are comparable with the benefits of the contract's flexibility.