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Why Do Firms Issue Green Bonds?

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Abstract

We hold that green finance certification allows managers to signal firms' efficiency at addressing the energy transition. In our model of green bond issuance, signaling amplifies incentives to decarbonize. The model predicts that firms' managers are more inclined to issue green bonds when they are more interested in stock prices. We test this prediction by exploiting cross-industry differences in the stock-price sensitivity of managers' compensation and cross-country variations in effective carbon prices. The effect of managers' incentives on green bond issuance increases with carbon penalties. These results suggest that green bonds are complements to, rather than substitutes for, carbon pricing.

Keywords: Green bonds; Green finance; Climate policy; Carbon pricing; Managerial incentives.

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I. Introduction

Green finance certification allows investors to link their decisions to firms' commitments toward the environment. Green bonds are the most prominent green finance instrument: They commit issuers to using the bond proceeds to finance a certified climate-friendly project.[1] For example, Unilever announced on March 19, 2014, one of the now most famous green bond issues, earmarking more than $400m to new CO2-reducing production capacities. This commitment generated positive abnormal stock returns[2] of more than 5%. Similarly, Apple issued more than $4.5bn of certified green bonds between 2016 and 2019, to develop its use of clean energy sources and improve its energy efficiency. In the past few years, a rapidly increasing number of firms have made similar commitments, leading to a boom in the global green bond market, whose volume has nearly doubled every year since 2013 to around 3.5% of total corporate bond issuance in 2020 (DIW [2021]).

Firms' issuance of green bonds is voluntary but seems nevertheless environmentally effective. Flammer (2021) shows that firms issuing certified green bonds largely reduce their CO2 emissions[3] and argues against the possibility of greenwashing.

This paper suggests that green bond certification provides firms with incentives to decarbonize because the issuance of green bonds signals firms' efficiency at addressing the energy transition. We build a signaling model that points to the role of managers' interest in stock prices, which we exploit empirically in order both to validate our theory and to draw implications for the relationship between green bonds and public policies.

In the face of the climate problem, economists keep recommending carbon pricing. But in practice this direct approach faces political barriers.[4] Similarly, public subsidies to climate-friendly initiatives and technology regulation are constrained by governments' indebtedness, and limited information and expertise. The urgency of the climate challenge, therefore, calls for examining all instruments that are feasible and potentially effective. This need is reflected by recent studies on other options such as energy-efficiency standards (Jacobsen, Knittel, Sallee, and van Benthem [2020]). As a matter of fact, the green bond boom is receiving a lot of attention by governments and financial institutions.[5] Yet little is known about the

1. Certified green bonds must finance projects that satisfy the Climate Bond Standards or the Green Bond Principles. These standards provide an external verification scheme. Compliance with green bond commitments is voluntary, but noncompliance seems costly. There are only few examples of "green defaults," probably because noncompliance causes a significant reputational loss. For instance, when Repsol's $500m green bond, initially certified, was finally deemed noncompliant with the Climate Bonds Standards, it was excluded from green indexes. This also suggests that current certification standards are relatively consensual among investors, despite controversies (Environmental Finance [2017]).

2. See Section V for details on our event-study estimation of abnormal stock returns.

3. Using a matching technique, Flammer (2021) estimates that firms issuing certified green bonds reduce their CO2 emissions by 13% over the course of the next two years.

4. Even in developed countries, the effective price of most CO2 emissions is far below the social cost of carbon (OECD [2018]).

5. "Over the last few years, the ECB raised the share of green bonds in its own-funds portfolio to 3.5%

mechanisms that make green bonds work and the role that they can play in the structure of climate policy.

Recent empirical analyses of the green bond boom establish the following stylized facts. **First, firms' stock price increases when they announce the issuance of certified green bonds.** Baulkaran (2019), Tang and Zhang (2020), and Flammer (2021) find abnormal stock returns of 0.5-1.5% around the announcement of certified green bonds. This is similar to environmental awards (Klassen and McLaughlin [1996]) and unlike conventional bond issuance (Eckbo [1986]; Mikkelson and Partch [1986]; Antweiler and Frank [2006]), which does not generate abnormal stock returns. **Second, corporate green bonds are not significantly less costly to firms;** green and conventional bonds pay virtually the same interest rate to investors. Empirical estimates of the green bond yield spread are low, ranging from 0 to 0.2% (Zerbib [2019]; Tang and Zhang [2020]; Kapraun and Scheins [2020]; Flammer [2021]).[6] This—along with qualitative evidence of industry practice (Chiang [2017])—indicates that concerned investors do not currently play a significant role (Harrison, Partridge, and Tripathy [2020]).[7] **Third, certification of green bonds is key.** So-called "self-labeled" green bonds are not associated with either CO2 reduction or stock market reaction (e.g., Flammer [2021]).

Our theory combines two main ingredients. First, we model green bonds as a signaling device, conveying positive, although imperfect, information about the expected profitability of firms' environmental projects. Spence's (1973) single-crossing property holds because certified environmental commitments are less costly to firms that are more able to efficiently decarbonize. The information that green bonds reveal generates abnormal stock returns. This informational role of green bonds is supported by Tang and Zhang's (2020) finding that stock markets react mainly to the first financing of green projects and much less to their refinancing.

Second, our model features managers' interest in the stock price of their firm. If man-

in 2020, while planning to further increase it in the immediate future." (Central Banking [2021])

6. Bancel and Glavas (2020) come to the same conclusion. As Marilyn Ceci, Head of Green Bonds at JP Morgan, sums up, green bonds "generally price in line with traditional bonds, but occasionally demand outstrips supply and they can price a few basis points tighter" (Harrison, Partridge, and Tripathy [2020]).

7. Some investors certainly have a preference for green bonds and for the firms issuing them (Flammer [2021]). Yet the absence of spread means that the currently marginal investor is not significantly concerned. Pastor, Stambaugh, and Taylor (2021) show that investors' concern increases as climate change become more manifest. Green investors are likely to take a more active part in the future and a green bond spread may emerge—see, for example, *Financial Times*, January 4, 2021, "Analysts expect as much as $500bn of green bonds in bumper 2021." Our theory accommodates concerned investors and a green bond spread—see the discussion in Section VI and details in Appendix C.

agers only cared about long-term shareholder value, signaling would be useless. Managerial concern for short-term stock returns, also sometimes coined "short-termism," has various origins. One is that managers' actual compensation schemes include stock components (Stein [1989]; Georgen and Renneboog [2011]). For example, Edmans, Gabaix, and Landier (2009) measure the sensitivity of managers' compensation to their firms' stock price.[8] Besides their compensation, managers' interest in stock prices results from the risk of takeover (Stein [1988]), short-term investors (Bolton, Scheinkman, and Xiong [2006]), and markets' attention to short-term returns (Summers and Summers [1989]). Summers and Summers (1989) suggest, and Cremers, Pareek, and Sautner (2020) confirm, that investors' short-termism and managerial myopia are reflected by stock share turnover. Cross-industry variations in both managerial compensation sensitivity to the stock price and share turnover are significant. These variations arguably reflect sector-specific informational issues that are independent of firms' propensity to undertake green projects.

Moreover, besides green bonds, public policies in most countries already provide firms with incentives, although insufficient, to undertake CO2 reducing projects (OECD [2018]): carbon tax or emission trading schemes, if any, and excise taxes on carbon energy sources. In our model, policy-induced incentives are captured by an exogenous carbon price. One of the main insights is that green bonds amplify the impact of carbon pricing through positive stock market reactions.

We derive, and test, a relationship between the proportion of green bonds issued by firms in an industry, the carbon price that this industry is applied, and managers' sensitivity to their firms' stock price. This relationship highlights that the positive role of managerial incentives relies on the carbon price.

We use data that relate public firms' certified green bonds to their environmental and financial characteristics, and to the effective carbon price that prevails where they are based. We exploit carbon penalties variations across countries and industry-level variations of the stock-price sensitivity of managers' compensation to validate the role that our model ascribes to managerial incentives: We find that managers issue more certified green bonds when they are more interested in signaling their firm's profitability, which amplifies the role of carbon penalties. This result supports our signaling theory. The novelty of our strategy with respect to tests of the signaling hypothesis in other contexts—see, e.g., Tyler, Murnane, and Willett (2000) on the labor market—is to exploit variations in managers' incentives to

8. Gopalan, Milbourn, Song, and Thakor (2014) show that this is mainly a short- to medium-run sensitivity. They find that the vesting period of most of executives' stock and options grants is less than five years.

signal. Moreover, our results have implications for carbon pricing, whose impact is amplified by green bonds, but also for green bonds, whose effectiveness relies on carbon prices. Finally, we exploit the recent implementation of green bond policy supports in various countries to corroborate existing evidence that green bonds contribute to reduce CO2 emissions.

Our study is at the intersection of the above literature on managerial compensation and the literature on the private and social benefits of firms' socially responsible initiatives. Bénabou and Tirole (2010) hold that firms' corporate social responsibility reflects both the mitigation of excessive managerial short-termism and the expression of stakeholders and managers' concern about unresolved external effects. Maxwell, Lyon, and Hackett (2000) point to firms' interest in deterring future political action. Heal (2005) and Daubanes and Rochet (2019) further stress that self-regulation avoids costly conflicts with the rest of society. Similarly, the frameworks of analysis of Magill, Quinzii, and Rochet (2015), Hart and Zingales (2017), and Edmans (2020) imply that firms should adopt a more inclusive perspective. By contrast with this literature, our analysis suggests that the recent boom in certified green bonds is likely driven by short-term incentives to signal economic efficiency. Moreover, our results indicate that firms' voluntary green finance commitments are not substitute for public policies.

Our theory uses a minimal set of ingredients. We model an industry in which each firm considers a single incremental project over two periods of time. In the first period, firms' managers decide whether to undertake their project in a conventional or in a green (CO2 reducing) fashion. We take as given the sensitivity of their objective to stock price. Nor do we address the imperfections of environmental certification. Instead, we focus on the mechanisms underlying its effectiveness. We consider that green projects are all financed through green bonds, which perfectly certify the adopted green technology, while other projects are financed by conventional securities, among which we do not make any distinction. Shareholders do not observe the profitability of green projects, but infer it from managers' commitments through green bonds and the carbon price in effect. They price firms' stock accordingly in the first period, anticipating rationally the profits realized in the second period. Finally, since investors' concern for the environment currently seems inconsequential, we purposely omit this aspect in the baseline version of our model. However, our analysis can be extended to the presence of environmentally concerned investors, the emergence of a green bond yield spread, and an ESG-augmented stock market reaction.

The rest of the article is structured as follows. Section II relates our paper to the literature. Section III presents the baseline model and derives the main testable prediction. Section IV describes data and uses them to test the main prediction of our model. Section V provides additional empirical findings that support our theory. Section VI discusses the case of concerned investors—with technical details in the Appendix—and draws policy implications.

II. Related literature

In addition to the studies of corporate social responsibility and green finance, our findings are related to literatures on certification, climate policy instruments, managerial incentives, and green finance markets.

Certification.—The literature on certification—e.g., Farhi, Lerner, and Tirole (2005), and Lerner and Tirole (2006)—and on credence goods' labelling for consumers—e.g., Bonroy and Constantatos (2015), or Bonneton (2020)—focuses on situations in which agents are directly interested in the certified information: production's environmental impact, potential of an innovation, credit risk, etc. In this context, Fischer and Lyon (2014) and Bouvard and Levy (2018) examine how certifiers set standards' stringency and accuracy.

In our baseline model, by contrast, investors are not directly interested in the certified environmental performance, but only indirectly because firms' financing choices reveal economic performance. Moreover, we overlook the choice of standards' stringency so as to focus our analysis on the mechanism that makes green finance effective in practice.

Climate policy instruments.—Much empirical research effort has been devoted to the Pigovian resolution to the carbon externality—e.g., Nordhaus (2017). In the face of large remaining carbon pricing gaps (OECD [2018]), some examine second-best instruments—see, e.g., Jacobsen et al. (2020) on energy efficiency standards—and how these instruments complement carbon pricing (e.g., Dimanchev and Knittel [2020]). Others have examined the role of information disclosure (Tietenberg [1988]). Voluntary actions raise the question of their effectiveness. Khanna and Damon (1999) suggest that voluntary programs might be effective because of significant public recognition efforts targeting customer goodwill. Denicolò (2008) suggests that firms' voluntary environmental actions may seek to obtain excessively stringent regulation at their benefit.

Our analysis is complementary to this literature. Green bond certification specifically targets investors, not consumers. We point to a new mechanism through which voluntary green finance commitments can effectively complement carbon pricing.

Managerial incentives.—Our theory relies on managers' interest in the short-term stock returns of their firm. The finance and business literatures have proposed several explanations: preferences of shareholders (Summers and Summers [1989]; Bolton et al. [2006]; Polsky and

Lund [2013]; Bebchuk [2021]); the need to incentivize managerial efforts (Marinovic and Varas [2019]), especially in a context of competition for executives (Thanassoulis [2013]); the horizon of industry projects and their mispricing (Schleifer and Vishny [1990]); the risk of takeover (Stein [1988]).

Edmans et al. (2009) measure the sensitivity of managers' compensation value to the stock price. Our empirical analysis will make use of this incentive measure and its variations across industries, confirming its practical relevance.

Some have pointed out that managers' short-term incentives have various, mostly detrimental, effects: information manipulation to inflate current profits (Sobel [1985]; Bénabou and Laroque [1992]); financial instability (Summers and Summers [1989]); (lack of) long-term information acquisition (Casamatta and Pouget [2015]); (lack of) long-term investments (Ladika and Sautner [2020]; Cremers, et al. [2020]); (lack of) corporate social responsibility (Bénabou and Tirole [2010]). However, our analysis suggests that managerial short-termism may paradoxically encourage green finance commitments.

Green finance.—This paper adds to a burgeoning literature that examines various other aspects of the recent development of green finance: shareholder activism (Gollier and Pouget [2021]); the selection of green projects (Kotchen and Costello [2018]); divestment (Chava [2014]); equity investors' concern (Gibson, Krueger, and Mitali [2020]; Pastor et al. [2021]); environmental disclosure (Krueger, Sautner, Tang, and Zhong [2021]); the impact of concerned investors (Landier and Lovo [2021]); municipal green bonds (Baker, Bergstresser, Serafeim, and Wurgler [2020]); climate risks (e.g., Barrage and Furst [2019]); stranded assets (e.g., van der Ploeg and Rezai [2019]).

III. A signaling theory of green bond issuance

In the model of this section, we consider that investors care only about their investments' financial returns, and not at all about these investments' environmental impact. Proofs are relegated to Appendix A. Appendix B presents a special case that yields explicit solutions. Section VI will discuss, with technical details in Appendix C, how this model accommodates the case of bond and equity investors who are sensitive to firms' environmental performance.

III.A. Technology

The industry consists of a continuum of firms. Each firm has regular activities (which are given) and one incremental project which can be either green ($k = G$) or conventional, i.e., brown ($k = B$).

Firms' incremental projects take place over two dates $t = 0, 1$. They all require one unit of capital at date $t = 0$ and generate some profits at $t = 1$.

Projects' technology $k = G, B$ determines their environmental performance. At date $t = 1$, green and conventional projects generate CO2 emissions x_G and x_B respectively, with $x_B > x_G \geq 0$. Emissions are penalized at an exogenous rate $\tau \geq 0$.[9] Although, in reality, large firms' total CO2 emissions are often estimated, they can hardly be attributed to individual projects unless these projects are certified. We assume, therefore, that emissions due to firms' incremental projects are not directly observable.

Projects' technology $k = G, B$ also impacts their financial performance and investors' ability to predict this performance. All projects generate the same revenue[10] $Y > 0$ and entail a business-as-usual cost $c_B > 0$, which are perfectly known. But green projects further entail an emission abatement cost $\Delta c(i)$ that depends on the type $i \in [0, 1]$ of the project, private information of the firm's manager. The type of firms' projects ranks them in decreasing order of their green efficiency. $\Delta c(i)$ is strictly increasing and convex.

The total cost of firm i's project is:

$$c_k(i) = \begin{cases} c_B & \text{if } k = B \\ c_B + \Delta c(i) & \text{if } k = G, \ i \in [0, 1] \end{cases} .$$

The marginal cost of emission reduction is $\Delta c(i)/\Delta x$, where $\Delta x \equiv x_B - x_B$ is the project-level potential CO2 reduction.

Although the interpretation of $\Delta c(i)$ in terms of abatement costs seems natural, our model allows a broader interpretation. Type i may capture, for example, revenues from new green products or future benefits from developing expertise in the energy transition.

III.B. Green finance and firms' problem

We assume that all incremental projects are financed by bonds and that green bonds perfectly certify the green technology of financed projects.[11] We only consider certified green bonds, i.e., we ignore so-called self-labeled green bonds, because empirical evidence shows that the latter not only are environmentally ineffective but also do not trigger investors' reaction (e.g., Flammer [2021]).

9. In practice, effective carbon prices include not only explicit carbon penalties such as carbon taxes and allowance prices, if any, but also specific excise taxes on carbon containing energy inputs.

10. For concreteness, we assume that the profits from firms' projects only differ in their cost; our model, however, allows a broader interpretation.

11. Conventional bonds, including self-labelled, non-certified green bonds may be interpreted as regular bank loans.

Green and conventional bonds have the same interest rate—see, e.g., Tang and Zhang (2020) and the literature reviewed by Harrison et al. (2020). In the baseline model of this section, we assume that both types of bonds repay the same[12] $R \equiv 1+r$ at date $t=1$, where r is the risk-free interest rate, which we take as exogenous.

To sum up, an incremental project of type $i \in [0,1]$ with technology $k = G, B$ generates an additional profit at date $t=1$:

$$\pi_k(i) = Y - R - c_k(i) - \tau x_k + \varepsilon_k(i), \tag{1}$$

where $\varepsilon_k(i)$ is a technology-specific random term with $\mathbb{E}[\varepsilon_k(i)] = 0$, $k = G, B$. We assume $\mathbb{E}[\pi_B] = Y - R - c_B - \tau x_B \geq 0$, which implies that all projects are undertaken, either in a green or in a brown form.

Besides their incremental project, firms may also differ in the profits generated by their regular activities at date $t=1$: $V + \varepsilon$, where $V \geq 0$ is the known firm-specific expected profit, ε is a random term with $\mathbb{E}[\varepsilon] = 0$, and both are independent of projects' type. Profits (1) from firms' incremental project add to profits generated by their regular activities.

Firms' managers correctly anticipate expected future profits $V + \mathbb{E}[\pi_k(i)]$. By contrast, investors do not observe the type of firms' project, but to the extent that certified financial decisions partly reveal the profitability of green projects. Firms' date-0 stock prices $\mathcal{S}_k$ will depend on their technology choice $k = G, B$, as will be determined further below.

Managers care not only about firms' future expected profits $V + \mathbb{E}[\pi_k(i)]$, but also about their current stock price $\mathcal{S}_k$. The finance literature points to various sources of short-term managerial incentives. On the one hand, they partly originate from shareholders' own interest in—or need to rely on—their current stock price, as is reflected by the actual structure of executives' compensation, with shares and options with relatively short vesting periods. On the other hand, besides compensation-related incentives, managers are concerned about the risk of takeover (Stein [1988]) and the attention that markets pay to short-term performance (Summers and Summers [1989]).

Our theory is agnostic about the origins of managers' concern for their stock price. We adopt Stein's (1989) direct modeling of managers' objective. Managers choose their project's technology $k = G, B$ in such a way as to maximize:

$$\mathcal{U}_k(i) = (1-\alpha)\frac{V + \mathbb{E}[\pi_k(i)]}{1+\rho} + \alpha \mathcal{S}_k, \tag{2}$$

12. In Section VI, we describe—with technical details in the Appendix—how this model easily accommodates concerned investors and a yield spread between green and conventional bonds.

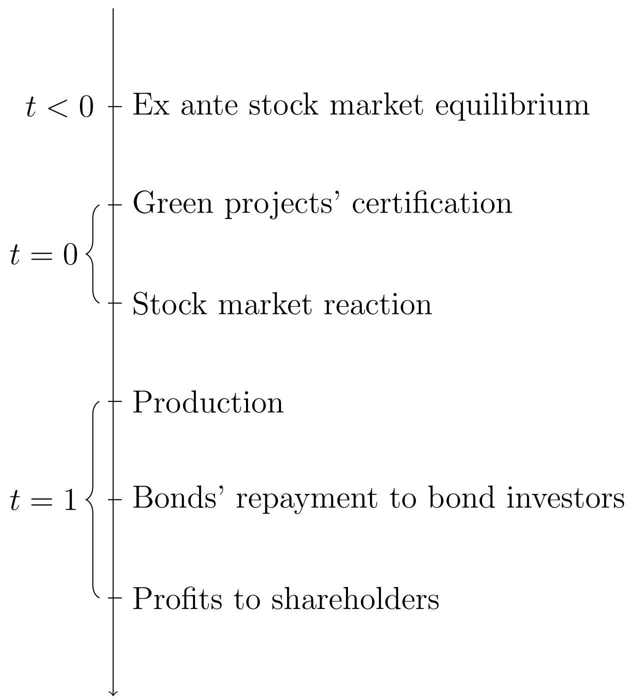

Figure I: Timing

where ρ is the discount rate and the parameter $\alpha \in (0, 1)$ captures the stock-price sensitivity of managers that prevails in the industry, which we both take as given.

III.C. Timing

The timing is represented in Figure III. Prior to date $t = 0$, firms' projects are indistinguishable and the ex ante stock price $\mathcal{S}$ only differs across firms because of their regular profits V.

At date $t = 0$, managers choose to undertake their incremental projects in a green ($k = G$) or conventional way ($k = B$). Green projects are certified and financed through green bonds. At the same time, stock prices become $\mathcal{S}_G$ and $\mathcal{S}_B$ for firms undertaking green and conventional projects respectively.

At date $t = 1$, firms' regular activity takes place and their project is realized under the committed technology, bonds are repaid to bond investors, and the resulting profits accrue to shareholders.

III.D. Green bond supply

Managers perfectly anticipate the stock price reaction to their choice of technology.

Despite its very rapid growth in the past few years, green bond issuance by non-financial corporations only represents 3.5% of their 2020 total bond issuance. We, therefore, focus the analysis on interior equilibria in which $0 < i^e < 1$. This rules out unrealistic situations in which the effective carbon price is either extremely high or extremely low.[13]

In particular, our setting assumes that $\mathbb{E}[\pi_B] \geq 0$, so the carbon price is not sufficiently high to discourage firms to undertake their projects. Indeed, we are mainly interested in firms' adoption of green technologies, less so in their decision to implement or not conventional projects. In general, voluntary approaches do not affect the latter margin—see, for example, Lyon and Maxwell (2003) in the context of voluntary agreements.

Appendix A shows how managers choose to undertake green projects according to the additional cost of green technologies and their benefit from the stock market reaction to green certification.

Lemma 1 (Green bond supply). *Given $\mathcal{S}_G$ and $\mathcal{S}_B$, a firm with a project of type i chooses a green technology $k = G$ if and only if $i \leq i^e$, where i^e is characterized by:*

$$(1-\alpha)\left(\Delta c(i^e) - \tau \Delta x\right) = \alpha(1+\rho)\Delta\mathcal{S}, \tag{3}$$

where $\Delta\mathcal{S} \equiv \mathcal{S}_G - \mathcal{S}_B$.

The proportion of green projects i^e increases with the stock market reaction $\Delta\mathcal{S}$.

For managers, the cost of an additional certified green project of type i is $(1-\alpha)\left(\Delta c(i) - \tau\Delta x\right)$. The property that this cost is increasing in i is the counterpart of Spence's (1973) critical assumption that signaling costs are negatively correlated with productivity. Lemma 1 tells that firms undertake green projects as long as managers' cost falls short of their benefit from the stock market reaction that green bonds generate.

For a given stock price reaction to green bond issuance $\Delta\mathcal{S}$, equation (3) determines the supply of certified green projects i^e, as depicted in Figure III. The relationship is increasing: As the stock reaction $\Delta\mathcal{S}$ is more pronounced, more managers are willing to undertake certified green projects. Moreover, all else held unchanged, the supply of green bonds is increased both by the carbon price τ, which penalizes more the profit of conventional projects,

13. Conditions under which the equilibrium proportion of green bonds in the industry is interior are $\Delta c(0) < \tau\Delta x < \int_0^1 \Delta c(i)di$ and $\tau x_B \leq Y - R - c_B$—see Appendix A for details.

and by the degree of short-term incentives α, which gives more weight to the stock price reaction.

The next step of the resolution is to derive the stock price reaction to green bonds. If there were no green finance certification of firms' technological choice, stock prices would not adjust at all.[14] Then, the equilibrium proportion of green projects i^0 would be determined by the standard equality between marginal cost and the incremental carbon penalty:

$$\Delta c(i^0) = \tau \Delta x. \tag{4}$$

In Figure III, this equilibrium is depicted at the intersection of the rising green bond supply curve with $\Delta \mathcal{S} = 0$.

With certification, however, we will show further below that $\mathcal{S}_G > \mathcal{S}_B$ in equilibrium, so that green bonds induce more managers to undertake green projects. Green bond certification does not require "additionality," i.e., green bonds also finance projects that would have been undertaken without green bonds. In our baseline model, all additional green projects are due to the positive stock market reaction to green bonds.

III.E. Stock market reaction to green bonds

At date $t = 0$, investors take as given firms' commitment to their green projects, and use it both to infer the profitability of these projects and to assess date-1 firms' value:

$$\mathcal{S}_k = \frac{V + \mathbb{E}\left[\pi_k(i)|k\right]}{1+\rho}, \; V \geq 0, \; i \in [0,1], \; k = G, B. \tag{5}$$

Prior to date-0 firms' announcements, investors rationally anticipate date-0 equilibrium proportion of green projects, so ex ante stock prices are:[15]

$$\mathcal{S} = i^e \mathcal{S}_G + (1 - i^e)\mathcal{S}_B. \tag{7}$$

14. In Section V, Table II indicates that self-labelled green bonds do not generate abnormal returns that are statistically different from zero, unlike certified green bonds.

15. Consequently, ex ante stock prices may also be written:

$$\mathcal{S} = \mathcal{S}_B + \frac{i^e \left(\tau \Delta x - \mathbb{E}\left[\Delta c(i)|i \leq i^e\right]\right)}{1+\rho}, \tag{6}$$

which depends not only on firms' specific regular expected profit V but also on the given proportion of green projects i^e. In our model, $\mathcal{S}$ would be maximum if the anticipated i^e was equal to i^0, the equilibrium proportion of green projects that would prevail if managers were focused on long-run profits ($\alpha = 0$). In the neighborhood of the green finance equilibrium in which $i^e > i^0$, $\mathcal{S}$ is decreasing with i^e because a greater proportion of green projects leads the industry further away from profit maximization—see Appendix A for details.

Appendix A shows the following results.

Lemma 2 (Stock market equilibrium). *Given the proportion i^e of green bonds, the stock price reaction to firms' green bond issuance is:*

$$(1+\rho)\Delta\mathcal{S}^e = \tau\Delta x - \mathbb{E}\left[\Delta c(i)|i \leq i^e\right]. \tag{8}$$

This reaction is less pronounced when the proportion of green bonds i^e is higher.

The stock market reaction to green bonds stems from the information that green bond commitments signal about the profitability of green projects. In our model, prior to firms' financing decisions, investors cannot make any distinction between firms' projects. With the announcement of green bond financed projects, they reassess that these projects are more profitable than expected, $i \leq i^e$, both because these projects will be relatively advantaged by carbon penalties and because their expected costs become $\mathbb{E}\left[\Delta c(i)|i \leq i^e\right]$ rather than the unconditional $\mathbb{E}\left[\Delta c(i)\right]$.

Formula (8) implies that the magnitude of the stock market reaction to green bonds is determined by the difference between the avoided carbon penalty and investors' expected additional cost—benefit, if negative—of green projects. The former will translate into an **amplification of carbon pricing**: Due to green bonds, carbon pricing increases investors' reaction to green commitments, an effect that would vanish without green certification.

The expected additional cost of green projects—benefit, if negative—increases with i^e because more green bonds mean that less efficient green projects are undertaken. This translates into a dilution effect of green bonds' signal.

III.F. Equilibrium proportion of certified green projects

In the rational expectations equilibrium, the stock market reaction characterized in (8) is consistent with the supply of green bonds in (3) that this reaction generates. We examine the resulting equilibrium proportion of green bonds in the industry, and its determinants. We obtain the following results.

Proposition 1 (Rational expectations equilibrium).

1. *The rational expectations equilibrium exists and is unique;*
2. *In this equilibrium:*
   (a) *The stock market reaction to green bonds is positive: $\Delta\mathcal{S}^e > 0$;*

(b) *The resulting proportion of green bonds increases with both the industry's managerial stock-price sensitivity* α *and the carbon price* τ.

The intersection of relationships (3) and (8) determines the unique equilibrium proportion, $i^e = i^e(\alpha, \tau)$, as depicted in Figure III. It depends on both managerial incentives and carbon pricing, whose joint role will be empirically exploited in the next section.

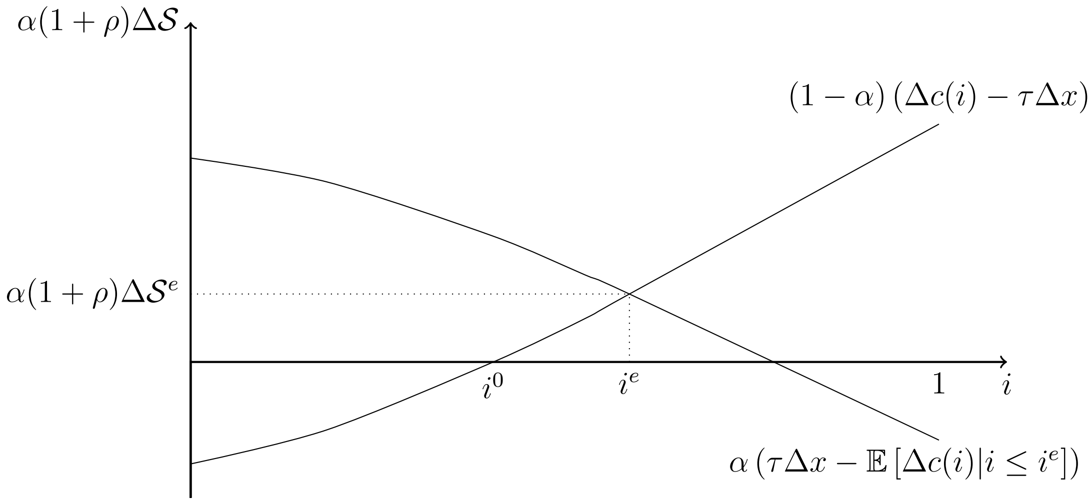

Figure II: Equilibrium proportion of green projects

In this equilibrium, the stock market reaction to green bonds is always positive:

$$\Delta\mathcal{S}^e = \frac{(1-\alpha)\left(\Delta c(i^e) - \mathbb{E}\left[\Delta c(i)|i \le i^e\right]\right)}{1+\rho} > 0, \tag{9}$$

immediately benefiting the shareholders of firms that issue green bonds. Managers do not issue green bonds as much as to make the positive stock reaction vanish.

The resulting proportion of green bonds is determined by the equality between the incremental carbon penalty and the marginal cost of green projects where the latter is adjusted by managers' benefit from green bonds' signal:

$$(1-\alpha)\Delta c(i^e) + \alpha\mathbb{E}\left[\Delta c(i)|i \le i^e\right] = \tau\Delta x = \Delta c(i^0). \tag{10}$$

Since $\Delta c(i^e) > \mathbb{E}\left[\Delta c(i)|i \le i^e\right]$, the equilibrium proportion of green bonds is higher than the proportion of green projects in absence of certification ($i^e > i^0$). Moreover, this effect increases with managers' stock-price sensitivity α.

The positive effect of the managerial stock-price sensitivity α on green bond issuance is the main implication of our model. It is this effect that we will exploit empirically. Our analysis explains that this is driven by the stock price reaction to green bonds, and that this reaction, all else held unchanged, is more pronounced as the effective carbon price is higher.

In general, our model characterizes the role of α and τ in $i^e(\alpha, \tau)$ implicitly, as we just described, and as one can show by shifting curves in Figure III. Assuming that cost $\Delta c(i)$ is affine yields a simple testable prediction.

Corollary 1 (Testable implication). *When the green technology cost is affine ($\Delta c(i) \equiv a + bi$, with $b > 0$), the equilibrium proportion of green bonds in the industry is:*

$$i^e = \underbrace{\frac{\tau \Delta x}{b} - \frac{a}{b}}_{i^0} + \underbrace{\frac{\Delta x}{b}\tilde{\alpha}\tau - \frac{a}{b}\tilde{\alpha}}_{\textit{managerial incentives}}, \tag{11}$$

where $\tilde{\alpha} \equiv \frac{\alpha}{2-\alpha} \in (0, 1)$.

In this expression, the first part reflects the proportion of green projects that would be undertaken in the absence of certification: It only depends on τ and is independent of managerial incentives.

The rest of the right-hand side of (11), which is positive, reflects the role of managerial incentives. Its main component is the positive interaction between managerial incentives and carbon pricing, which matters for two reasons: First, it drives the positive role of managerial incentives, our main prediction. Second, this interaction implies that the effect of carbon pricing is augmented by green bonds.[16]

In the next section, we test the role of managerial incentives as it is indicated by expression (11). We do so by exploiting variations in managerial incentives across sectors and over time as well as changes in effective carbon prices across countries and over time.

As a complement to this section, Appendix B assumes a more general, nonlinear functional form for cost $\Delta c(i)$—including the affine case of Corollary 1—that yields an explicit characterization of the equilibrium. Appendix C extends our model to the presence of concerned investors.

16. The last component on the right involves managerial incentives only. However, this last term cannot be immediately interpreted as the effect that managerial incentives would have if there were no carbon price. Irrespective of the effective carbon price, managerial incentives induce more green projects if and only if the industry has incentives to undertake green projects in the first place, absent green bonds, i.e., $i^0 > 0$, which managerial incentives further amplify. Indeed, expression (11) shows that the role of managerial incentives is proportional to i^0.

IV. Empirical analysis of the role of managerial incentives and carbon prices

In this section, we test our model's main prediction: the role of managerial stock-price sensitivity in green bond issuance, and its dependence on carbon prices.

IV.A. Data

Our main sample is a panel that relates yearly data on individual firms, the green bonds that they issued, and effective carbon prices that prevail in their countries. The period under review is 2007-2019.

To assemble this sample, we start from data extracted from Bloomberg on **all** corporate green bonds issued between January 2007 and December 2019: their issuer, amount, yield, maturity, announcement and issuance dates. We use information from the non-profit Climate Bond Initiative (CBI) to eliminate non-certified green bonds. 432 certified green bonds have been issued by public firms between 2013 and 2019.

We consider **all** public firms in countries where green bonds have been issued and use the above data to relate them to the volume of certified green bonds they issued every year. Only a small number of firms issue green bonds. Therefore, the data feature not only differences in green bonds' volume across firms that issue green bonds, but also differences between firms that issue green bonds and those that do not.

Each firm is associated with the effective carbon price that prevails in its country.[17] Effective carbon penalties consist not only of tradeable emission permit prices and carbon taxes, but also of all excise taxes on carbon-based fuels. Estimates of effective carbon prices and their coverage of all sources of CO2 emissions are provided by the OECD for 2012, 2015, and 2018—"the most detailed and most comprehensive account of [the largest and most developed economies'] price of carbon emissions" (OECD [2018]). First, we use these estimates to derive the weighted average effective carbon price in each country in 2012, 2015, and 2018, in current US$. Second, we linearly interpolate to obtain data for intermediate years.

Moreover, each firm is associated with annual financial data extracted from CRPS and Compustat: market capitalization, book value, net debt issuance, monthly traded number of shares, number of shares outstanding, as well as the percentage of foreign sales, assets, and income. We add firms' environmental scores and CO2 emissions from ASSET4.

17. We will address the case of multinationals both with firm fixed effects and with the addition of firms' measures of foreign activities—see Table VII of Appendix D.

Since our model predicts the proportion of green bonds in total debt issuance, we take the ratio of firms' volume of green bonds over their net debt issuance. For simplicity, we call the obtained, standardized variable "*Green bonds*."

Each firm is associated with its industry categories according to the Global Industry Classification Standard (GICS). Firms are classified into the 69 industries—in 11 sectors—that are described in Appendix D.

The managerial sensitivity to firms' stock price ("*Incentives*") is captured by two alternative proxies. The first one is the wealth-performance sensitivity, suggested by Edmans et al. (2009), and provided by Alex Edmans on a yearly basis: the $ change in CEO wealth, following a 100 percentage point change in firm value, scaled by annual flow compensation.[18] This directly measures the weight of stock components in managers' financial compensation—an immediate interpretation of the sensitivity of managers' objective to the stock price in our model—in a way that allows comparisons across firms and industries. Since our model's testable implication (11) captures managerial incentives by the weight $\tilde{\alpha} \in (0, 1)$, we divide the wealth-performance sensitivity by its highest value in the sample. For simplicity, we call the obtained variable, "*WPS*." It varies significantly across industries, as Figure IV illustrates—see, moreover, the data description of Appendix D. However, *WPS* is not available for firms based outside the US. Therefore, we aggregate *WPS* at the industry and year level in the US, and extrapolate it to the same industries in other countries. For example, we consider that the *WPS* measure for the Automobiles industry in a given year is the same in the US and in Germany.

Our second, complementary proxy is based on stock share turnover, which is available for all industries and countries. It reflects not only the focus of stock markets on short-term executive results, but also the intensity of speculation and the risk of takeover. For example, Summers and Summers (1989) suggest that stock share turnover is linked to executive myopia. Cremers et al. (2020) confirm that it is associated with the presence of short-term investors. To construct our share turnover variable, first, we divide, for each firm and year, the average number of monthly traded shares by the number of shares outstanding, and, second, we divide it by its highest value. We call it "*Turnover*." Like *WPS*, it varies significantly across industries—see Appendix D.

In Appendix D, we provide more practical details on the way we collected, and assembled, green bond data, as well as summary statistics.

18. CEO wealth includes shares and stock options, while compensation flows represent salary, bonuses, and new grants of equity (Edmans et al. [2009]).

IV.B. Green bonds, managerial incentives, and carbon prices

We now test the main prediction of our theory, that is the positive role of managerial incentives. More precisely, we seek to verify that, on average, in an industry, firms' proportion of green bonds increases with managers' sensitivity to their firms' stock price, in a way that is more pronounced as their country's effective carbon price is higher.

For example, Figure III shows the unconditional relationship between the *Green bonds* and *WPS* variables in sectors that issue green bonds. It illustrates that sectors in which managers' pay is the most stock-price sensitive issue more green bonds.

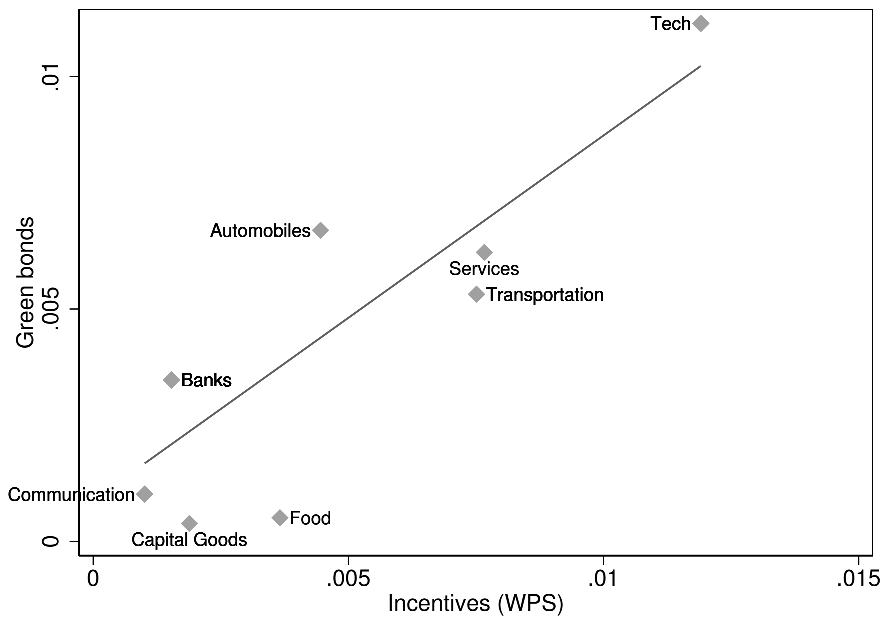

Figure III: Green bonds issuance and stock price sensitivity of managers' compensation (2007-2019)

Closer to our prediction (11), we estimate the following model in which the role of managerial incentives includes the interaction with carbon prices:[19]

$$\begin{aligned} \textit{Green bonds}_{i,t} &= \beta_0 + \beta_1 \textit{Carbon price}_{c(i),t-1} \times \textit{Incentives}_{j(i),t-1} + \beta_2 \textit{Incentives}_{j(i),t-1} \\ &+ \beta_3 \textit{Controls}_{i,t-1} + \textit{Fixed effects} + \epsilon_{i,t}. \end{aligned} \tag{12}$$

19. We omit the autonomous role of carbon prices encompassed in i^0 in (11), because it is fully absorbed by the time-varying country fixed effects.

In this empirical model, the dependent variable is the proportion of green bonds issued in year t by firm i. The independent variables of interest are the degree of managerial incentives in industry $j(i)$ and the effective carbon price that prevails in country $c(i)$, both taken at year $t-1$. For managerial incentives, we will alternately use our two proxies. Control variables include firm i's market capitalization and its book-to-market ratio in year $t-1$ as well as its environmental score for year $t-1$. Moreover, we include firm fixed effects (FE), as well as industry, time-varying industry, and time-varying country fixed effects.

We estimate the model of equation (12) using the method of least squares with standard errors clustered at the country level.[20] Table I reports the estimation results. It shows similar estimates whether *Incentives* = *WPS* or *Incentives* = *Turnover*. With *WPS*, for example, we find coefficients for the terms that involve managerial incentives in column (1) that are significantly different from zero at the 1% level and that have signs in line with their theoretical counterparts in our model's prediction (11). The positive contribution of the main interaction term in (12) is confirmed in column (2) where the term in *WPS* alone is replaced by industry-year fixed effects to capture other potentially omitted factors. We obtain comparable estimates with *Turnover* in columns (3) and (4).

IV.C. The total impact of managerial incentives

With the estimated coefficients of columns (1) and (3) of Table I, the total contribution of *Incentives* variables appears positive on average, that is, at the average effective carbon price in our sample of \$32;[21] on average, an increase in *WPS* by one standard deviation leads to an increase in firms' proportion of green bonds by 20%.[22] Yet, this effect is not statistically different from zero at this carbon price level.

Like formula (11), the results of Table I indicate that the total role of managerial incentives is more pronounced as the carbon price is higher. In Appendix D, for example, we consider the \$81.75 average effective carbon price in the EU, where the green bond market is the most developed, accounting for about 50% of the global current volume. We find that the total contribution of *Incentives* is positive and significantly different from zero at the 5 or 10% level respectively when *Incentives*=*Turnover* and *Incentives*=*WPS*. At this level of

20. In Appendix D, Table V shows estimation results when standard errors are clustered at the country and industry level.

21. Effective carbon prices may seem high because they include various excise taxes.

22. $\frac{(0.017\times 32-0.505)\times 0.018}{0.0035} \simeq 0.2$, where 0.018 is the standard deviation of *WPS* across industries and 0.0035 is the average proportion of green bond issuance across firms in our sample, including many firms that have issued no green bond.

Table I: Green bond issuance, managerial incentives, and carbon price

This table presents estimates from panel regressions of the proportion of green bonds issued by firms on their countries' effective carbon prices and proxies of managers' stock-price sensitivity in their industries. We control for firm size, book-to-market ratio, and environmental score. Standard errors are clustered at the country level. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

	Green bonds			
	(1)	(2)	(3)	(4)
Carbon price × Incentives (WPS)	0.017***	0.024*		
	(0.006)	(0.014)		
Incentives (WPS)	-0.505***			
	(0.110)			
Carbon price × Incentives (Turnover)			0.006**	0.005***
			(0.002)	(0.002)
Incentives (Turnover)			-0.158***	
			(0.053)	
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	No
Industry-year FE	No	Yes	No	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	15011	15008	15148	15145
R^2	0.335	0.358	0.335	0.358

the effective carbon price, an increase in *WPS* by one standard deviation multiplies firms' proportion of green bonds by more than four.

Our estimates can be used to indicate how effective carbon penalties and managerial incentives contribute to green bond commitments by firms in a particular industry. For example, German car manufacturers have issued green bonds in the past few years. In the Automobiles sector, on average, managers' pay is moderately sensitive to the stock price: $WPS_{Automobiles} = 0.0002$. The effective carbon price in Germany in 2018 was $74, slightly below the EU average. Our estimates predict that firms in this industry issue around 4% more green bonds than the average firm.[23]

In general, where carbon emissions are sufficiently penalized, firms issue more green bonds in industries in which managers are more sensitive to their stock price. Moreover, this effect is more pronounced as carbon effective prices become higher.

Our results stress the key role of the interaction between managerial incentives and carbon prices, with important implications. First, it means that one should expect more green projects for a given carbon price, than there would be otherwise in the absence of green bond certification. But, second, this interaction implies that green bond commitments depend on the level of carbon pricing.

IV.D. Extensions

Firm level variation.—The model of Section III and the estimated equation (12) assume that firms' managers in the same industry and country are equally sensitive to their firms' stock price. Indeed, both *WPS* and *Turnover* vary significantly across (US, for *WPS*) industries, and our main approach exploits this variation. However, firm level variations in stock share turnover can also be exploited because *Turnover* is available for firms in all industries and countries. In Appendix D, we verify that the central role of the interaction between carbon prices and managerial incentives survives when *Turnover* is measured at the firm level, along with industry-year fixed effects—see Table VII.

Multinationals.—Moreover, we have assumed that firms are only applied the carbon price of the country where they are based. Although it seems questionable for multinationals, one can defend our approach by invoking Ben-David, Kleimeier, and Viehs' (2020) finding that it is environmental policies **where** multinationals are based that play the most significant role. Besides firms' characteristics captured by fixed effects in equation (12), Table VII of

23. $\frac{(0.017\times 74-0.505)\times 0.0002}{0.0035} \simeq 0.043$, where 0.0035 is the average proportion of green bond issuance across firms in our sample.

Appendix D also verifies that similar results are obtained once firms' shares of foreign sales, assets, and income, as measures of foreign activity, are included in *Controls*.

V. Empirical analysis of green bonds' effectiveness and of stock market announcement reactions

The theory presented in Section III deals with the factors explaining corporate green bond issuance. Our model predicts the role of managerial incentives and its interaction with carbon prices, which we examine empirically in Section IV.

Our model further suggests that two main aspects underly the joint role of managerial incentives and carbon prices. The first one is that green bonds effectively finance **CO2 reduction**. According to our theory, this is why carbon prices induce more green projects and positive stock market reactions. The second one is that green bond issuance actually generates **positive stock returns**. In our model, this is the channel through which managers are interested in issuing certified green bonds.

In this section, we examine these two aspects.

V.A. Stock price reaction to green bonds

Positive stock price reactions to events like green bond announcements reflect that these events reveal information about firms' future profitability that investors could not anticipate. In practice, these reactions are measured by abnormal stock returns around green bond announcements that are left unexplained by other factors.

We first express our model's stock market reaction in terms of stock returns. Then, we run an event-study estimation of abnormal returns.

V.A.1. Stock market returns at green bond issuance

In our model, firms' date-0 stock returns are:

$$\mathcal{A}_k \equiv \frac{\mathcal{S}_k - \mathcal{S}}{\mathcal{S}},\ k = G, B, \tag{13}$$

depending on whether they choose a green or regular technology.

An immediate consequence of (8) is that the stock price of firms issuing green bonds increases at a rate:

$$\mathcal{A}_G^e = (1 - i^e)\frac{\Delta\mathcal{S}^e}{\mathcal{S}} > 0, \tag{14}$$

which is the theoretical counterpart of abnormal stock returns at issuance.

Therefore, positive stock returns at the issuance of green bonds $\mathcal{A}_G$ only differ across firms issuing green bonds because the ex ante stock price $\mathcal{S}$ increases with V, the firm-specific profit from regular activities, diluting stock returns induced by certified projects.[24] In other words, our model predicts that green bond announcement stock returns are higher as green bond volumes are larger with respect to firms' capitalization, which we now attempt to verify.

V.A.2. Event-study estimation of abnormal stock returns at green bond announcement

Various empirical studies examine abnormal stock returns at green bond issuance. For example, Tang and Zhang (2020), Baulkaran (2019), and Flammer (2021) find that announcement abnormal returns are significant.

We first replicate their results on our sample by estimating cumulative abnormal returns from an event-study analysis based on Fama and French (2012), as we describe more precisely shortly below. We then examine abnormal announcement returns for certified green bonds that are relatively large with respect to firms' size.

Data.—We extend the panel data sample that we describe in Section IV to non-certified green bonds. Moreover, we include daily stock prices to firms' characteristics, from which we derive stock market daily returns that we will denote by R. Our event study will also use market factors data from Kenneth French.[25]

Event study analysis.—Following prior studies (e.g., Tang and Zhang [2020], and Flammer [2021]), we explore how stock market reacts to green bond announcements using an event window around the announcement date. More specifically, our event window is [-5;+5] with respect to the announcement date 0. For each company we estimate the global three-factor model (Fama and French [2012]) to compute abnormal returns using an estimation window of 250 days. We have a gap of 50 days between the end of the estimation window and the beginning of the event window, so that the estimation window can be represented by [-305;-55].

We estimate the following model:

$$R_{i,t} = \beta_{0,i} + \beta_{1,i} R_m + \beta_{2,i} R_s + \beta_{3,i} R_v + \epsilon_{i,t}, \tag{15}$$

24. We omit the cost of certification, expertise, and monitoring, because it is probably negligible for the large firms that currently issue green bonds. Admittedly, these costs may limit the supply of green bonds by smaller firms.

25. See `https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html`.

where $R_{i,t}$ is the daily stock market return of firm i at time t and R_m, R_s, and R_v are the global market factor, size factor, and value factor respectively. We then obtain the abnormal return as the difference between the observed daily stock return of firm i and the estimated return:

$$AR_{i,t} = R_{i,t} - \hat{R}_{i,t}, \tag{16}$$

where

$$\hat{R}_{i,t} = \hat{\beta}_{0,i} + \hat{\beta}_{1,i} R_m + \hat{\beta}_{2,i} R_s + \hat{\beta}_{3,i} R_v, \tag{17}$$

with the coefficients estimated from equation (15). Finally, the abnormal returns are summed over the event window [-5;+5] to obtain cumulative abnormal returns. This is, for example, the method by which we estimate the stock returns that Unilever's 2014 green bond generated in our introductory example.

We now estimate similar returns for various categories of green bonds and firms that issue them, in the same manner as, for example, Tang and Zhang (2020) and Flammer (2021). The "financial" group denotes companies with one of the following Bloomberg industry code: bank, financial, REIT (real estate investment trust), or insurance. The "first issue" group refers to the first green bonds issued by firms. The "large" category refers to certified green bonds of a $ amount standardized by their issuers' market capitalization that is above the median. Table II shows our results.[26]

On average, firms' valuation increases by approximately 0.68% around the announcement of green bond issuances. The effect is statistically significant at the 1% confidence level. It is further concentrated among firms' certified, first, and large issuances. For example, the effect of certified green bonds is stronger in economic and statistical significance, increasing firms' value by approximately 0.75% around their announcement. Our results are similar both for firms' first issuances and for their large certified green bonds. The effect of large certified green bonds is in line with our model's implication (14) of announcement stock returns, suggesting that, in practice, such reactions have to do with the size of financed projects.

V.B. CO2 emissions following green bond issuance, and green bond public policies

We now examine the relationship between green bond issuance and subsequent CO2 emissions, exploiting the implementation of public policy supports to green bonds in some

26. The results presented in Table II are robust to an alternative event window specification (e.g., [-10;+10]).

Table II: Event Study: Stock Market Reaction to Green Bonds Announcements

This table presents results from event studies around the date of green bonds' announcement.

	CAR	N
All (corporates)	0.68%***	432
	(3.00)	
Financials	0.65%*	194
	(1.87)	
Non-financials	0.68%**	238
	(2.19)	
First issues	0.75%**	215
	(2.37)	
Secondary issues	0.25%	217
	(0.75)	
Certified	0.75%***	282
	(3.24)	
Non-certified	0.46%	150
	(1.08)	
Large certified	0.75%**	141
	(2.05)	
Small certified	0.29%	141
	(0.55)	

countries.

In a recent yet influential paper, Flammer (2021) uses a matching method to show that firms issuing certified green bonds reduce their CO2 emissions by 13% over the course of the next two years. This result rules out the greenwashing hypothesis. The following analysis seeks to further suggest a direction of causality, consolidating Flammer's result.

Our identification strategy relies on the implementation of green bond policies in China, Hong-Kong, Japan, Malaysia, and Singapore. These policies amount to a public support to green bond issuance, irrespective of firms' current and future CO2 emissions or of other measures of firms' environmental performance. Firm-level data for companies in these countries are limited so we would not be able to systematically control for firms' characteristics that might affect green bond issuance. We, therefore, use a country-level aggregated version of the sample presented in Section IV.

Data.—There are two basic differences between the firm-level sample presented in Section IV and the sample that we use here. First, we construct the latter by aggregating volumes of green bonds at the country level, which we divide by firms' bond net issuance in each country. Second, for each country and year, we indicate whether public policies supporting the use of green bonds are implemented. In recent years, China, Hong-Kong, Japan, Malaysia, and Singapore have implemented programs to support the issuance of green bonds, helping issuers face various difficulties related to the certification process, disclosure requirements, and monitoring of the financed projects—see the Climate Bonds Initiative's (2018) report. In the baseline model of Section III, the cost of certified green projects may be interpreted to include issuance, certification and monitoring costs, that are alleviated by green bond supporting policies. These policies all amount to a form of green bond subsidy. There is no available information on the intensity of these policies. Therefore, we include a dummy variable taking value one if and when a country has a green bond policy, which we call "*Policy*." This variable is an indicator that takes the value 1 for China post-2016, Malaysia and Singapore post-2017, and Hong Kong and Japan post-2018. This variable will be used as an instrument.

Instrumental variable analysis.—In the first stage, we show how green bonds were affected by green bond policy supports. Formally, we estimate the following model:

$$Green\ bonds_{c,t} = \beta_0 + \beta_1 Policy_{c,t-1} + \beta_2 Controls_{c,t-1} + Fixed\ effects + \epsilon_{c,t}. \tag{18}$$

In this model, the index c refers to countries. The dependent variable is the proportion of green bonds issued in year t by firms based in country c. The independent variable of interest is the *Policy* variable evaluated in country c and year $t-1$. Moreover, controls consist of

Gross Domestic Product (GDP), GDP per capita, total volume of bonds, and the effective carbon price in country c and year $t-1$.

We estimate all coefficients by the method of least squares with standard errors clustered at the country level. The results are presented in column (1) of Table III. They show that the estimated coefficient β_1 is positive and significantly different from zero at the 5% level. The implementation of green bond policy supports was associated with an increase in green bonds in the next year. Moreover, we reject the null hypothesis of weak instrument. The first-stage F-statistic is 123.01, significantly higher than Stock and Yogo's (2005) critical value of 16.38 for a 10% maximal bias of the instrumental variable estimator relative to the bias of ordinary least squares.

Table III: Green bond policy and country-level CO2 emissions

This table presents estimates from panel regressions of countries' CO2 emissions on the proportion of green bonds issued by countries, instrumented by whether policies supporting green bonds have been implemented. We control for GDP, GDP per capita, the total volume of bonds issued by each country in each year, as well as the carbon price. Standard errors are clustered by country. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

	1st stage *Green bonds*	2nd stage *CO2*	
	(1)	(2)	(3)
Policy (1 year), instrument	0.120**		
	(0.049)		
Instrumented *Green bonds*, (1 year)		-0.606**	-0.623**
		(0.272)	(0.260)
Controls	Yes	Yes	Yes
Year FE	Yes	No	Yes
Observations	211	211	211
R^2		0.703	0.701

We now take a two-stage-least-squares estimation approach to show how the instrumented values of *Green bonds* for country c and year t, denoted by $\widehat{Green\ bonds}$ are linked to CO2 emissions. The model that we now estimate is:

$$CO2_{c,t+1} = \beta_0 + \beta_1 \widehat{Green\ bonds}_{c,t} + \beta_2 Controls_{c,t} + Fixed\ effects + \epsilon_{c,t}. \tag{19}$$

Our dependent variable is total CO2 emissions of all firms in country c in year t. Besides the main independent variable of interest $\widehat{Green\ bonds}$ for country c and year $t-1$, we include GDP, GDP per capita, total debt, and the effective carbon price as controls, as well as year fixed effects, as in the first stage. We cluster standard errors at the country level.

The results are presented in columns (2) and (3) of Table III, showing that the coefficient of the predicted proportion of green bonds is negative and significantly different from zero at the 5% level. Our estimates mean that firms on average reduce their CO2 emissions by approximately 15% following an increase in green bonds issuance of 1 percentage point.

VI. Conclusion

This paper investigates why firms issue green bonds in the absence of any significant green bond yield spread. We suggest that this is because green bonds signal firms' capacity to address the energy transition efficiently. Like in Spence (1973), managers, in issuing green bonds, do not need to think of themselves as signaling. Managers commit to green investments if their benefit is higher than their signaling cost. Green bonds' role is effective because climate-friendly initiatives are less costly to firms that have the most efficient options to reduce CO2 emissions.

From the formal analysis of Section III, and empirical results of Sections IV and V, we draw the following conclusions. First, although voluntary, certified green bonds provide firms with incentives to invest in CO2 reducing projects. This is because firms' announcement of certified green projects conveys positive information about the profitability of these projects, which generates stock returns. Second, perhaps surprisingly, firms' incentives to issue green bonds are stronger when managers are short-termist. Third, green bonds are complementary to carbon pricing, with important practical implications. With green bonds, governments cannot dispense with carbon penalties; on the contrary, the latter are instrumental in the effectiveness of the former. At the same time, if carbon prices are sufficiently high, green bonds are likely to make them more effective.

Our theory does not rely on investors' concern for environmental performance, but easily accommodates it. Although investors' concern has hitherto not played an apparent role, some expect it to change in the medium run.[27] Appendix C shows how our model carries over

27. See, for example, *Financial Times*, January 4, 2021, "Analysts expect as much as $500bn of green

to the case of concerned investors on both bond and stock markets, generating respectively a green bond yield spread and augmented stock returns at green bond issuance that would induce additional incentives to undertake green projects. It shows that the presence of concerned investors would not qualitatively change our baseline model's prediction as to the role of managerial incentives.

To our knowledge, there exists no study on the economic mechanisms that drive green bond issuance, neither in the finance literature, nor in the environmental economics and policy literature, despite the fact that green bonds are becoming increasingly prominent and the fact that financial institutions are currently paying a lot of attention to green finance instruments. This paper's attempt to provide consistent theoretical and empirical foundations to sustainable green finance instruments may be useful not only to economic applications to new green finance markets, but also to the understanding and empirical assessments of the role that they may play in the structure of climate policy in contexts in which carbon pricing is a restricted option.

If carbon pricing remains a limited option for governments, the urgency of the climate challenge will require that all alternatives to reduce CO2 emissions be examined. Our analysis points to the critical, perhaps paradoxical, role of managerial incentives, and calls for more research on the design of managerial compensation as a climate policy tool.

bonds in bumper 2021."

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Internet Appendix to
"Why Do Firms Issue Green Bonds?"

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A. Baseline model: Proofs

Proof of Lemma 1

The manager of the firm with the project of type i chooses the green technology if and only if $\mathcal{U}_G(i) \geq \mathcal{U}_B(i)$ in which $\mathcal{S}_G$ and $\mathcal{S}_B$ are parametric. By the managerial objective (2), this is equivalent to condition (3) in the lemma.

The rest of the lemma follows directly from the implicit definition of i^e in (3).

Proof of Lemma 2

Firms opting for a conventional technology bear business-as-usual cost c_B. Therefore, their stock price is

$$\mathcal{S}_B = \frac{V + Y - R - \tau x_B - c_B}{1 + \rho} \geq 0, \tag{A.1}$$

which only varies by V, and is further independent of the bond market equilibrium.

As for firms that issue green bonds, investors infer that they have the most profitable green projects, as per Lemma 1, even though investors cannot perfectly assess these projects' costs. Consider a given proportion of green bonds i^e. The resulting stock price of firms issuing a green bond will be:

$$\mathcal{S}_G = \frac{V + Y - R - \tau x_G - c_B - \mathbb{E}\left[\Delta c(i) | i \leq i^e\right]}{1+\rho}, \tag{A.2}$$

which decreases with i^e because an expansion of green projects means that green projects are less profitable on average.

Moreover, in an interior equilibrium, all projects $i \leq i^e$ will be green and their firms' stock will be priced according to (A.2); otherwise, projects will be conventional and their firms' stock will be priced according to (A.1).

The stock market reaction is $\Delta\mathcal{S} = \mathcal{S}_G - \mathcal{S}_B$. Using (A.2) and (A.1), we obtain expression (8).

The expression of the ex ante stock price (7) is the average of the anticipated stock prices of all firms, whether they undertake a green project or not. (6) follows from (7) and (8). Let us now show that (7) is maximum when the anticipated proportion of green projects i^e is the proportion of green projects that would prevail in the absence of green bonds i^0. In (7), only the term on the right depends on i^e. Its derivative is equal to $\tau\Delta x - \Delta c(i^e)$. It is equal to zero for $i^e = i^0$. When i^e is anticipated to be greater than i^0, as will turn out to be true in equilibrium, this derivative will be negative.

Note that if investors anticipated the corner equilibrium $i^e = 1$, then, by (7), the ex ante stock price would become $\mathcal{S} = \mathcal{S}_G$, so that there would be no stock market reaction to green bonds.

Proof of Proposition 1

(3) and (8) are relationships between the proportion of green bonds i^e and the stock market reaction $\Delta\mathcal{S}^e$ that are respectively increasing and decreasing. Therefore, their intersection yields a unique proportion of green bonds

$$i^e = i^e(\alpha, \tau),$$

and expression (9) of the equilibrium stock market reaction to green bonds. Since $\Delta c(i^e) > \mathbb{E}\left[\Delta c(i) | i \leq i^e\right]$, (9) implies that this reaction is always positive.

Moreover, (3) and (8) implies that $i^e(\alpha, \tau)$ can be characterized by (10). Since both $\Delta c(i^e)$ and $\mathbb{E}\left[\Delta c(i)|i \leq i^e\right]$ are increasing in i^e and $\Delta c(i^e) > \mathbb{E}\left[\Delta c(i)|i \leq i^e\right]$, the comparative-static effects of α and τ follows immediately.

The main prediction of our theory is the positive total contribution of managerial incentives to green bond issuance. Totally differentiating (10) with respect to i^e and α, holding τ unchanged, and rearranging terms, we obtain:

$$\frac{\partial i^e(\alpha, \tau)}{\partial \alpha} = \frac{\Delta c(i^e) - \mathbb{E}\left[\Delta c(i)|i \leq i^e\right]}{(1-\alpha)\Delta c'(i^e) + \alpha \frac{d\mathbb{E}[\Delta c(i)|i \leq i^e]}{di^e}} > 0, \tag{A.3}$$

which, for example, depends on carbon pricing positively through the stock market reaction in the numerator.

Similarly, one obtains:

$$\frac{\partial i^e(\alpha, \tau)}{\partial \tau} = \frac{\Delta x}{(1-\alpha)\Delta c'(i^e) + \alpha \frac{d\mathbb{E}[\Delta c(i)|i \leq i^e]}{di^e}} > 0, \tag{A.4}$$

establishing that carbon pricing contributes to increase the proportion of green projects, in a way that depends on managerial incentives.

Conditions for the equilibrium to be interior are $i^0 > 0$ and $i^e < 1$. The former is equivalent to $\tau \Delta x > \Delta c(0)$; that is, the carbon price is sufficiently high to induce some green projects even in the absence of green bond certification and stock market reaction. The second inequality $i^e < 1$ requires, first, that some projects are not certified green, i.e., $\mathbb{E}\left[\pi_B\right] = Y - R - c_B - \tau x_B \geq 0$, and, second, that i^e as characterized by (10) is less than 1, which is guaranteed by $\mathbb{E}\left[\Delta c(i)|i \leq 1\right] = \int_0^1 \Delta c(i) di > \tau \Delta x$.

The linear expression (11) obtained under the affine assumption that $\Delta c(i) = a + bi$, $b > 0$, is derived in the more general case solved explicitly in Appendix B.

B. Baseline model: An example with explicit solutions

In this appendix, we assume the following functional form for the additional cost of green projects:

$$\Delta c(i) \equiv a + bi^\gamma, \;\; b, \gamma > 0.$$

The resulted expected cost of certified green projects $i \leq i^e$ is:

$$\mathbb{E}\left[\Delta c(i)|i \leq i^e\right] = a + b\frac{(i^e)^\gamma}{\gamma + 1}.$$

The supply of green bonds (3) becomes:

$$i^e = \left[\left(i^0\right)^\gamma + \frac{\alpha}{1-\alpha} \frac{(1+\rho)\Delta\mathcal{S}}{b} \right]^{\frac{1}{\gamma}}, \tag{B.1}$$

where

$$i^0 = \left(\frac{\tau \Delta x - a}{b} \right)^{\frac{1}{\gamma}}.$$

The stock market reaction to green bonds (8) becomes:

$$(1+\rho)\Delta\mathcal{S}^e = b \left(\left(i^0\right)^\gamma - \frac{(i^e)^\gamma}{\gamma+1} \right). \tag{B.2}$$

Replacing (B.2) into (3) and rearranging, one obtains the rational expectations equilibrium green bond proportion:

$$i^e = \left[\frac{\gamma+1}{\gamma+1-\alpha\gamma} \right]^{\frac{1}{\gamma}} i^0,$$

in which the amplification effect of green bonds is reflected by the fact that the term between brackets is greater than one. Moreover, the equilibrium proportion of green bonds is increasing in α in a way that is more pronounced when τ is higher.

Finally, when $\gamma = 1$, as in Corollary 1,

$$i^e = \left(\frac{2}{2-\alpha} \right) i^0,$$

from which one can directly recover the linear prediction (11).

C. Extension to investors' concern

In this appendix, we extend the model of Section III to the presence of bond and stock investors that value the environmental impact of firms' projects. We retain the assumptions of Section III, apart from the following changes.

C.A. Green finance and firms' problem

We assume that green and conventional bonds have different yields. Like in Section III, we consider that conventional bonds repay $R_B = R \equiv 1 + r$, given by the exogenous interest rate r. By contrast, we consider that the yield of green bonds is lower than r, by a spread $s \geq 0$, so that

$$R_G = R_B - s.$$

The additional profit generated at date $t = 1$ by an incremental project of type $i \in [0, 1]$ with technology $k = G, B$ becomes, instead of (1):

$$\pi_k(i) = Y - R_k - c_k(i) - \tau x_k + \varepsilon_k(i). \tag{C.1}$$

C.B. Green bond supply and demand

Managers' maximization of (2) by choice of their project's technology $k = G, B$ now takes the green bond spread as given. It follows that the marginal project that is certified through a green bond is now characterized by, instead of (3):

$$(1 - \alpha)\left(\Delta c(i^e) - \tau\Delta x - s\right) = \alpha(1 + \rho)\Delta\mathcal{S}. \tag{C.2}$$

In reality, investors are certainly heterogenous as far their preference for environmental performance is concerned; it is the marginal investor that matters. However, the simplifying assumption that all investors are similarly concerned is sufficient to figure out the consequence of a green bond spread. We assume that bond investors attach the same warm glow value $\theta_B\Delta x \geq 0$ to the CO2 reduction due to certified green bonds so that, in equilibrium, the no-arbitrage condition $r = r_G - \theta_B\Delta x$ holds, implying the following demand condition for green bonds:

$$s = \theta_B\Delta x. \tag{C.3}$$

Following (C.1) and (C.3), the results of Lemma 1 should be amended as follows: The equilibrium green bond spread is $s^e = \theta_B\Delta x$; for a given stock market reaction $\Delta\mathcal{S}$, the proportion of green bonds issued increases with the degree of bond investors' concern θ_B through the green bond yield spread, and it is larger than in the absence of green bonds if $\alpha > 0$ and $\Delta\mathcal{S} > 0$ or if $\theta_B > 0$.

C.C. Stock market reaction to green bonds

Shareholders may be interested in the overall environmental performance of a firm, as reflected, in practice, by its environmental rating. We assume, in a similar way as we do for bond investors, that stock investors attach the same value $\theta_S\Delta x \geq 0$ to firms' CO2 reduction due to a certified green project. Equilibrium stock prices, therefore, become:

$$\mathcal{S}_k = \frac{V + \mathbb{E}\left[\pi_k(i)|k\right] + \theta_S\Delta x}{1 + \rho}, \; V \geq 0, \; i \in [0, 1], \; k = G, B. \tag{C.4}$$

Lemma 2 should in this context be amended as follows: At date $t = 0$, the stock price of firms issuing green bonds increases with respect to others by:

$$(1 + \rho)\Delta\mathcal{S}^e = \tau\Delta x - \mathbb{E}\left[\Delta c(i)|i \leq i^e\right] + \theta_S\Delta x; \tag{C.5}$$

for a given proportion of green bonds, this stock market reaction is more pronounced when the degree of stock investors' concern θ_S becomes higher.

An immediate consequence of (C.5) is that the stock price of firms issuing green bonds increases at a rate:

$$\mathcal{A}_G^e = (1 - i^e)\frac{\Delta \mathcal{S}^e}{\mathcal{S}} > 0, \tag{C.6}$$

where $\mathcal{A}_k \equiv (\mathcal{S}_k - \mathcal{S})/\mathcal{S},\ k = G, B$. $\mathcal{A}_G$ is the theoretical counterpart of abnormal stock returns at issuance. (C.5) and (C.6) imply that the environmental rating effect of stock investors' concern on stock prices depends on the size of the financed project with respect to issuing firms' capitalization.

C.D. Equilibrium proportion of certified green projects

Finally, the intersection of relationships (C.2), with (C.3), and (C.5) determines a unique rational expectations equilibrium proportion of green bonds:

$$i^e = i^e(\alpha, \tau, \theta_B, \theta_S),$$

as depicted in Figure V, which is the counterpart of Figure III in the presence of concerned investors. The thick curves are those of Figure III ($\theta_B = \theta_S = 0$), and the dashed curves result from the introduction of concern parameters $\theta_B, \theta_S > 0$.

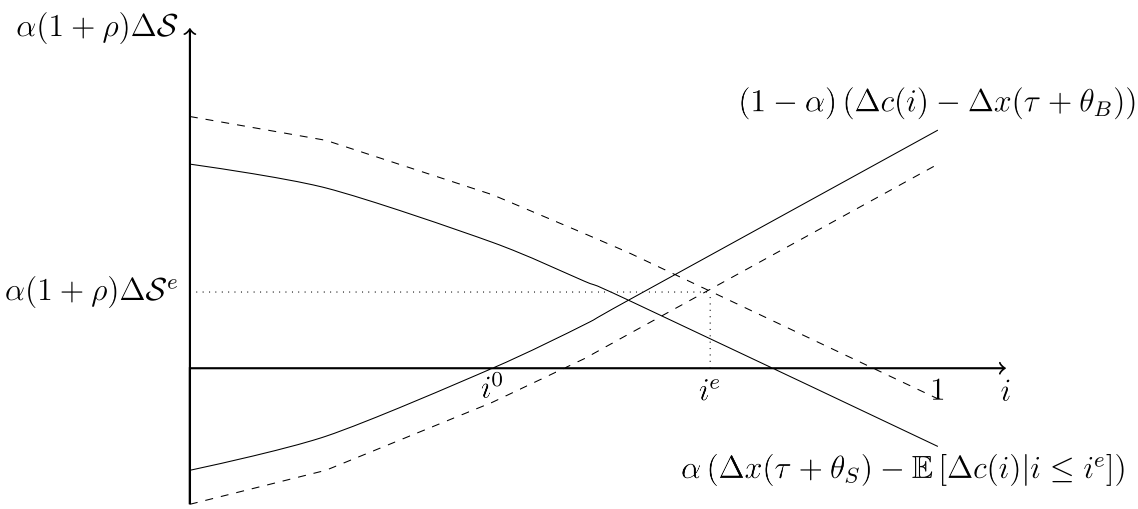

Figure IV: Equilibrium proportion of green projects with concerned investors

The following results are obtained, which are the counterparts of Proposition 1 and Corollary 1. They show how the equilibrium characterized in Section III and its testable prediction accommodate the presence of concerned investors.

Proposition 2 (Rational expectations equilibrium with concerned investors).

1. *The rational expectations equilibrium exists and is unique;*

2. *In this equilibrium:*

   (a) *The stock market reaction to green bonds is* $\Delta\mathcal{S}^e > 0$*;*

   (b) *The resulting proportion of green bonds increases with the industry's managerial sensitivity to the stock price* α*, the carbon price* τ*, and the degrees of investors' concern* θ_B *and* θ_S*;*

3. *When the green technology cost is affine (*$\Delta c(i) = a + bi$*, with* $b > 0$*), the equilibrium proportion of green bonds in the industry is:*

$$i^e = \underbrace{\frac{\tau\Delta x}{b} - \frac{a}{b}}_{i^0} + \underbrace{\frac{\Delta x}{b}\frac{\alpha\tau}{2-\alpha} - \frac{a}{b}\frac{\alpha}{2-\alpha}}_{\textit{managerial incentives}} + \underbrace{\frac{2\Delta x}{b}\frac{[(1-\alpha)\theta_B + \alpha\theta_S]}{2-\alpha}}_{\textit{investors' concern}}. \tag{C.7}$$

To sum up, the role of managerial incentives in our theory carries over to the presence of concerned investors, although investors' concern shifts the demand of, and the stock market reaction to, green bonds in a way that strengthens firms' incentives to undertake certified green projects.

D. Empirics

Mode details on the green bond data

Green bonds' data are extracted from the fixed income Bloomberg database. Corporate green bonds are indicated by the use of proceeds "Green Bond/Loan" and asset class "Corporate." Identifiers used are bond ISIN, company ISIN, and CUSIP. The unique bond ISIN identifier is used to merge Bloomberg green bonds' data with CBI's certification information.

We include all public firms with codes 10 and 11, which makes a total for our analysis of 19844 distinct firms.

We merge bond information with CRSP and Compustat using firms' CUSIP and ISIN identifiers.

We define industries using the Global Industry Classification Standard (GICS), which is provided with the green bond dataset. It is divided into 69 industries which can also be categorized into 24 industry groups and 11 sectors.

Industry classification

Code	Industry
code101010	Energy Equipment and Services
code101020	Oil, Gas and Consumable Fuels
code151010	Chemicals
code151020	Construction Materials
code151030	Containers and Packaging
code151040	Metals and Mining
code151050	Paper and Forest Products
code201010	Aerospace and Defense
code201020	Building Products
code201030	Construction and Engineering
code201040	Eletrical Equipment
code201050	Industrial Conglomerates
code201060	Machinery
code201070	Trading Companies and Distributors
code202010	Commercial Services and Supplies
code202020	Professional Services
code203010	Air Freight and Logistics
code203020	Airlines
code203030	Marine
code203040	Road and Rail
code203050	Transportation Infrastructure
code251010	Auto Components
code251020	Automobiles
code252010	Household Durables
code252020	Leisure Products
code252030	Textiles, Apparel and Luxury Goods
code253010	Hotels, Restaurants and Leisure
code253020	Diversified Consumer Services
code255010	Distributors
code255020	Internet and Direct Marketing Retail
code255030	Multiline Retail
code255040	Specialty Retail

Code	Industry
code301010	Food and Staples Retailing
code302010	Beverages
code302020	Food Products
code302030	Tobacco
code303010	Household Products
code303020	Personal Products
code351010	Health Care Equipment and Supplies
code351020	Health Care Providers and Services
code351030	Health Care Technology
code352010	Biotechnology
code352020	Pharmaceuticals
code352030	Life Sciences Tools and Services
code401010	Banks
code401020	Thrifts and Mortgage Finance
code402010	Diversified Financial Services
code402020	Consumer Finance
code402030	Capital Markets
code402040	Mortgage Real Estate Investment Trusts (REITs)
code403010	Insurance
code451020	IT Services
code451030	Software
code452010	Communications Equipment
code452020	Technology Hardware, Storage and Peripherals
code452030	Electronic Equipment, Instruments and Components
code453010	Semiconductors and Semiconductor Equipment
code501010	Diversified Telecommunication Services
code501020	Wireless Telecommunication Services
code502010	Media
code502020	Entertainment
code502030	Interactive Media and Services
code551010	Electric Utilities
code551020	Gas Utilities
code551030	Multi-Utilities
code551040	Water Utilities
code551050	Independent Power and Renewable Electricity Producers

Table IV below shows summary statistics of all green bonds obtained from the Bloomberg database. Panel A shows a stable growth in the volume of green bonds issued from 2007 to 2019—see also Figure 1 of the introduction. Most green bonds are issued by private industrial companies followed closely by banks.

Other variables' description

This section describes firm and country-level variables' sources and construction.

Book-to-market ratio.—To obtain book equity from Compustat, we subtract from the shareholders' equity the preferred stock value, using redemption, liquididating or carrying value in that order (items PSTKRV, PSTKL, PSTKQ). For shareholders' equity we use the item SEQ, or Total Common Equity plus Preferred Stock Par Value (CEQ, PSTKQ) if SEQ is missing and Total Assets minus Total Liabilities minus Minority Interest if CEQ or PSTKQ is missing, using items ATQ, LTQ, and MIBQ. We then divide by the market value of the firm, which is obtained as the number of shares outstanding multiplied by the stock price, as in CRSP, and Compustat Global for international firms.

Effective carbon price.—It is a weighted average of effective carbon prices across all sectors (Road transport; Non-road transport; Industrial facilities; Households, commercial and public services; Electricity) weighted by the amount of emissions of each sector and each coverage type (permit prices and/or taxes). We obtain these data from the OECD for years 2012, 2015 and 2018 and we linearly interpolate the resulting estimates to obtain data for intermediate years.

CO2 emissions.—We collect firm-level carbon emissions from ASSET4 (item ENERDP023, Total Carbon dioxide (CO2) and CO2 equivalents emission in tonnes, i.e., scopes 1 and 2).

Environmental score.—We collect firm-level environmental scores from ASSET4 (item ENSCORE; notes: "Refinitiv's Environment Pillar Score is the weighted average relative rating of a company based on the reported environmental information and the resulting three environmental category scores").

Exchange rate.—We use yearly exchange rates from the OECD to convert all carbon prices to US$ denominated prices. More specifically, the exchange rate is the price of one country's national currency units in relation to US$ as of the end of each year.

Foreign sales, assets, an income.—We collect the proportion of foreign sales, assets, and income from Worldscope, which is defined as international sales, assets, and income, divided by net sales, total assets or revenues (item WC08731).

GDP.—We collect international data for GDPs from the World Bank.

Market capitalization.—We compute market capitalization as the number of shares outstanding multiplied by the stock price using CRSP and Compustat Global data.

Net debt issuance.—We define net debt issuance following Lian and Ma (2021). We compute it as long-term debt issuance (Compustat item DLTIS) minus long-term debt reduction (Compustat item DLTR).

Wealth-performance sensitivity.—This measure is obtained from Alex Edmans' website. It is defined as the $ change in CEO wealth for a 100 percentage point change in firm value, standardized by the annual flow compensation (Edmans et al. [2009]).

Share turnover.—For each firm and each year, it is the sum of the monthly number of shares traded in a given year (trading volume), divided by the number of shares outstanding as of the end of the year. We take the average of this ratio for each industry and year.

Trading volume.—We collect trading volumes from CRSP and Compustat Global and adjust them for stock splits.

Total debt (country-level).—We collect country-level total debt from the BIS database. We consider gross issues of debt in a given country (domestic market) and year by all institutions except governments, central banks, and international institutions.

The following table presents some summary statistics, including Alex Edmans' original wealth-performance sensitivity and share turnover, before they are normalized to fit with our model as explained in Section IV.

Panel B: Distribution of green bonds by company type

	N	Total (MM)
N/A	177	24,068
Private	1557	356,571
Public	461	188,090

Table IV: Summary Statistics

This table presents summary statistics on Bloomberg's Corporate Green Bonds data. The sample is restricted to bonds with a green bond indicator that equals one according to Bloomberg and with a use of proceeds that includes Green Bond/Loan.

Panel A: Distribution of green bonds by issuance year

	N	Total (MM)
2007	1	808
2008	7	427
2009	13	920
2010	50	4,229
2011	22	975
2012	21	2,047
2013	36	13,642
2014	123	31,314
2015	301	43,758
2016	225	85,477
2017	377	103,996
2018	457	113,946
2019	562	167,189

Panel C: Distribution of green bonds by (Bloomberg) industry

	N	Total (MM)
Bank	866	240,350
Financial	162	62,091
Industrial	933	227,183
Insurance	7	2,563
Municipal	2	945
Real Estate	195	20,101
Utility	30	15,495

Panel D: Distribution of green bonds by country

	N	Total (MM)
China	275	109,085
France	193	39,585
Italy	21	10,267
Japan	69	10,762
Mexico	9	12,186
Netherlands	81	53,496
Norway	34	8,188
Others	578	159,694
SNAT	445	85,766
Sweden	220	18,548
UK	22	8,005
US	248	53,147

Panel E: Summary statistics of the main variables

	mean	sd	min	p25	p50	p75	max
Green bonds (proportion)	17.009	24.179	0.070	0.742	5.043	21.332	92.589
Carbon price ($)	32.480	37.202	0.882	8.042	11.364	55.519	163.147
Environmental score	48.998	23.079	0.000	29.480	47.340	67.560	99.310
Firm size ($B)	239.843	5,422.056	0.000	0.102	0.641	3.981	4.48e+05
Wealth-performance sensitivity (original)	529.688	15771.873	0.992	7.096	13.615	40.943	8.69e+05
Share turnover (original)	142.685	407.876	0.000	71.814	97.905	135.681	7,880.690
Firm CO2 emissions (Mt)	4.00	10.8	0.000	0.082	0.359	2.14	99

Moreover, the obtained proxies *WPS* and *Turnover* both vary significantly across industries. For both variables respectively, the ANOVA test rejects the hypothesis that industries' means are equal at the 1% level.

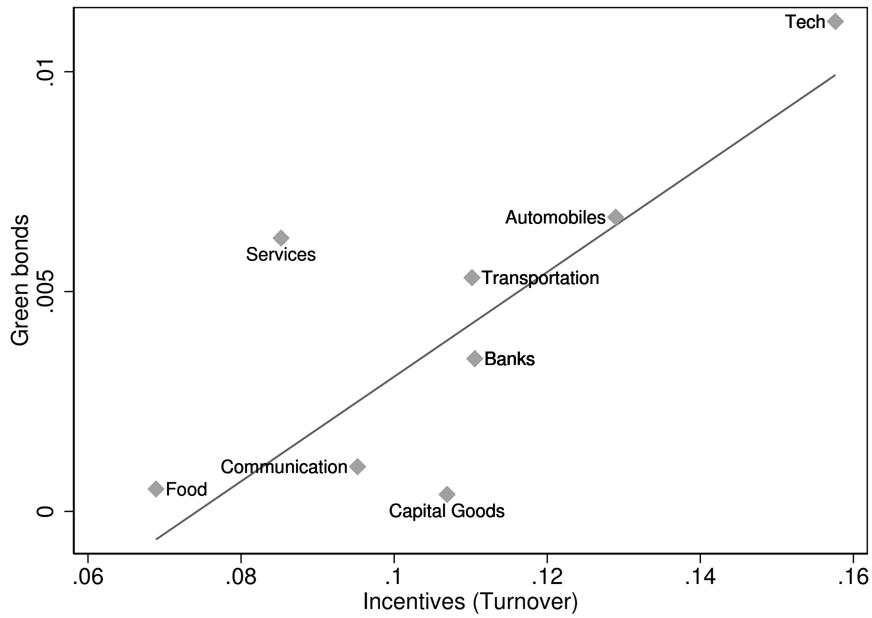

Figure V: Certified green bond issuance and stock share turnover (2007-2019)

Replication and additional robustness exercises

The following estimation results complete those presented in Table I.

Table V shows how the results of Section IV are modified when standard errors are clustered at the country-industry level. In particular, when *Incentives=WPS* and in the presence of industry-year fixed effects, the coefficient of the interaction component of (12) becomes significantly different from zero at the 11% level. The difference with results presented in Table I raises the possibility that an unobserved variable affect green bond issuance at the industry level.

We now examine the total impact of managerial incentives according to the regression results presented in Table I of Section IV. According to these results, the total effect is positive on average, i.e., at least for any effective carbon price greater than the OECD average of $32.

In order to test whether the total effect of managerial incentives is statistically different from zero at a given threshold level $\overline{\textit{Carbon price}}$, we rewrite the empirical model (12) by

Table V: Green bond issuance, managerial incentives, and carbon price: alternative clustered standard errors

This table presents estimates from panel regressions of the proportion of green bonds issued by firms on their countries' effective carbon prices and proxies of managers' stock-price sensitivity in their industries. We control for firm size, book-to-market ratio, and environmental score. Standard errors are clustered at the country-industry level. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

	Green bonds			
	(1)	(2)	(3)	(4)
Carbon price × Incentives (WPS)	0.017	0.024		
	(0.010)	(0.021)		
Incentives (WPS)	-0.505**			
	(0.220)			
Carbon price × Incentives (Turnover)			0.006***	0.005**
			(0.002)	(0.002)
Incentives (Turnover)			-0.158***	
			(0.048)	
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	No
Industry-year FE	No	Yes	No	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	15011	15008	15148	15145
R^2	0.335	0.358	0.335	0.358

reducing countries' effective carbon prices by this threshold level, which yields:

$$\begin{aligned} \textit{Green bonds}_{i,t} &= \beta_0 + \eta_1 \textit{Incentives}_{j(i),t-1} \\ &+ \eta_2 \left(\textit{Carbon price}_{c(i),t-1} - \overline{\textit{Carbon price}}\right) \times \textit{Incentives}_{j(i),t-1} \\ &+ \beta_3 \textit{Controls}_{i,t-1} + \textit{Fixed effects} + \epsilon_{i,t}, \end{aligned} \tag{D.1}$$

where $\eta_1 \equiv \beta_1 \times \overline{\textit{Carbon price}} + \beta_2$ becomes the coefficient of the total contribution of managerial incentives.

This total effect is not statistically different from zero at the average level $\overline{\textit{Carbon price}} =$ \$32.

Take, for example, the average effective carbon price in the EU, accounting for about 50% of the global volume of green bonds: $\overline{\textit{Carbon price}} = \$81.75$. Table VI shows our regression results with this threshold. The coefficient of the total contribution of managerial incentives is statistically different from zero at the 5% and 10% level when *Incentives=Turnover* and *Incentives=WPS* respectively.

Table VII presents various regressions that extend those of Section IV. It examines the firm-level variation in share turnover by using $\textit{Turnover}_{i,t}$ rather than the industry-level aggregate $\textit{Turnover}_{j(i),t}$ used in Section IV. Moreover, it includes firms' *Foreign sales*, *Foreign assets*, and *Foreign income*, on top of firm fixed effects, to deal with the case of multinationals.

Table VI: Green bond issuance, managerial incentives, and carbon price: total impact of managerial incentives at the average EU carbon price average

This table presents estimates from panel regressions of the proportion of green bonds issued by firms on their countries' effective carbon prices reduced by the average EU carbon price and proxies of managers' stock-price sensitivity in their industries. We control for firm size, book-to-market ratio, and environmental score. Standard errors are clustered at the country level. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

	Green bonds			
	(1)	(2)	(3)	(4)
Incentives (WPS)	0.908*			
	(0.454)			
$\overline{\textit{Carbon price}}$ × *Incentives (WPS)*	0.017***	0.024*		
	(0.006)	(0.014)		
Incentives (Turnover)			0.340**	
			(0.144)	
$\overline{\textit{Carbon price}}$ × *Incentives (Turnover)*			0.006**	0.005***
			(0.002)	(0.002)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	No
Industry-year FE	No	Yes	No	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	15011	15008	15148	15145
R^2	0.335	0.358	0.335	0.358

Table VII: Green bonds issuance, managerial incentives, and carbon price: robustness

This table presents estimates from panel regressions of the proportion of green bonds issued by firms on their countries' effective carbon prices and their share turnover. We control for firm size, book-to-market ratio, environmental score, and measures of firms' foreign activities. Standard errors are clustered at the country level. *, **, and *** denote significance at the 10%, 5%, and 1%, respectively.

	Green bonds			
	(1)	(2)	(3)	(4)
Carbon price × (Firm-level) Turnover	1.463**	1.588**	0.403*	0.441*
	(0.637)	(0.682)	(0.235)	(0.240)
Foreign sales		0.250		
		(0.230)		
Foreign assets			229.362*	
			(121.177)	
Foreign income				2.191
				(2.510)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Industry-year FE	Yes	Yes	Yes	Yes
Country-year FE	Yes	Yes	Yes	Yes
Observations	15145	14008	11912	11260
R^2	0.358	0.359	0.428	0.429

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