The Optimal Design of Green Securities *

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Abstract

We develop a model of green project financing which incorporates investors with green preferences into an otherwise standard framework of corporate financing with asymmetric information. Firms seek to finance green projects whose outcomes embed an uncertain component that is revealed only to the firm and which can be manipulated. Firms can raise funds using non-contingent 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 signaling device, and we find empirically that contingent green debt securities have lower credit rating, higher yields and are issued by more emissions intensive firms.

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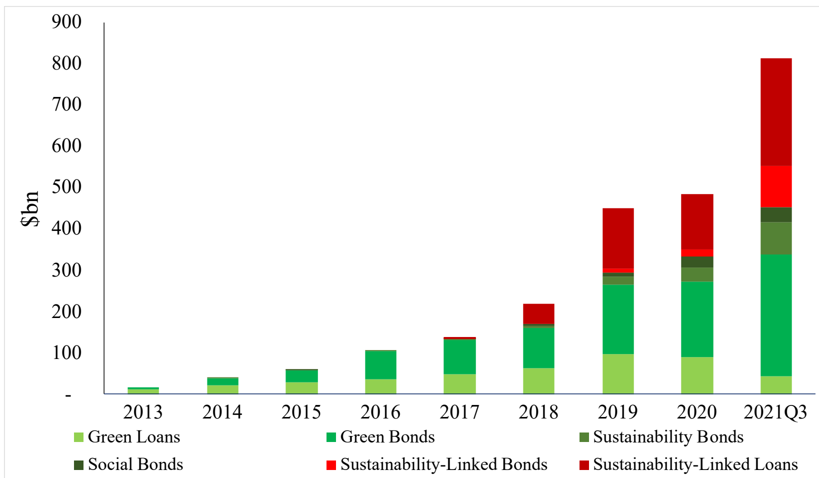
1 Introduction

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.[1] 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.

[1] In line with the ICMA standards governing the issuance of securities on the sustainable finance market, the term green refers to environmentally related outcomes, while the terms sustainability is wider and refers to environmental as well as social and potentially governance related issues.

The introduction of contingencies in securities' payoff addresses the limitations inherent to the design of 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 (see, for example, 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.

The model we propose in this paper rationalizes observed debt issuance patterns as equilibrium outcomes of a firm financing model which embeds verifiable moral hazard, manipulation and asymmetric information. The baseline model features two time periods, an investor, and a representative firm in the market. 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 conceptualised 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.[2] 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 can only be observed by the firm at an interim date, and can be manipulated in reports at some manipulation cost.[3] 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

[2]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.

[3]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.

monitoring of green outcomes (similar in spirit to SLLs/SLBs).[4] The investor accepts the debt contract provided it generates at least zero return in expectation.

We first consider a model with a single firm. We show that vanilla contracts are affected by a moral hazard problem and can only finance business-as-usual projects, such 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, the current co-existence of the two contract categories is the result 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 helps capturing interesting 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, referred to as the green outcome *materiality*, captures the degree to which a firm can control and measure green outcomes.[5] According to the model, projects which are more

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

[5]As detailed in the empirical section, we use the definition of materiality and materiality threshold provided by the GHG Protocol standard, which refers to the expected level of discrepancy between one firm's reported emissions

likely to be financed using non-contingent green debt are those with very high or very low levels of green outcome materiality. When we proxy green outcomes using carbon emissions, 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 financial (because here the distortion discount is very high).[6]

Next, we extend the model along the firm type dimension to explain issuance patterns within industry. Firm types are differentiated with respect to the cost of action and the cost of distortion that they face. 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.[7]

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 will issue either contingent or non-contingent green debt, whereas low firm types will 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 will 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 powerful signalling devices by allowing high types to credibly reveal their ability to commit ex-ante. Since the marginal benefit of manipulation decreases with the 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.[8] Importantly, as a result of the combined

and a verifier's belief about the firm's total emissions if all omitted sources where accounted for. Defined as such, materiality is increasing as the level of measurability/control over a firm's emissions increases, and is captured by the emission intensity scopes 1, 2 and 3 as defined by the GHG Protocol standard. A similar ordering of carbon emissions' scopes according to their level of control can be found in a recent work by Kacperczyk and Peydro (2021).

[6]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).

[7]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.

[8]As we clarify in the paper, such flip in the equilibrium predictions relies, among other factors, on the assumption

presence of measurement and information frictions, the model predicts that holding an outcome-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.

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 correct identification of firms' types within industry, then we should see that the best types, as ordered using those proxies, are the ones innovating with 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 issuance choice and 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 total emissions scopes per unit of the firm's 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 more credible signal of environmental commitment captured by the firm's actual adoption of an Environmental Management System (EMS).[9] 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, therefore supporting 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. To do that, 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

that action and distortion costs are negatively correlated across types.

[9]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]).

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-contingent green debt is higher than the green premium on contingent green debt, although those differences are not statistically significant ?. This evidence appears in line with the equilibrium prediction that contingent securities are issued by lower environmental types, and should therefore compensate the investor with higher financial returns than green bonds. 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,[10] 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[11] 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

[10]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.

[11]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.

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 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.[12] 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

[12] 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.

in their green debt contracts. A paper related to ours is Manso, Strulovici, and Tchistyi [2010] who study performance sensitive debt (PSD), an innovative debt instrument whereby the interest rate varies ex-post with some performance metric of the borrower. Despite sharing the same security payoff structure, theirs is a model 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 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

This section provides some institutional background behind the evolution of the corporate sustainable debt market.

The market for sustainable debt started in 2007 with the issuance of the world's first green bond by the European Investment Bank, the so called Climate Awareness Bond.[13] Green bonds (GB) 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 GB 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 subsidy, 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 obtain a green label from a number of certification providers, most of which adhere to the Green Bond Principles (GBPs).[14] The GBPs provide issuers with high level

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

[14]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 bond align with the principles, and their services or involvement range from second party opinion to rigorous verification against standardized scientific criteria and involving the appointment of approved 3rd party verifiers. The major certification

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 the projects.[15] Alongside the development of GBs, the market has seen a proliferation of debt instruments that are similar in spirit but which serve to finance 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. As for 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.[16] 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.[17] In the case of SLLs, which represent the private debt counterpart of SLBs and whose issuance is guided by the voluntary guidelines issued by the Loan Market Association (LMA), ex-post reporting and verification of performance is only *recommended*, and subject to negotiation between the borrower and lenders on a transaction-by-transaction basis.

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.

[15]For example, Apple clearly states that there can be no assurance" that funded projects meet investor criteria or expectations regarding sustainability performance".

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

[17]For a discussion about the difference between auditing reports and proper certifications of green securities see also the discussion in 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 about 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 at some cost. 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 that can be manipulated by the firm in reports. 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 σ controls the level of discrepancy between the overall green outcome and its unverifiable/uncertain component, which we call the degree of *materiality* of the project.[18] The higher is σ the less material the project outcome, that is, the more uncertain and harder-to-assess the outcome.

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

[18]When the green outcome is interpreted as a reduction in carbon emissions, this maps into the concept of materiality proposed by the GHG Protocol standard which is the maximum percentage difference between the company's *reported* emissions and the verifier's *belief* of what the company's emissions would be if all omitted sources were accounted for. More detail are provided in the empirical section.

green project, the investor's utility reads

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

with endowments $n_0^I >> 1$ 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

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

with θ 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

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

The Euler conditions yield the following project and action choices

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

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 in (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 \$1 to the firm, so that the latter can afford the implementation of (at least) the baseline project that has a positive certain monetary return.[19] 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 $\$1 + \rho^y$, with ρ^y denoting the interest rate associated with the debt contract.

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 vary with 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 the most simple form of debt contract which repays the investor at date $t = 1$ a fixed interest rate ρ^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 ρ^g that will remain fixed throughout the life of the contract. At issuance, the firm also pays a verification cost α 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 GBPs.

The *outcome-based contingent* green debt contract, indexed by cg, does not involve ex-ante selection of projects nor commitment to actions, but incentivize commitment to outcomes through the introduction of a state-dependent interest rate ρ^{cg} which is contingent on the realization of the uncertain green outcome:

$$\rho^{cg} = \bar{\rho}^{cg} - x^{cg} g(z_r^{cg}, a^{cg}) \tag{6}$$

[19] The positive certain monetary return and the fact that the firm has zero endowments ensures that external financing is always profitable in equilibrium, e.g. there are no equilibrium outcomes where no contract y is chosen.

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 (6) 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 α in order to produce the report about the green outcome $g(z_r^{cg}, a^{cg})$ and let the investor observe it.[20] 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 function of an optimal level of distortion as

$$z_r^{cg} = z + d^{cg} \tag{7}$$

with d distortion choice variable that comes at a quadratic cost (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 preferences for issuing a non-contingent or a contingent debt contract. The extended model with firm types, as well as its equilibrium predictions in presence of asymmetric information are considered in the next section.

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 issuance of this contract (e.g. $x^v = 0$ independently of the realized state z), and will therefore not be willing to pay a green premium by accepting a

[20] 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.

negative interest rate (e.g. the minimum contract rate would be $\rho^v \geq 0$). It is simple to show that, conditional on issuance of this contract, firm's utility reads

$$\mathcal{U}_v^f = R. \tag{8}$$

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 α to make the commitment credible. This is interpreted as the cost that the firm incurs to set up the process 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 issuance of a debt contract g, the firm problem can be simplified as follows

$$\mathcal{U}_g^f = \max_{a,x} R - \rho^g - x\frac{1}{2}\theta a^2 \tag{9}$$

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

$$\mathbb{E}[\rho^g + x^g g(\tilde{z}, a^g)] \geq 0 \tag{10}$$

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 (10) into (9), the firm problem becomes

$$\mathcal{U}_g^f = R + \max_{a,x} x(\mathbb{E}[g(\tilde{z}, a)] - \frac{1}{2}\theta a^2 - \alpha) \tag{11}$$

from which we obtain optimal project and action choices

$$x^g = 1\{\frac{1}{2}a^g - \alpha > 0\} \quad \text{with} \quad a^g = \frac{1}{\theta}. \tag{12}$$

From (10), 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, nothing that[21]

$$\mathcal{U}_g^f > \mathcal{U}_v^f \quad \longleftrightarrow \quad x^g = 1 \tag{13}$$

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, then necessarily if contract g is issued, $\rho^g = -\frac{1}{\theta}$ and one expects this contract to be issued at a *lower rate* than the vanilla contract. 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 [Kapraun and Scheins, 2019, Baker et al., 2018]. 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 that to spur 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 of another (green) non-contingent contract, there are some inefficiencies related to the fact that 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 thus 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

[21] 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 $x^g = 1$ the firm utility is $\mathcal{U}_g^f = R = \mathcal{U}_v^f$.

outcomes, which can be manipulated.

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

$$\mathcal{U}_{cg}^{f} = R - \bar{\rho}^{cg} + \max_{a,x,d} x(g(z_r, a) - \frac{1}{2}\theta a^2 - \frac{1}{2}\psi d^2 - \alpha) \tag{14}$$

where ψ is a distortion cost parameter, α is the cost of auditing and the base interest rate is now subject to the participation constraint

$$\bar{\rho}^{cg} \geq \mathbb{E}[x^{cg} g(\tilde{z}_r^{cg}, a^{cg}) - x^{cg} g(\tilde{z}, a^{cg})]. \tag{15}$$

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 $\psi = +\infty$ such that $d^{cg} = 0$, the green outcome is truthfully reported $z_r^{cg} = z$ for each realization z of the uncertain state $\tilde{z}$. The minimum required interest rate $\bar{\rho}^{cg}$ is thus zero and the variable, state-contingent interest rate ρ^{cg} in (6) will depend on the reported green outcome; specifically, it will be set so as to perfectly offset the reported green performance across each state z. Making explicit the dependence on the realised state z, first-order conditions yield optimal choices

$$x^{cg}(z) = 1\{\frac{1}{2}a^{cg} + \sigma z - \alpha > 0\} \text{ with } \; a^{cg} = \frac{1}{\theta}. \tag{16}$$

The firm's utility in this case is

$$\mathcal{U}_{cg}^{f} = \mathcal{U}_{v}^{f} + \Big(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z} - \alpha\Big)^{+} \tag{17}$$

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 $\psi << +\infty$, meaning when the contingency depends on a measurement system which can be manipulated, action and distortion choices read

$$x^{cg}(z) = 1\{\frac{1}{2}a^{cg} + \frac{\sigma}{2}d^{cg} + \sigma z - \alpha > 0\} \text{ with } a^{cg} = \frac{1}{\theta} \text{ and } d^{cg} = \frac{\sigma}{\psi}. \tag{18}$$

Result (18) states that when manipulation is possible, the firm's optimal distortion d^{cg} increases with the uncertainty of the project green outcome σ and decreases with the distortion cost ψ.[22] Importantly, note that the firm may optimally spend more in distortion than in actual investment 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 (18) 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 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 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 lies between the outcome obtained using the non-contingent green security g, and that obtained using the contingent green security cg with no manipulation.

Plugging in optimal choices into the firm utility we have

$$\mathcal{U}^f_{cg} = \mathcal{U}^f_v + (\frac{1}{2}\frac{1}{\theta} + \frac{1}{2}\frac{\sigma^2}{\psi} + \sigma\tilde{z} - \alpha)^+ - \bar{\rho}^{cg}. \tag{19}$$

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, 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

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

[22]This derives from the fact that the cost of distortion is independent of σ, hence distortion benefits increase with σ. A different specification where the distortion costs increase linearly in σ does not affect qualitatively any of the predictions in the paper.

which is given by plugging in the optimal distortion choice in (18) into (15). 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 (15).

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

$$y = argmax_{v,g,cg}\{\mathcal{U}^f_v, \mathcal{U}^f_g, \mathbb{E}[\mathcal{U}^f_{cg}]\} \tag{21}$$

where $\mathcal{U}^f_v, \mathcal{U}^f_g$ and $\mathbb{E}[\mathcal{U}^f_{cg}]$ 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's assume for a moment that the fixed cost $\alpha = 0$, so 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* generated by the fact that reported outcomes can be manipulated associated with the contingent contract. These competing forces are identified in equation (22) by adding and subtracting the firm's utility from the issuance of a synthetic *project-based contingent green* contract pcg, that is a contingent contract which embeds the incentive to manipulate as in cg, but which also involves ex-ante selection of the green project at issuance as in g,[23] so that net profits can be decomposed as

$$\mathbb{E}[\mathcal{U}^f_{cg}] - \mathcal{U}^f_g = \underbrace{(\mathbb{E}[\mathcal{U}^f_{cg}] - \mathbb{E}[\mathcal{U}^f_{pcg}])}_{\text{opportunity cost} \geq 0} - \underbrace{(\mathcal{U}^f_g - \mathbb{E}[\mathcal{U}^f_{pcg}])}_{\text{distortion discount} \geq 0} . \tag{22}$$

It is therefore immediate to see that, if the *opportunity cost* of committing ex-ante to the green

[23] One can easily show that $\mathbb{E}[\mathcal{U}^f_{pcg}] = \mathcal{U}^f_v + \frac{1}{2}\frac{1}{\phi} - \frac{\sigma^2}{2}\frac{1}{\psi}$.

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 (22) (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 $\alpha = 0.0$, $\phi = 1.5$, $\psi = 1.8$ (left plot), $\alpha = 0.0$, $\psi = 2.0$, $\sigma = 0.5$ (right plot), $\alpha = 0.0$, $\phi = 1.0$, $\sigma = 0.5$ respectively.

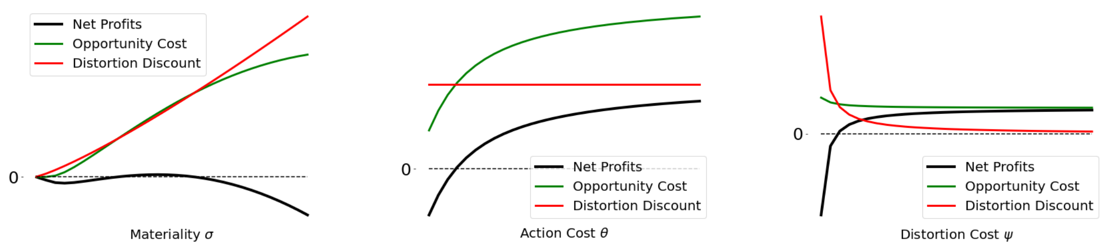


Figure 2 shows how the trade-off in (22) varies with the materiality of the project σ (left-hand plot), the action cost θ (mid plot), and the distortion cost ψ (right-hand plot) respectively. The left-hand plot shows that preferences are non-monotonic as a function of the materiality parameter σ. As σ increases, then both the opportunity cost of commitment (in green) as well as the distortion discount (in red) increase as a function of σ.[24] However, one notes that the distortion discount is convex in σ, whereas the opportunity cost of commitment is first convex and then concave in σ. 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 (20)) is quadratic in σ. On the other hand, the convexity and then concavity of the opportunity cost of commitment requires more explanation: for small values of σ, 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 σ increases the "value of the option to wait" in the standard quadratic manner[25], generating the observed convexity. On the other hand when σ 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 non-linearities, the

[24]Note that for fully material activities (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.

[25]See, for example, Kandel and Pearson [2002].

firm tends to prefer non-contingent green contracts when σ is low, contingent green contracts for intermediate values of σ, and it eventually opts for the non-contingent green contracts when σ 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 issuance of the contingent contract increase monotonically with the action cost θ 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 θ) 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 issuance of the contingent contract increase monotonically with the distortion cost ψ 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 ψ, 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.

Proposition 1. *Let y denote the optimal contract choice in* (19). *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 materiality of the project outcome. In this section we aim to impose restrictions on the firm's action and distortion technology 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 with the cost of action and the cost of distortion parameters as follows

$$\theta_k = \phi \frac{1}{k}, \quad \psi_k = \psi \frac{1}{1-k} \tag{23}$$

meaning that the highest type firm, $k = 1$, has infinite distortion cost and action cost equal to θ, while the lowest type firm, $k = 0$, has infinite action cost and distortion cost equal to ψ. The pair (θ_k, ψ_k) identifies the firm type and is independent of the parameter σ, which now uniquely identifies the project type in terms of green outcome materiality.

Condition (23) 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*". While the adoption of an EMS stands for commitment to environmental performance, Lyon and Maxwell [2011] also 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 costs α satisfies $0 < 2\alpha\theta < 1$ for a given action cost θ, so that the issuance of the project-based non-contingent green contract has positive (negative) net present value for the highest (lowest) type $k = 1$ ($k = 0$).[26]

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.

6.1.1 Optimal security choice

A firm k's contract choice is

$$y_k = argmax_{v,g,cg}\{\mathcal{U}_v^f, \mathcal{U}_g^f(k), \mathbb{E}[\mathcal{U}_{cg}^f(k)]\} \tag{24}$$

where $\mathcal{U}_g^f(k)$ and $\mathbb{E}[\mathcal{U}_{cg}^f(k)]$ are type-specific utilities from issuance of the non-contingent green contract g and the contingent green contract cg obtained substituting the expressions for θ_k and ψ_k in (23) into the utility functions (11) and (19), respectively.[27]

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

$$\begin{cases} \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_v^f & \text{if } \; k \in [0, 2\alpha\theta] \\ \mathbb{E}[\mathcal{U}_{cg}^f(k)] - \mathcal{U}_g^f(k) & \text{if } \; k \in (2\alpha\theta, 1]. \end{cases} \tag{25}$$

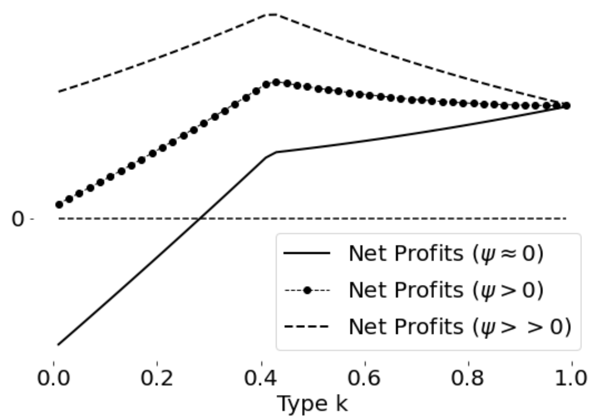
Figure 3 shows that if $k \in [0, 2\alpha\theta]$, then the net profits in (25) are strictly increasing as a function of the type k. This is because when the alternative is a vanilla contract, higher types are better off issuing contingent contracts because of their combined lower action costs and higher distortion costs. On the other hand, when $k \in (2\alpha\theta, 1]$, then the net profits in (25) 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 manipulation discount. Specifically, the opportunity cost of ex-ante commitment decreases monotonically in k as the action cost θ_k decreases, making contingent contracts pro-

[26] 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 $\mathcal{U}_g^f(k) = \mathcal{U}_v^f + \frac{k}{2\theta} - \alpha$, 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.

[27] Explicit expressions for these utilities can be found in Appendix B.

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 contract as a function of the firm type k in (25) 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 $\theta = 0.7$, $\alpha = 0.3$, $\sigma = 1.0$.



gressively *less* appealing for the higher type. On the other hand, the manipulation discount also decreases monotonically in the type k as the cost of distortion ψ_k increases, making contingent contracts progressively *more* appealing for the higher type. Depending on the magnitude of ψ relative to θ, 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 $\theta \in (0, +\infty)$,[28] the lowest types can either issue contingent contracts or vanilla contracts,[29] 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* (29) *for a type $k \in [0, 1]$ with action and distortion costs that vary as in* (23)*. Then for a given triple of parameters $(\theta, \sigma, \psi) \in (0, \infty)$ and verification cost α such that $0 < 2\alpha\theta < 1$, there exists two types $\underline{k} \leq \overline{k}$ such that*

- *if $k \geq \overline{k}$ then $y_k = cg$ the firm issues a contingent green contract.*
- *if $k \leq \underline{k}$ then $y_k = v$ and the firm issues a non-contingent plain vanilla contract.*
- *if $\underline{k} < k < \overline{k}$ then either $y_k = g$ and the firm issues a non-contingent green contract, or*

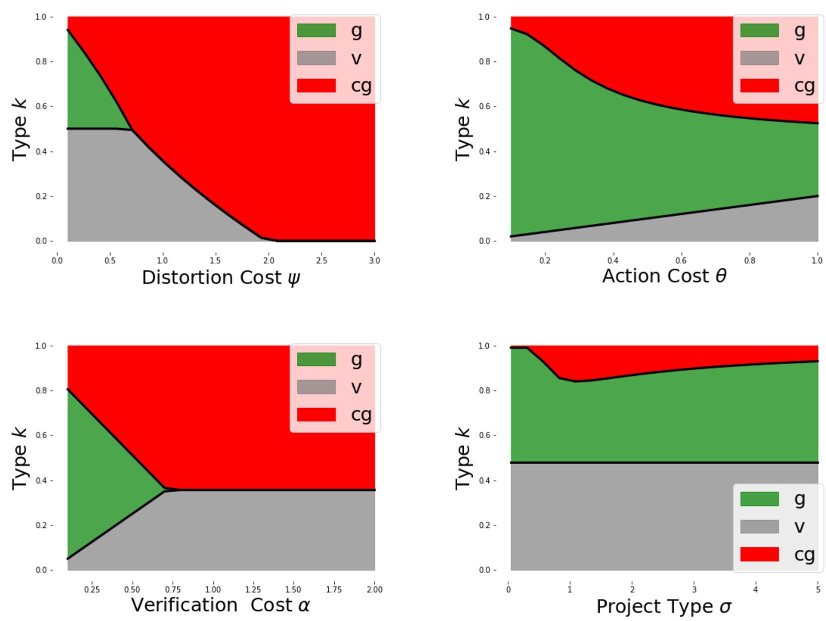
[28] This follows from Proposition 1 and from the specification of the distortion cost function across types.
[29] This follows from the assumption that $0 < 2\alpha\theta < 1$.

there exists an intermediate cutoff type k' *such that if* $\underline{k} < k < k'$ *then* $y_k = cg$*, whereas if* $k' < k < \overline{k}$ *then* $y_k = g$*.*

Figure 4 shows how the optimal issuance strategies vary as a function of the distortion cost ψ, the action cost θ, the verification cost α and the project materiality σ. 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).[30] 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 materiality (bottom right-hand plot 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 ψ, θ, α, and σ 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.

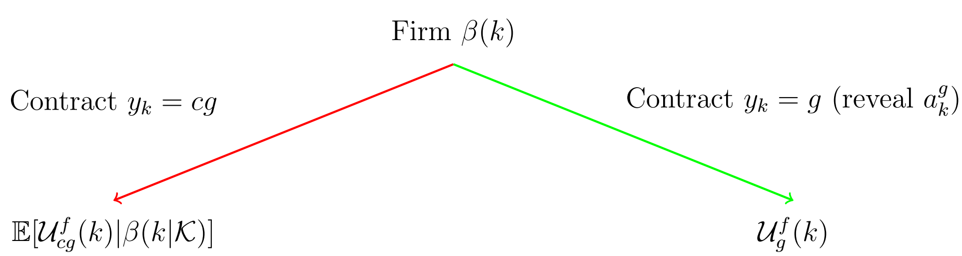


[30]As we outline in detail in the Appendix B, it may exist a region of the model parameters where the issuance strategy $y_k = cg$ is non-monotonic in k. However, such region is very small and not attained for any of the parameters choices reported in Figure 2.

6.2 Asymmetric Information

In this section we elaborate 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 belief over the firm's type given by the distribution function $\beta(k) \sim \mathcal{U}(2\theta\alpha, 1]$.[31]



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 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

[31]Note that in principle, the investor has also 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.

contract, denoted $\mathcal{K} := \{k \in (2\alpha\theta, 1]\ s.t.\ y_k = cg\}$. 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

$$\bar{\rho}^{cg}_{\mathcal{K}} = \int_{2\alpha\theta}^{1} \bar{\rho}^{cg}_k \beta(k|\mathcal{K}) dk \tag{26}$$

which differs from the type-specific rate $\bar{\rho}^{cg}_k$ obtained plugging ψ_k and θ_k into (20). A firm k's expected utility from issuing the contract cg conditional on the investor's posterior belief is then expressed as

$$\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] = \mathbb{E}[\mathcal{U}^f_{cg}(k)] + \bar{\rho}^{cg}_k - \bar{\rho}^{cg}_{\mathcal{K}}. \tag{27}$$

From the expression in (27), 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. $\bar{\rho}^{cg}_{\mathcal{K}} < \bar{\rho}^{cg}_k$ such that $\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] > \mathbb{E}[\mathcal{U}^f_{cg}(k)]$, whereas higher types (those k above the average type in group $\mathcal{K}$) are receiving a higher rate than the benchmark case with perfect information, i.e. $\bar{\rho}^{cg}_{\mathcal{K}} > \bar{\rho}^{cg}_k$ such that $\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] < \mathbb{E}[\mathcal{U}^f_{cg}(k)]$. 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

$$y_k : \begin{cases} = cg \quad if \quad k \ \in \ \mathcal{K} \\ = g \quad if \quad k \ \notin \ \mathcal{K} \end{cases} \tag{28}$$

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

$$y_k = argmax_{v,g,cg}\{\mathcal{U}^f_v, \mathcal{U}^f_g(k), \mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})]\} \tag{29}$$

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*

$$\frac{\partial}{\partial k}\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] - \mathcal{U}^f_g(k) \leq 0 \tag{30}$$

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 $k \in (e, 1]$.*

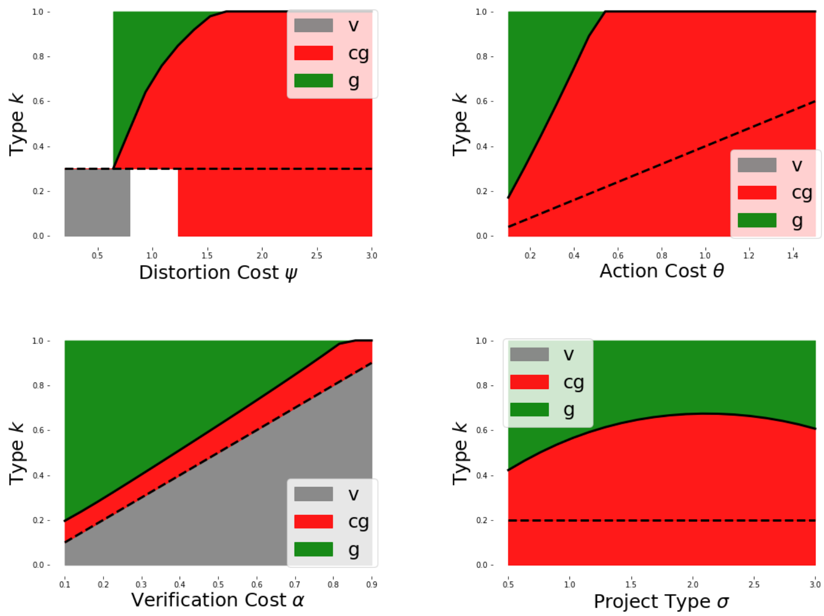
Proposition 3 states that, if it exists a (semi-) separating equilibrium, then necessarily higher types are those ones issuing the non-contingent contract g, whereas lower types are those issuing the contingent contract cg. This is because issuing a non-contingent green contract allows the good types 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 (30),[32] which states that the net gains from issuing the contingent contract are monotonically decreasing in the firm's type k. This happens because when the investor is 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 smaller 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 (30) is satisfied.

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 the Appendix B, condition (30) 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

[32] 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.

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 ψ, θ, α, and σ 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.



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.

Importantly, by focusing on the conditional set of types that issue contingent or non-contingent green contracts in equilibrium (e.g. 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 ψ, θ, α and σ. 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

The analysis that follows aims to test the predictions outlined in the theoretical sections combining green securities data with issuers characteristics.

7.1 Data

Securities. We first compile the universe of sustainable corporate debt securities screening for Green, Social, Sustainability instrument indicators as well as for Sustainability-linked indicators in the Bloomberg's fixed income database between January 2013 through April 2021 (details are provided in the Appendix A). We find a total of 8,589 securities, of which 4,618 bonds (including Green, Social, Sustainable and Sustainability-linked), and 3,971 loans (including Green and Sustainability-linked). Consistently with earlier evidence documented in Baker et al. [2018], Table A.5 shows that sustainable bonds and loans are on average larger than ordinary bonds and loans in terms of amount issued, have a longer maturity, and lower coupon rates. Interestingly though, we find that SLBs have significantly *lower* credit ratings than Green, Social, or Sustainable bonds (Figure A.7), whereas Green loans and SLLs have similar credit ratings, although credit ratings are available only for few securities in the private sample.

We find that SLB holders are similar to Green, Social, and Sustainable bond holders (Figure A.8), and that the performance metrics on which SLBs and SLLs are written match well the observed proportions of Green, Social, and Sustainable bonds and loans in the market (Table A.6). Specifically, using information from Bloomberg New Energy Finance (BNEF) on the performance targets of SLLs and SLBs, we find that 65% of the targets are written on environmental metrics (of which about half of these environmental metrics are GHG emissions), about 30% on social or ESG metrics, and only 5% on governance metrics respectively. These figures are in line with the overall proportion of Green, Social, and Sustainable bonds and loans in the sustainable finance market (roughly 80% of these bonds and loans are Green, whereas the remainder 20% are Social or Sustainable). This evidence mitigates concerns regarding the possibility that a firm might issue one or the other contract category depending on clientele effects, and it allows us to focus on environmental outcomes and more specifically on greenhouse gas (GHG) emissions as the single most popular metric underlying green debt contacts.

Security-Issuer Data. We construct the security-issuer dataset by matching the universe of sustainable corporate debt securities from Bloomberg with issuers' financial and emissions data from Standard & Poor (S&P) Trucost.[33] 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.[34] Given limitations in the availability of emissions data, we restrict our empirical analysis to the time period between 2017 and 2021, covering the years in which both contingent and non-contingent green debt categories are present in the market.[35] We also include Environmental, Social, and Governance (ESG) performance ratings in the analysis by matching firms in our dataset with the universe of firms in Sustainalytics.[36] Sustainalytics is a Morningstar rating company which measure a company's exposure to industry-specific ESG risks and how well a company is managing those risks. As reported in Appendix A, Sustainalytics is the most popular rating provider on which contingent green debt securities are written on. The final dataset comprises a total of 661 unique firms of which 476 with ESG ratings, issuing a total of 1,847 green debt securities between 2017 and 2021, where 334 of those securities are categorised as contingent green debt and the remainder as non-contingent green debt.

Table 1 reports summary information as of 2017 on the firms in our sample (column Issuers) comparing them with the universe of firms in Trucost (column S&P Trucost Universe). From a financial perspective, the average issuer of green debt securities is larger, has a higher proportion of debt in its capital structure, and is more profitable than the average firm in S&P Trucost. From an environmental perspective, the average 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. To the extent that size and the availability of emissions/sustainable performance metrics are barriers to entry in the sustainable finance market (e.g. small firms cannot afford upfront verification costs and/or do not have the technology for writing contingent contracts), these statistics are consistent with the model prediction

[33] We match issuers in Bloomberg with firms in S&P Trucost using their ticker symbol where possible and using the name for the remainder.

[34] 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*.

[35] The year 2017 is the start of the market for sustainability-linked loans and bonds.

[36] We match the Bloomberg/S&P Trucost dataset with Sustainalytics using the company ticker symbol where possible and using the name for the remainder.

that issuers of vanilla contracts should lie at the lowest end of the type spectrum.[37] Interestingly though, 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.

Table 1
Summary Statistics

Data are from the Sustainalytics/Bloomberg/Trucost merged dataset. The left column (Issuers) refers to the selected sample of firms that issue at least one green debt security between 2017 and 2021, as identified from the Bloomberg's fixed income database (Appendix A). The right column (S&P Trucost Universe) is the universe of firms in S&P Trucost. Balance-sheet and emissions data are from S&P Trucost and refer to the fiscal year 2017. *All continuous variables are winsorized between the 5^{st} and the 95^{th} percentiles of the pooled distribution. $^{+}$ESG performance indicators are available for a subset of the sample.

	Issuers		S&P Trucost Universe	
Variable	**Mean**	**(Std.)**	**Mean**	**(Std.)**
Total Assets*($ bl)	10.8	(28.8)	5.14	(9.82)
Total Revenues*($ bl)	9.79	(15.8)	1.91	(3.26)
EBIT to Revenues Ratio*	0.37	(0.42)	0.14	(0.21)
Debt to Value Ratio*	0.49	(0.19)	0.31	(0.23)
Self-Disclosure of Emissions	0.68	(0.45)	0.25	(0.42)
Emissions* (ml tCO2e)	5.70	(12.7)	0.86	(1.78)
Tracked by Sustainalytics	0.65	(0.47)	0.27	(0.45)
Sustainalytics ESG Score^{+}	62.3	(11.3)	56.9	(10.4)
Unique Firms	661		14,613	

7.2 Issuance by Project Type

A first prediction of the model is that non-contingent green debt contracts are preferred to contingent green debt when the project has either a high level or a low level of materiality. In the model, materiality defines the magnitude of the measurable component represented by costly action relative to the non-measurable uncertain component, meaning how much of the total outcome can be controlled by the firm and credibly verified. Interpreting the green outcome in terms of GHG

[37]Furthermore, although not directly modelled in our framework, it should be noted that size is also increasing the expected benefits from issuance of a green debt contract, consistent with the view that large firms are more visible and likely face greater level of investor pressure as well as greater exposure to global environmental regulation.

emissions allows for a neat mapping from the concept of materiality developed in the model to the notion of emissions materiality proposed by the GHG Protocol Standard. The GHG protocol defines a materiality threshold as the maximum percentage difference between the company's *reported* emissions and the verifier's *belief* of what the company's emissions would be if all omitted sources were accounted for.[38] Following this line of reasoning, we define industries as fundamentally *material* (*not material*) when their carbon emissions have a high (low) degree of measurement and control, resulting in a low (high) expected discrepancy between the firm's report and the verifier's belief. We order industries according to the degree of materiality of their emissions by making use of the emissions scope breakdown provided by the GHG protocol standard. Scope 1 emissions are those produced by sources directly owned or controlled by the firm, and so they are deemed as most material. Scope 2^+ emissions, which we define as including scope 2 emissions and scope 3 upstream emissions, capture indirect emissions produced by the firm's suppliers or by energy input sources, and so they are deemed as having an intermediate degree of materiality, i.e. intermediate level 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 least material.

We define an industry-level materiality index as

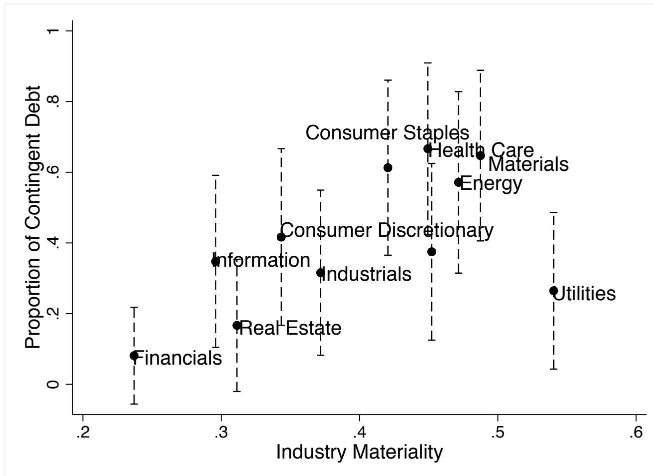
$$materiality_j = \frac{1}{N_j} \sum_{i=1}^{N_j} m^1 w^1_{i,j} + m^2 w^2_{i,j} + m^3 w^3_{i,j} \tag{31}$$

where for each firm i in industry j, the term $w^1_{i,j}$ is the proportion of scope 1 emissions out of total emissions, $w^2_{i,j}$ is the proportion of scope 2+ emissions out of total emissions, $w^3_{i,j}$ is the proportion of scope 3 emissions out of total emissions, and $m^1 = 1 > m^2 = 0.5 > m^3 = 0$ are decreasing levels of materiality of each of the emissions scopes. Figure 6 plots the proportion of contingent debt securities relative to all green securities issued between 2017 and 2021 against the industry-level materiality index as of 2017. In line with the model predictions, industries with intermediate levels of materiality 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 materiality 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.[39] The model rationalizes this pattern by showing that the

[38]Information can be found at *https://ghgprotocol.org/sites/default/files/standards/ghg−protocol−revised.pdf.*
[39]Figure A.9 in the data Appendix A shows absolute proportions of green issuances by industry.

Figure 6. Issuance Choice by Materiality

The plot shows the proportion of outcome-contingent green debt securities out of the total green debt securities issued between 2017 and 2021 (y-axis) against industry-level materiality index (x-axis). The index is constructed as in (31) using emissions data from S&P Trucost relative to 2017. Industry sectors refer to the Global Industry Classification Standards (GICS) provided by S&P Trucost.



ex-ante commitment to actions associated with non-contingent contracts is less costly when the firm has either very good control of the outcome (such that there is a low opportunity cost of foregoing more profitable investments), or when it has very poor control of the outcome (such that issuing a contingent contract is too costly because of the distortion discount).

7.3 Issuance by Firm Types

We first look for the presence of information frictions by regressing firms' green issuance choice on *observable* characteristics that should proxy for firms' environmental types. The argument is that if firms' types are correctly identified by those proxies, then we should expect a positive or insignificant correlation between contingent issuance and firms' types. On the other hand, if those proxies are only weakly correlated with firms' environmental types, then we should expect a negative correlation between contingent issuance and those 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 argument is that once controlling for location and industry effects, a higher historical emissions intensity is an endogenous outcome of higher historical abatement costs, in turn predicting lower future abatement capacity, everything else equal. Therefore, we proxy for action cost as

$$actioncost_{i,j} = log(emissions_{i,j}) - log(assets_{i,j}) \tag{32}$$

where for each firm i in industry j, $emissions_{i,j}$ are the sum of scope 1, scope 2+, and scope 3 emissions in kilo tons of carbon dioxide equivalent[40] (ktCO2e) and $assets_{i,j}$ refers to total assets in million dollars. Proxying distortion costs using realized manipulation is challenging in that one cannot disentangle reported from actual carbon emissions data. To circumvent this challenge, we conceptualize manipulation as *greenwashing*, defined 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.[41] 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 the green outcome but it also makes it more difficult for the firm to manipulate the measurement system which monitors those outcomes. Therefore, we proxy for distortion cost as

$$distortioncost_{i,j} = ems_{i,j} - esg_{i,j} \tag{33}$$

[40]Carbon dioxide equivalent or CO2e is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO2e signifies the amount of CO2 which would have the equivalent global warming impact.

[41]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−systemswhat−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.

where $esg_{i,j}$ is the industry-standardized ESG score of firm i in industry j and $ems_{i,j}$ is the sub-component of the score that indicates whether the firm has adopted an EMS and whether the EMS has been externally certified. The assumption in our model that the costs of action and distortion are negatively correlated is supported by empirical evidence reported in Table A.7 in Appendix A which confirms a negative correlation between the selected proxies for actions and distortion costs also controlling for industry and location fixed effects.[42]

Table 2

Security Choice - Linear Regressions

Linear regressions of green debt security choice between 2017 and 2021 on issuers characteristics as of 2017. The dependent variable is a dummy indicator equal to 1 if the firm issues uniquely an outcome-based contingent green debt contract in the observation period, and 0 otherwise. Regressors are collected from Bloomberg/Sustainalytics/S&P Trucost merged dataset. *,**,*** indicate statistical significance at the 10%, 5% and 1% level respectively.

Regressor	Regression I			Regression II		
Cost of Action	0.06***	0.04**	0.05***	0.07***	0.04**	0.04**
	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
Cost of Distortion				-0.01***	-0.01***	-0.01**
				(0.00)	(0.00)	(0.00)
Log Revenues		-0.03**	-0.02		-0.06***	-0.03*
		(0.01)	(0.01)		(0.02)	(0.02)
EBIT to Revenues Ratio		0.07	0.04		0.03	-0.01
		(0.05)	(0.05)		(0.07)	(0.07)
Debt to Value Ratio		-0.16	-0.14		-0.13	-0.09
		(0.10)	(0.09)		(0.12)	(0.12)
Self-Disclosure of Emissions		0.16***	0.03		0.01	0.02
		(0.04)	(0.04)		(0.01)	(0.05)
Tracked by Sustainalytics		0.01	0.02			
		(0.04)	(0.04)			
Intercept	Yes	Yes	Yes	Yes	Yes	Yes
Industry Dummy	No	Yes	Yes	No	Yes	Yes
Location Dummy	No	No	Yes	No	No	Yes
$\mathcal{R}^2$	0.11	0.18	0.26	0.14	0.21	0.28
Unique Firms	647	647	647	476	476	476

Table 2 reports linear regressions of firm's issuance choice on the selected proxies for firm types.

[42]The regression Table shows that the correlation flips sign and becomes statistically insignificant when controlling for firm's financial characteristics. The reason is primarily related to the fact that firm's revenues, which are strongly negatively correlated with action costs, are also strongly positively correlated with the firm's overall ESG score (without any effect on the EMS-related sub-component of the score), therefore capturing other the relation between action and distortion costs.

The dependent variable is a dummy equal to 1 if the firm issues only non-contingent debt securities between 2017 and 2021. The regressors are the firm's action and distortion costs proxies as well as other controls for the firm's financial conditions, all as observed in 2017. The column Regression I refers to the entire sample of firms, while column Regression II refers to the subsample of firms tracked by Sustainalytics. 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 the sample choices and when controlling for industry fixed effects, financial characteristics, as well as for location fixed effects. One notes that firms issuing contingent securities have lower revenues relative to non-contingent green debt issuers in the same sector, which interpreted in light of the recent evidence in De Haas, Martin, Muûls, and Schweiger [2021] that financial constraints inhibit corporate investment in green technologies, provides further support to the model prediction that contingent debt issuers are not the best environmental types. Interestingly, contingent 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 fixed effects.[43] On the other hand, as summarized by the regression coefficients on the dummy variable Tracked by Sustainalytics, it seems that being publicly rated at the sustainability level is not a statistically significant determinant of the firm's issuance choice, consistently with the fact that conditional on the issuance of green debt, issuance choices are not driven by a different cost of access to the technology on which contingent securities are written on. Moving on to the subsample of firms tracked by Sustainalytics, one finally notes that issuers of contingent 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 when controlling for industry fixed effects, financial characteristics, as well as for location fixed effects.

7.4 Ex-post Debt Performance

To complete the analysis, we look at the ex-post financial performance of contingent and non-contingent green debt securities. We recall that in the model, because of a binding investor par-

[43] 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.

ticipation constraint in equilibrium, all securities issued are expected to yield zero total returns. Specifically, the interest rate on each green debt contract is set to offset – in expectation or across states – the green outcome delivered by the project, in such a way that the monetary and green returns sum to zero. Consequentely, the model predicts that in presence of asymmetric information, contingent green debt contracts issued by lower firm types are expected to yield higher monetary returns so as to compensate the investor for lower green outcomes. To test this implication, we look at differences in the *green bond premia* across the two types of green debt securities, namely contingent and non-contingent debt, where the green bond premium is defined as the negative yield differential between green bonds and the conventional bond counterparts traded in the secondary market. Our empirical estimation follows the methodology in Zerbib [2017], but we are interested in yield differentials across contingent and non-contingent green debt rather than estimating the magnitude of the green bond premium per se.

For this analysis we restrict our attention to the sample of public debt and disregard private green debt securities, namely green loans and sustainability-linked loans. Specifically, we estimate the green premium of green, social, and sustainable bonds (non-contingent green bonds) and compare it with that one of sustainability-linked bonds (contingent green bonds) by using a matching methodology which consists of constructing pairs of securities with the same properties except for the one property whose effects we are interested in. That is, for each green issuer summarized in Table 1, we first collect from Bloomberg the list of conventional bonds issued by that same firm in the same year, finding a total 5,059 of conventional bond issuances against 754 total green issuances (79 contingent and 675 non-contingent bonds respectively). We pair each of the 754 green securities with a conventional bond (or a set of conventional bonds) with similar characteristics from the same issuer, meaning one with the closest maturity, bond type, coupon type, issue year and currency. We disregard differences at the rating level given that only half of the securities are rated. However, in green premium determinants regressions we account for differences in credit ratings at the issuer-level, as well as maturity and coupon biases due to the fact that maturities and coupon rates are not exactly equal. This exercise leaves us with a dataset of 368 pairs of green-conventional bonds (of which 29 contingent green-conventional and 339 non-contingent green-conventional respectively). For each pair of green-conventional bonds, we collect weekly ask yields since the issuance of the green security until the second week of September 2021, and measure the green premium as the average yield differential between each pair of green and conventional bonds.[44] We use average differentials in bid-ask spreads across green and conventional bonds to control for yield differences related to the liquidity bias (see Beber, Brandt, and Kavajecz [2009]).

Table 3

Debt Performance - Linear Regressions

Linear regressions of the green bond premium on the bonds characteristics. The premium is expressed in average percentage differences in ask yields between green bonds and their conventional bond counterparts. The variable Issue Amount is the amount of green bond issuance in $ billions. The variables ΔLiquidity, ΔMaturity, and ΔCoupon refer to differences in average bid-ask spreads, maturity, and coupon rates across the pairs of securities. All variables are collected from Bloomberg. *,**,*** indicate statistical significance at the 10%, 5% and 1% level respectively.

Regressor	Green Premium		
Constant	-0.35	-0.28	-0.30
	(0.94)	(0.60)	(0.62)
Contingent Debt	0.06	0.08	0.30*
	(0.17)	(0.15)	(0.18)
log(Issue Amount)		-0.01	-0.01
		(0.03)	(0.03)
ΔLiquidity		-0.76**	-0.49*
		(0.32)	(0.30)
ΔMaturity		0.06***	0.06***
		(0.01)	(0.01)
ΔCoupon		0.03	0.03
		(0.03)	(0.02)
Currency Dummy	Yes	Yes	Yes
Bond Type Dummy	Yes	No	Yes
Coupon Type Dummy	Yes	No	Yes
Issuer Rating Dummy	No	No	Yes
$\mathcal{R}^2$	0.61	0.70	0.72
Unique Matches	368	368	368

Table 3 shows the results of the regression of the green premia for each green-conventional bond pair against a selected set of bonds characteristics. The first column shows that when controlling for currency, bond structure, coupon type and issue year, we find negative yet statistically insignificant

[44] We select ask yields following the methodology in Zerbib [2017]. When more than one conventional bond is available, we take the average across each of the ask yields. If, on a specific week, the green or conventional ask yields are not available, we remove that observation from the dataset. The result is a cross-section of 368 green premia.

green premia of approx -35 basis points between non-contingent green and conventional bonds, and approx -29 basis points between contingent green and conventional bonds. In other words, the green bond premium seems to be 6bp larger for non-contingent green bonds than contingent green bonds, consistent with the evidence summarized in Table 2 which indicates that bad types are more likely to issue contingent green debt, although regression coefficients are not statistically significant. Column two shows that the results do not change when accounting for liquidity effects, residual differences in maturity and coupon rates, as well as differences in amount issued, although the magnitude of the coefficients changes as liquidity and maturity seem to be relevant determinants of yield differentials. Interestingly, the third regression shows that when controlling for rating differences at the issuer level, the positive difference across contingent and non-contingent yield spreads becomes larger (30bp on average) and statistically significant (see also Figure A.11 in the Appendix A). This is in line with evidence that issuer credit rating is one of the strongest determinants of cross-sectional variation in green bond premia reported by Zerbib [2017] and more recently by Larcker and Watts [2020]. Taken together, the reduced-form evidence reported in Table 2 and Table **??** 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 sustain the transition to a green 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

Institutional Details. The issuance of green/social/sustainability bonds as well as sustainability-linked bonds is governed by the principles put forth by the International Capital Market Association (ICMA), summarized in Table A.4. Under the GBPs, SBPs, and SBGs, an amount equal to the net bond proceeds is dedicated to financing elibigle projects (from which the term use of proceeds bonds), while under the SLBPs, proceeds are primarily for the general purpose of an issuer in pursuit identified Key Performance Indicators (KPIs) and Sustainable Performance Targets (SPTs). 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 applicable to their public counterpart. 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.

Table A.4
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) resepctively as issued by ICMA. Further detils 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

Securities data. 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".[45] Bloomberg applies a green/social/sustainability

[45] 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 if the issuer self-report (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's indicator therefore follows loosely the reference guidelines issued by the ICMA corresponding to each of those categories, in that only the component 1) out of the four key components in Table A.4 is captured by the indicator.[46] In a similar manner, Bloomberg applies a sustainability-linked label 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 one of the five key requirements summarized in Figure 1.

Bonds. As Panel A in Table A.5 indicates, our global sample, which runs from January 2013 through April 2021, contains 4,618 "sustainable" bonds (which comprise 3,758 green, 306 social, 391 sustainable bonds, and 149 sustainability-linked bonds) versus 1,055,033 ordinary corporate bonds. The Table shows that relative to ordinary bonds, sustainable bonds are larger in terms of amount issued ($289 mil versus $97 mil), a fact that may owe something to the fixed costs of certifying their green/social/sustainable status. On average, sustainable bonds have a lower coupon rate (about 1.8% difference), and more likely to have a fixed coupon rate than ordinary bonds (76% vs 63% have a fixed coupon, respectively). Consistently with early evidence in Baker et al. [2018], they also tend to have longer maturity and higher credit rating. The maturity gap is perhaps not surprising given that green and sustainability-oriented projects tend to have a longer payback horizon than general corporate projects not aimed at helping the company transition to a more sustainable business model. On the other hand as summarized by Figure A.7, differences in credit ratings are uniquely driven by the class of non-contingent green debt, namely green, social, and sustainable bonds, since sustainability-linked bonds have considerably lower ratings than the universe of bonds issued in the same period.

Loans. As Panel B in Table A.5 indicates, our total sample contains 3,971 "sustainable" loans (consisting of 3,251 green loans and 720 sustainability sustainability-linked loans) versus 108,592 ordinary corporate loans. The Table shows that, similarly to their bonds counterpart, sustainable loans are larger in terms of amount issued and longer in maturity than ordinary loans. Interestingly, the difference in maturity seems to be mostly driven by green loans, as the new class of

[46]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.*

sustainability-linked loans appear to have an average maturity more similar to ordinary loans. The interest rates associated with sustainable loans is lower than that of ordinary loans (this difference is particularly pronounced for sustainability-linked loans), and similarly to ordinary loans, sustainable loans predominantly have a floating interest rate (98% for sustainable loans and 96.5% for ordinary loans). Another interesting fact is that unlike green loans, the majority of sustainability-linked loans is of revolving type. Related to this fact, it is worth mentioning that approximately 20% of the existing sustainability-linked loans were issued as ordinary or green loans, and then later linked to a metric of sustainability performance. Sustainable loans have a poorer credit coverage compared to ordinary loans but a slightly higher credit rating, and unlike their public counterpart, SLLs have a similar credit rating compared to green loans.

Performance Metrics. We obtain data on the sustainability performance targets (SPTs) underlying sustainability-linked loans and bonds from Bloomberg New Energy Finance (NEF). Table A.6 breaks down the available SPTs[47] by major categories, namely SPTs based on public Environmental, Social, and Governance (ESG) scores, as well as SPTs based on specific environmental, social, and governance metrics respectively. Worth noting is that 64% of the SPTs are written on environmental metrics, of which 44% are GHGs emissions, a clear evidence of the centrality of climate change with respect to other sustainable issues. In decreasing order, the SPTs based on ESG scores account for roughly 17% of the total sample (which most of those scores being provided by Sustainalytics, the same rating provider that we use in our empirical analysis), whereas social and governance metrics account for roughly 15% and 4% of the remaining SPTs, respectively.

[47]One must note that there is not a one-to-one correspondence between SPTs and securities in that one or more SPTs can be associated to the same sustainability-linked bond or loan.

Table A.5

Corporate Sustainable Bonds and Loans

The Table shows summary statistics on corporate bonds (panel A) and loans (panel B) issued between January 2013 and April 2021 as collected from 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.

Panel A: Bonds	**Green/Social/Sustainable/Sustainability-linked**	**Sustainability-linked**	**Ordinary**
Variable	**Mean**	**Mean**	**Mean**
Amount Issued ($ mil)	289	425	97
Coupon Rate (%)	2.5	1.9	4.2
Maturity (years)	8.2	7.7	3.2
Project Selection (%)	96.9	1.3	0.4
Management (%)	95.5	1.3	0.3
Reporting (%)	95.4	1.3	0.3
Assurance (%)	85.1	6.7	0.3
Securities	4,618	149	1,055,033

Panel B: Loans	**Green/Sustainability-linked**	**Sustainability-linked**	**Ordinary**
Variable	**Mean**	**Mean**	**Mean**
Loan Tranche Size ($ mil)	214	695	326
Is Loan Revolving (%)	18.2	57.2	25.9
Coupon Rate (%)	2.6	1.9	4.5
Maturity (years)	15.7	7.8	8.6
Project Selection (%)	7.9	0.7	0.3
Management (%)	6.6	0.7	0.2
Reporting (%)	5.1	1.1	0.2
Assurance (%)	2.5	1.0	0.1
Securities	3,971	720	108,592

Figure A.7. Bonds Credit Ratings

The histogram shows the distribution of Standard & Poor (S&P) credit ratings of corporate bond securities issued between January 2013 and April 2021. 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.

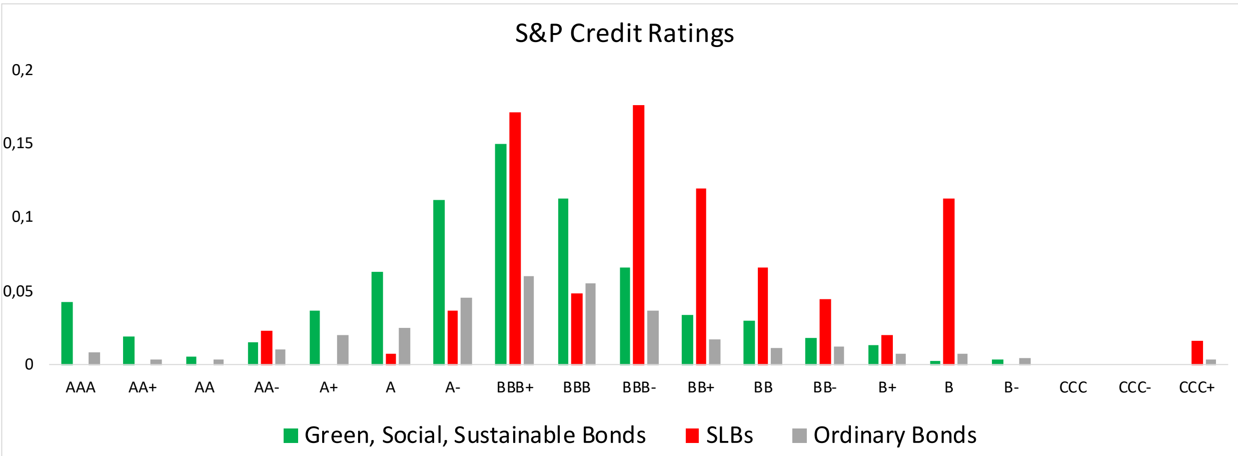


Figure A.8. Bonds Holders

The histogram shows the distribution of holding shares of corporate bond securities issued between January 2013 and April 2021 by type of investor. 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.

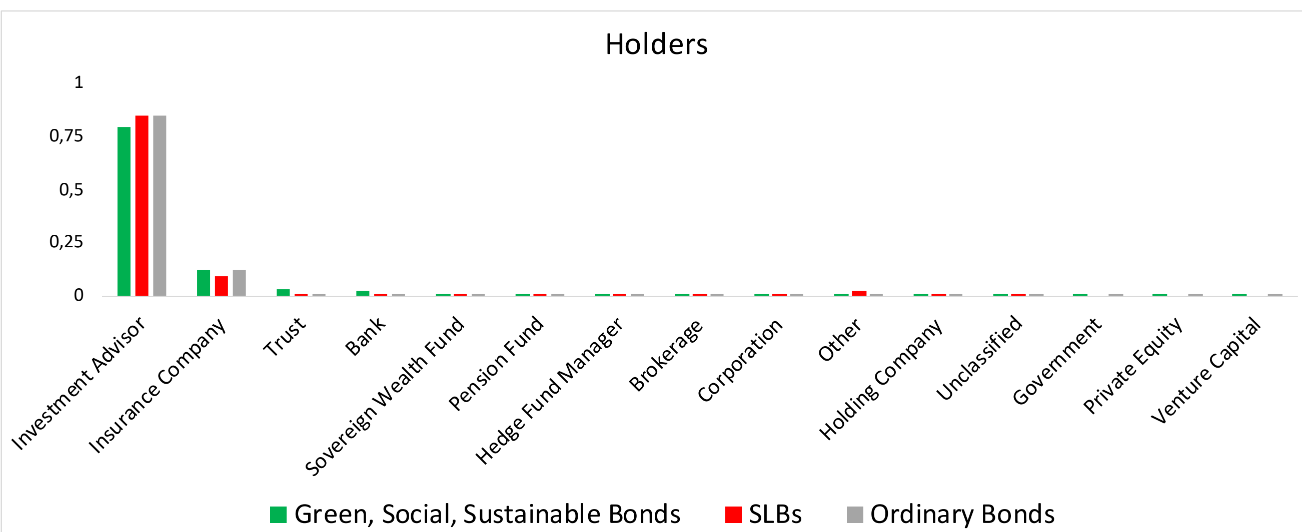


Figure A.9. Issuances by Industry

The top histogram shows the number of "green" issuers in the Bloomberg/S&P Trucost matched dataset by Global Industry Classification (GIC) Sectors. The bottom histogram shows to the conditional proportion of contingent and non-contingent debt in red and green respectively by GIC Sectors.

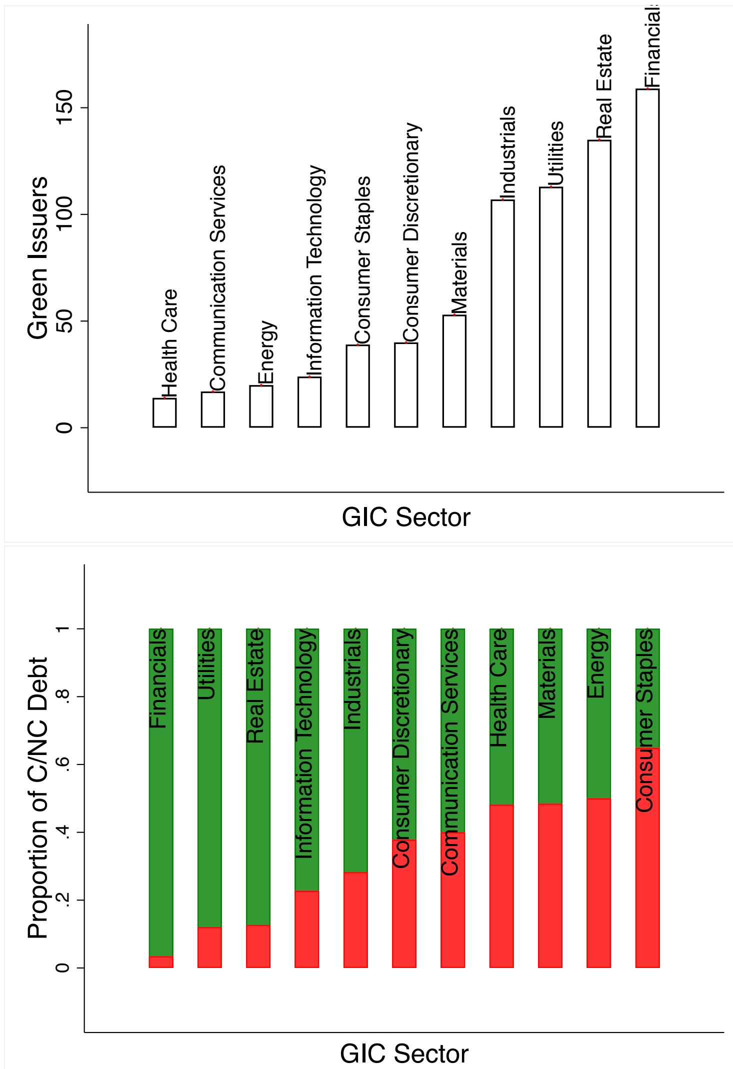


Table A.6

Sustainability Performance Targets (SPTs)

The table breaks down the target performance metrics linked to Sustainability-Linked Loans (SLLs) and Bonds (SLBs) by categories types (general ESG Scores, Environmental metrics, Social metrics, Governance metrics) and sub-categories respectively. Data are collected from Bloomberg NEF and refer to issuance of SLLs as of May 2021.

ESG Score	Environmental Metrics	Social Metrics	Governance Metrics
143	537	124	38
• Sustainalytics 31% • GRESB 12% • EcoVadis 10% • Vigeo Eiris 6% • Other/Unknown 41%	• GHGs 44% • Renewables 16% • Waste 14% • Energy Efficiency 7% • Water 5% • Transport 3% • Other/Unknown 11%	• Work Accidents 21% • Labor Rights 11% • Female Staff 6% • Education 5% • Social Returns 3% • Disabilities 2% • Other/Unknown 51%	• Female Board 26% • Other 74%

Figure A.10. Targets by Industry

The bar plot shows the relative proportion of the four target performance categories (e.g. general ESG Score, Environmental metrics, Social metrics, and Governance metrics respectively) across industry sectors ordered by increasing number of SLLs and SLBs issuances.

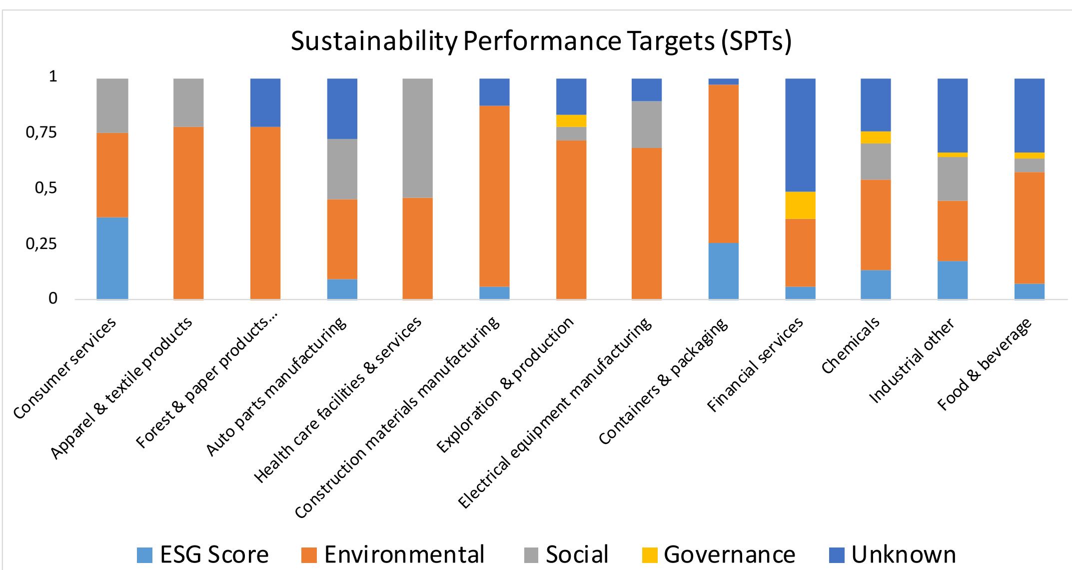


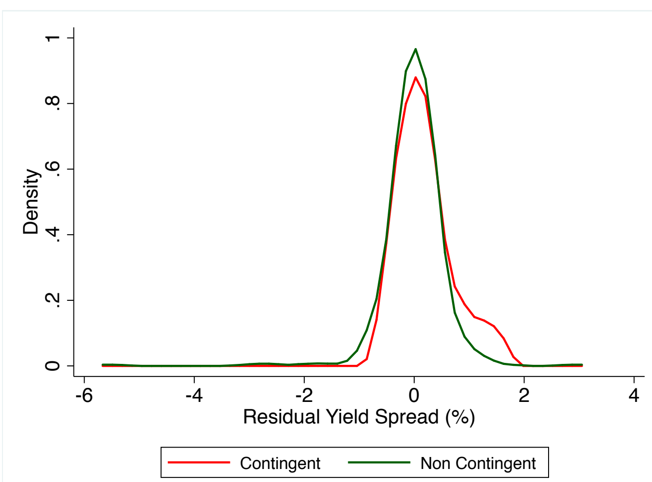
Table A.7
Action and Distortion Cost - Correlations

The table shows correlations (linear regressions) from the firm's distortion cost and action cost as proxied by historical emissions intensity and propensity of greenwashing respectively. Other controls are collected from Bloomberg/Sustainalytics/S&P Trucost merged dataset. *,**,*** indicate statistical significance at the 10%, 5% and 1% level respectively.

	Cost of Distortion		
Cost of Action	- 0.44**	-0.58*	0.62*
	(0.21)	(0.36)	(0.39)
Log Revenues			-2.61***
			(0.34)
EBIT to Revenues Ratio			-3.12**
			(1.48)
Debt to Value Ratio			1.06
			(2.49)
Self-Disclosure of Emissions			-0.05***
			(0.01)
Intercept	Yes	Yes	Yes
Industry Dummy	No	Yes	Yes
Location Dummy	No	No	Yes
$\mathcal{R}^2$	0.01	0.26	0.41
Unique Firms	476	476	476

Figure A.11. Spread Differentials - Regression Residuals

The plot shows the distribution of residuals in green-conventional bond green premia grouped by type of green security (e.g. contingent green bonds in red and non-contingent green bonds in green respectively). Residuals are obtained from the regression of yield spreads on bond characteristics where the dummy variable Contingent Debt has been excluded.



B Model Appendix

Proposition 1. The financing choice can be expressed as

$$y^* = cg \ \text{ iff } \ \mathbb{E}[\mathcal{U}^f_{cg}] > \mathcal{U}^f_v + \max\{0, \frac{1}{2\theta} - \alpha\}. \tag{34}$$

If $\psi = +\infty$, then

$$\mathbb{E}[\mathcal{U}^f_{cg}] = \mathcal{U}^f_v + \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z} - \alpha)^+] \tag{35}$$

rewriting condition (34) and applying the Jensen's inequality

$$\begin{aligned} \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z} - \alpha)^+] - \max\{0, \frac{1}{2}\frac{1}{\theta} - \alpha\} &\geq \mathbb{E}[(\frac{1}{2}\frac{1}{\theta} + \sigma\tilde{z} - \alpha)^+] - \frac{1}{2}\frac{1}{\theta} + \alpha \\ &> \frac{1}{2}\frac{1}{\theta} + \sigma\mathbb{E}[\tilde{z}] - \frac{1}{2}\frac{1}{\theta} = 0 \end{aligned} \tag{36}$$

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

$$\mathbb{E}[\mathcal{U}^f_{cg}] = \mathcal{U}^f_v + \mathbb{E}[(\frac{1}{2\theta} - \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha)\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha > 0\}] \tag{37}$$

For any (σ, θ, α), it holds that

$$\lim_{\psi\to 0} \mathbb{E}[(\frac{1}{2\theta} - \frac{\sigma^2}{2\psi} + \sigma\tilde{z})1\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} > 0\}] = -\infty \tag{38}$$

since the project will be picked with probability one whereas the distortion discount will approach infinite. This implies that for any (σ, θ, α)

$$\lim_{\psi\to 0} \mathbb{E}[\mathcal{U}^f_{cg}] < 0 < \max\{0, \frac{1}{2\theta} - \alpha\} \tag{39}$$

which by definition of the limit proves the result. On the other hand for any (σ, θ, α) one has

$$\lim_{\psi\to +\infty} \mathbb{E}[(\frac{1}{2\theta} - \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha)1\{\frac{1}{2\theta} + \frac{\sigma^2}{2\psi} + \sigma\tilde{z} - \alpha > 0\}] = \mathbb{E}[(\frac{1}{2\theta} + \sigma\tilde{z} - \alpha)^+] \tag{40}$$

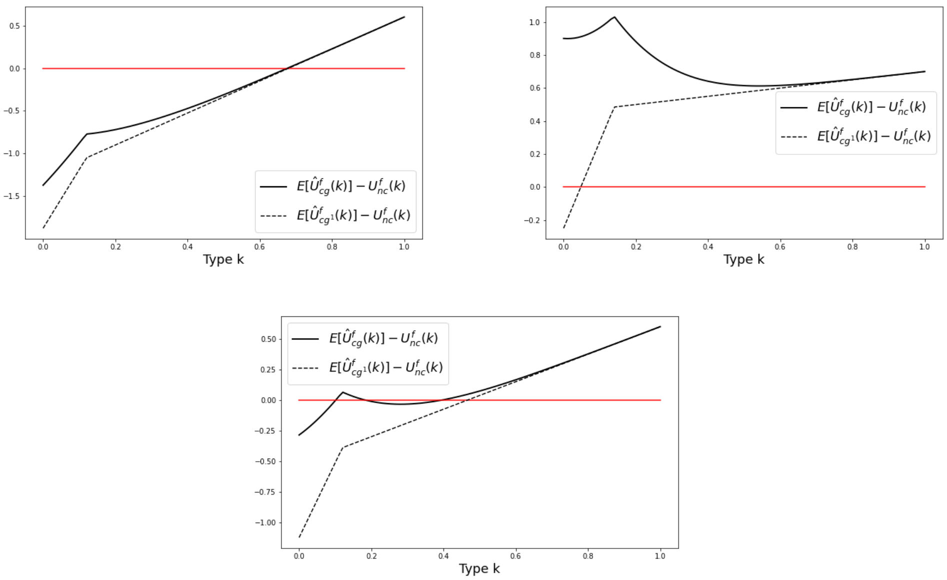
which by definition of the limit and the result stated in (36) proves the result.

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

$$\mathcal{U}^f_v + \max\{\mathcal{U}^f_g(k) - \mathcal{U}^f_v, 0\} = \mathcal{U}^f_v + \max\{\frac{k}{2\theta} - \alpha, 0\} \tag{41}$$

Figure B.12. Net Profits From Issuance of Contingent Contract - Perfect Information

The plots show the net profits in (43) (black thick line) and the second component in (43) (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

$$\begin{aligned}\mathbb{E}[\mathcal{U}^f_{cg}(k)] &= \mathcal{U}^f_v + \mathbb{E}[(\frac{k}{2\theta} - \frac{1}{2}\frac{\sigma^2(1-k)}{\psi} + \sigma\tilde{z} - \alpha)1\{\frac{k}{2\theta} + \frac{1}{2}\frac{\sigma^2(1-k)}{\psi} + \sigma\tilde{z} - \alpha > 0\}] \\ &= \mathcal{U}^f_v + (\frac{k}{2\theta} - \frac{1}{2}\frac{\sigma^2(1-k)}{\psi} - \alpha)F(k,\sigma,\theta,\psi,\alpha) + \sigma f(k,\sigma,\theta,\psi,\alpha)\end{aligned} \tag{42}$$

where $F(k,\sigma,\theta,\psi,\alpha) = \mathcal{N}(\frac{1}{2}\frac{k}{\sigma\theta} + \frac{1}{2}\frac{\sigma(1-k)}{\psi} - \alpha)$ 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

$$\begin{cases} kF_k\frac{1}{2\theta} - (1-k)F_k\frac{\sigma^2}{2\psi} - \alpha F_k + \sigma f_k \ if \ k \in [0, 2\alpha\theta] \\ k(F_k - 1)\frac{1}{2\theta} - (1-k)F_k\frac{\sigma^2}{2\psi} - \alpha(F_k - 1) + \sigma f_k \ if \ k \in (2\alpha\theta, 1] \end{cases} \tag{43}$$

Figure B.12 shows how the net profits in (43) vary across types k for low, intermediate, and high values of the distortion cost $\psi \in (0, +\infty)$. When the distortion cost ψ is low (left-hand plot), preferences for the contingent contracts are strictly increasing in k. This is because the net profits in (43) 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 ψ is low. In such a scenario, it exists a $\overline{k}$ and $\underline{k}$ such that if $k > \overline{k}$ then $y_k = cg$, if

$k \in [\underline{k}, \overline{k}]$ then $y_k = g$, whereas if $k < \underline{k}$ then $y_k = v$, which proves the result. When the distortion cost ψ is high (right-hand plot), then the profits in (43) 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 (43) simplifies to

$$\approx \begin{cases} kF_k \frac{1}{2\theta} - \alpha F_k + \sigma f_k \ if \ k \in [0, 2\alpha\theta] \\ k(F_k - 1)\frac{1}{2\theta} - \alpha(F_k - 1) + \sigma f_k \ if \ k \in (2\alpha\theta, 1] \end{cases} \tag{44}$$

deriving the first term with respect to k, one gets

$$\begin{aligned} \frac{\partial}{\partial k}(kF_k\frac{1}{2\theta} - \alpha F_k + \sigma f_k) &= F_k\frac{1}{2\theta} + F_k^{'}(\frac{k}{2\theta} - \alpha) + \sigma f_k^{'} \\ &= F_k\frac{1}{2\theta} + \frac{1}{\sigma}f_k(\frac{k}{2\theta} - \alpha)\frac{1}{2\theta}(\frac{k}{2\theta} - \alpha) - \sigma f_k\frac{1}{\sigma}(\frac{k}{2\theta} - \alpha)\frac{1}{2\theta} \\ &= F_k\frac{1}{2\theta} > 0 \end{aligned} \tag{45}$$

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

$$\begin{aligned} \frac{\partial}{\partial k}(k(F_k - 1)\frac{1}{2\theta} - \alpha(F_k - 1) + \sigma f_k) &= \frac{\partial}{\partial k}(kF_k\frac{1}{2\theta} - \alpha F_k + \sigma f_k) - \frac{1}{2\theta} \\ &= F_k\frac{1}{2\theta} - \frac{1}{2\theta} < 0 \end{aligned} \tag{46}$$

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, $k = \overline{k} = 0$, 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 (43) 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 $\underline{k} < \overline{k}$ such that if $k < \underline{k}$ then $y_k = v$ whereas if $k > \overline{k}$ then $y_k = cg$, it may exist a $k^{'} < \overline{k}$ such that if $k \in [\underline{k}, k^{'}]$ then $y_k = cg$ whereas if $k \in [k^{'}, \overline{k}]$ 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 $\beta(k) \sim \mathcal{U}[2\theta\alpha, 1]$ 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 $\min\{\mathbb{E}[\mathcal{U}^f_{cg}(k)], \mathcal{U}^f_g(k), \mathcal{U}^f_v\} \geq R > 0$. Consequentely, the firm will always propose a contract rate so as to satisfy the investor's participation constraint – meaning that the investor always buys the contract $b = 1$ 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 **??**, 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

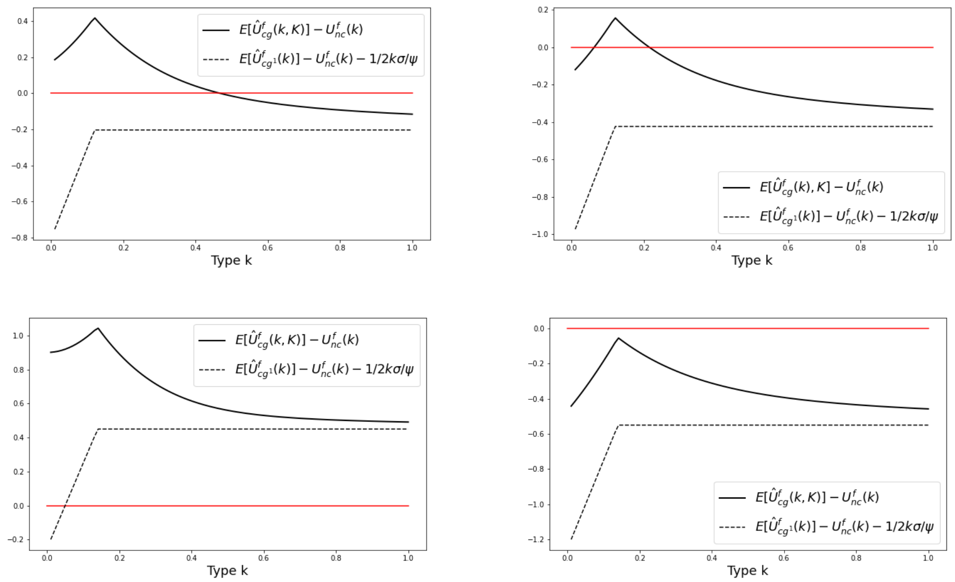
$$\frac{\partial}{\partial k}\big(\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] - \mathcal{U}^f_g(k)\big) \leq 0 \tag{47}$$

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

$$\begin{aligned}
\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] &= \mathbb{E}[\mathcal{U}^f_{cg}(k)] + \bar{\rho}^{cg}_k - \int_{2\alpha\theta}^{k} \bar{\rho}^{cg}_k dk \\
&= (\frac{k}{2\theta} - \alpha)F_k - \frac{1}{2}\frac{\sigma^2(1-k)}{\psi}F_k + \sigma f_k + \frac{\sigma^2(1-k)}{\psi}F_k - \frac{1}{k-2\alpha\theta}\int_{2\alpha\theta}^{k}\frac{\sigma^2(1-k)}{\psi}F_k dk \\
&= (\frac{k}{2\theta} - \alpha)F_k - \frac{1}{2}\frac{\sigma^2}{\psi}F_k(1-2\theta\alpha) + \sigma f_k
\end{aligned} \tag{48}$$

Figure B.13. Net Profits From Issuance of Contingent Contract - Asymmetric Information

The plots show the net profits in (44) (black thick line) and the second component in (44) (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 (47) with respect to k, one gets

$$
\begin{aligned}
\frac{\partial}{\partial k}\big(\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] - \mathcal{U}^f_g(k)\big) &= -\frac{1}{2}\frac{1}{\theta}(1-F_k) + F_k'\Big(\frac{k}{2\theta} - \alpha - \frac{\sigma^2}{2\psi}(1-2\theta\alpha)\Big) + \sigma f_k' \\
&= -\frac{1}{2}\frac{1}{\theta}(1-F_k) + f_k\Big(\frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi}\Big)\Big(\frac{k}{2\theta} - \alpha - \frac{\sigma^2}{2\psi}(1-2\theta\alpha)\Big) + \\
&\quad - f_k\Big(\frac{k}{2\theta} + \frac{(1-k)\sigma^2}{2\psi} - \alpha\Big)\Big(\frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi}\Big) \\
&= -\frac{1}{2}\frac{1}{\theta}(1-F_k) + f_k\Big(\frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi}\Big)\Big(\frac{(1-k)\sigma^2}{2\psi} - \frac{\sigma^2}{2\psi}(1-2\theta\alpha)\Big) \\
&= -\frac{1}{2}\frac{1}{\theta}(1-F_k) - f_k\Big(\frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi}\Big)\frac{\sigma^2}{2\psi}(k-2\theta\alpha)
\end{aligned}
\tag{49}
$$

noting that $(1-F_k) > 0$ and that $k - 2\alpha\theta) > 0$, it derives that a sufficient condition for (47) to be negative is that $(\frac{1}{2\sigma\theta} - \frac{\sigma}{2\psi}) > 0$, 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

$$
\frac{\partial}{\partial k}\big(\mathbb{E}[\mathcal{U}^f_{cg}(k)|\beta(k|\mathcal{K})] - \mathcal{U}^f_v\big) \leq 0 \tag{50}
$$

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.[48] Specifically, assume an otherwise equivalent model with a risk-adverse investor, denote Λ the investor's discount factor, with $\mathbb{E}[\Lambda] = 1$ and $Cov(\Lambda, \tilde{z}) < 0$, then recalling the firm's problem in (9), the new investor participation constraint reads

$$\begin{aligned} -b_0^y + \mathbb{E}[\Lambda(b_1^y + x^y g(\tilde{z}, a^y))] &\geq 0 \\ -1 + \mathbb{E}[\Lambda(1 + \rho^y + x^y g(\tilde{z}, a^y))] &\geq 0 \\ \mathbb{E}[\Lambda(\rho^y + x^y g(\tilde{z}, a^y))] &\geq 0 \\ \mathbb{E}[\rho^y + x^y g(\tilde{z}, a^y)] + Cov(\Lambda, \rho^y + x^y g(\tilde{z}, a^y)) &\geq 0 \end{aligned} \tag{51}$$

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

$$\rho^g \geq -\mathbb{E}[g(\tilde{z}, a^g)] - Cov(\Lambda, g(\tilde{z}, a^g)) \tag{52}$$

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

$$\bar{\rho}^{cg} \geq \mathbb{E}[\sigma x^{cg}(\tilde{z}) d^{cg}(\tilde{z})] - Cov(\Lambda, \sigma x^{cg}(\tilde{z}) d^{cg}(\tilde{z})) \tag{53}$$

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 (53) depends on the level of manipulation in the contract. Specifically in absence of manipulation, the covariance term in (53) 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 ψ 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.

[48] Similarly, one can show that under the current model specification, a risk-adverse 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

$$\mathcal{U}_{y,w} = \max_{a,x} \mathcal{C}^f_{0,y,w} + \mathcal{C}^f_{1,y,w} - xc(a) \tag{54}$$

where

$$\begin{aligned} \mathcal{C}^f_{0,y,w} &= we_0 + (1-w)b^y_0 - 1 = w\bar{R} \\ \mathcal{C}^f_{1,y,w} &= 1 + R(\tilde{\epsilon}) - we_1 - (1-w)b^y_1 = (1-w)(R(\tilde{\epsilon}) - \rho^y) \end{aligned} \tag{55}$$

such that

$$\begin{aligned} -we_0 - (1-w)b^y_0 + \mathbb{E}[(1-w)(b^y_1 + x^y g(\tilde{z}, a^y)) + w(1 + R(\tilde{\epsilon}))] &\geq 0 \\ -w\bar{R} + \mathbb{E}[(1-w)(\rho^y + x^y g(\tilde{z}, a^y)) + wR(\tilde{\epsilon})] &\geq 0 \\ (1-w)\mathbb{E}[(\rho^y + x^y g(\tilde{z}, a^y))] &\geq 0 \end{aligned} \tag{56}$$

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

$$\mathbb{E}[\mathcal{U}_{y,w}] = w\bar{R} + (1-w)\mathbb{E}[R(\tilde{\epsilon})] + \mathbb{E}[x^y g(\tilde{z}, a^y)] = \bar{R} + (1-w)\mathbb{E}[x^y g(\tilde{z}, a^y)] \tag{57}$$

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.