Decoding Corporate Green Bonds: What Issuers Do With the Money and Their Real Impact

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Abstract

I investigate the use of proceeds and the real impact of global corporate green bonds issued by non-financial firms, with a focus on greenhouse gas (GHG) emissions. The research reveals that green bond proceeds are allocated at a slower pace, are not used for shareholder payouts, and are less likely to be used for debt rollover compared to conventional bonds. This unveils a distinct motivation for issuing green bonds in contrast to conventional bonds. Employing market-level greenium as an instrumental variable in a Difference-in-Differences (DID) framework, I investigate the causal impact of green bond issuance on firm-level GHG intensity. Although improvements in GHG intensity are observed through Two-Way Fixed Effects (TWFE) and Event-study DID analyses, these improvements are not causally attributed to green bond issuance and are likely due to green initiatives that would have been funded regardless. I further explore the underlying mechanisms in this self-regulated market and find that repeat issuers voluntarily comply with the green bond framework, achieving tangible environmental improvements and giving credibility to the signal at issuance. The findings challenge the view that green bonds are simply conventional bonds with a "green" label and the view that green bonds causally lead to incremental sustainable outcomes.

Keywords: Sustainable Finance; Climate Change; Green Bonds; Corporate finance

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1 Introduction

A green bond is a type of debt security designed exclusively to finance climate-friendly projects, such as renewable energy, clean transportation, sustainable agriculture, or climate change adaptation initiatives. The green bond market has experienced rapid growth, with the market size reaching $2 trillion in 2022[1]. Its exponential growth and substantial market size, coupled with its potential to drive the transition toward a sustainable society, have propelled green bonds to become a prominent research topic. A prevailing concern since the inception of green bonds is whether their proceeds are genuinely allocated toward environmentally sustainable investments that make tangible impacts, or if they simply serve as another form of window-dressing. Further, the concept of "additionality" raises questions about whether these financial instruments channel new money into environmental investments or if such projects would have been funded regardless[2]. While previous literature on green bonds has mainly addressed pricing (Caramichael and Rapp (2022), Benincasa et al. (2022), Slimane et al. (2020), Wang and Wu (2022), Larcker and Watts (2020)), stock market reactions to green bond issuance (Bhagat and Yoon (2022), Flammer (2021) and Tang and Zhang (2020)), and the motivations to issue green bonds (Flammer (2021), Daubanes et al. (2021)), the use of proceeds and the real impact of green bonds issuance, especially in the corporate sector, remains less explored.

This paper seeks to bridge this gap by presenting evidence on the allocation of green bond proceeds, their tangible impacts, and the market dynamics, thereby contributing to the ongoing discussion on sustainable finance. The allocation of green bond proceeds is of particular importance, as these bonds are explicitly designed as "use-of-proceeds" instruments. Given that they are backed by a firm's overall cash flow rather than earmarked for specific green projects, questions have arisen about the fungibility of green bonds' proceeds. This structure obliges firms to repay the bonds even if the green projects they finance do not succeed, potentially incentivizing investment in non-green but high net-present-value (NPV) projects. Such a scenario could introduce a new agency problem, where value is transferred from green bondholders to shareholders. While green bond terms are not directly linked to tangible environmental outcomes, evaluating these outcomes is not only a natural progression to understanding how the proceeds are allocated but also aligns with the ultimate goal of green bond issuance, and broader climate finance. Furthermore, the question of additionality can be addressed by endeavoring to establish a causal relationship between the issuance of green bonds and measurable environmental outcomes.

[1] Green bond issuance crosses $2trn milestone. Environmental Finance. https://www.environmental-finance.com/content/news/green-bond-issuance-crosses-$2trn-milestone.html

[2] Grene, S. (2015). The Dark Side of Green Bonds. Retrieved from https://www.ft.com/content/16bd9a48-0f76-11e5-b968-00144feabdc0

Through the analysis of a comprehensive dataset of non-financial corporate green bonds, I investigate how firms allocate green bond proceeds and the subsequent implications for both environmental outcomes and corporate sustainability practices. By examining the efficiency of the self-regulated market and providing empirical evidence on the real effects of green bond issuances, this study offers valuable insights into this emerging market.

Green bond market regulation is primarily driven by market norms, voluntary standards, and the potential for exclusion from the market rather than stringent legal enforcement, as further elaborated in Section 2. It is possible that laxer enforcement can be an equilibrium in new financial markets based on broad goals lacking a common definition. This lenient regulatory environment offers advantages to various stakeholders. Issuers of corporate green bonds will benefit from reduced compliance costs as lighter regulations can lead to lower reporting and non-compliance expenses. Additionally, the relaxed regulatory environment could offer more accessible green financing, stimulating market entry by additional participants. Investment banks, underwriters, and other financial intermediaries involved in the green bond issuance process can reap the benefits of increased transaction volume and less stringent due diligence requirements. However, these benefits come with certain drawbacks, such as decreased transparency, credibility, or alignment with environmental goals. Striking an appropriate balance between regulation and market accessibility is crucial for the long-term success of the corporate green bond market. This unique institutional feature makes the real impact of green bonds an interesting empirical question. As the corporate green bond market continues to expand, understanding its tangible impacts on firm behavior and the environment becomes increasingly vital. This understanding is crucial for investors, policymakers, and academics seeking to navigate and shape this rapidly evolving financial landscape.

I start by compiling a global corporate green bond issue dataset from various sources, including Bloomberg and firms' sustainable finance reports. My final sample contains 1,122 green bonds and spans 122 industries by 4-digit SIC code, 48 regions, from the year 2014 to the year 2021. Unlike the existing literature on corporate green bonds that studies green bonds issued by firms in all sectors (Flammer (2021), Bhagat and Yoon (2022), Tang and Zhang (2020), Caramichael and Rapp (2022)), this study focuses on non-financial corporate issuers since financial institutions such as banks allocate green proceeds via loans instead of direct investment.

Empirically, tracking the internal allocation of proceeds within a firm is infeasible, especially given the lack of uniform and timely reporting requirements for green bond allocations. To investigate the allocation of green bond proceeds, I employ a set of accounting variables and the firm's capital market transactions to capture the deployment of funds garnered through green bond issuances.

By leveraging the cash flow identity, both the sources and applications of funds are tracked. Over a period extending from six months to eighteen months, I analyze the increments in early bond repayment, bond rollover, loan repayment, cash holdings, working capital, capital expenditures, stock repurchases, cash dividends, mergers and acquisitions (M&A), research and development (R&D), and total assets, which act as a data integrity check. Derived from the specifications set forth by Kim and Weisbach (2008), I account for alternative funding sources and firm size and further control for leverage, investment opportunities, and fixed effects at the firm and year levels. Ultimately, parallel analyses are conducted for conventional bonds and for issuers with varying characteristics.

The findings indicate that in contrast to conventional bonds —typically issued for immediate cash needs as indicated by Huang and Ritter (2021) —proceeds from green bonds are (i) more likely to be held in cash for extended periods, (ii) not used for shareholder payouts and (iii) used less frequently in bond rollover. Contrary to the prevalent perception of green bonds, only a small fraction of green bond proceeds are allocated to investments. While the point estimates could be affected by data quality and measurement errors, the relative allocation of proceeds in investments between green and conventional bonds remains similar. This, along with the refinancing practices that permit refinancing existing or past green investments in the past 24 months, suggests that firms are either taking time to identify eligible green projects or refinancing existing ones. On average, green bond proceeds are not predominantly invested in new capital expenditures. When extending the observation window to 18 months, approaching the standard 24-month allocation deadline, the allocation of green bond proceeds shows no significant deviation from that of conventional bonds. Overall, the above findings suggest a distinct motivation behind the issuance of green bonds, challenging the fungibility view.

I then investigate the tangible environmental impact of green bonds, utilizing GHG emissions data from Bloomberg. I first show significant reductions in GHG intensity, defined as firm-level GHG emissions adjusted by total assets, among green bond issuers. The reductions commence from the refinancing date, which is 24 months before the issuance date. Using the combined sample with control firms in the same industry-country sets with green issuers, where the country is the pair where the firms are registered and headquartered, I employ Difference-in-Differences (DID) with Two-Way Fixed Effects (TWFE) and event-study DID (stacked DID) methodologies. I find an 8% reduction in GHG intensity post-issuance compared to control firms, suggesting the environmental performance improvements supported by Flammer (2021). However, given the decision to issue green bonds is not random, causal inferences cannot be readily drawn. Such improvements could be attributed to green investments that would have been undertaken regardless of the green bond issuance. Those firms may opt for green bonds to signal their commitment to sustainability, expand their investor base, or capitalize on lower financing costs. To rigorously assess the causal impact of green bond issuance on reducing greenhouse gas emissions, I employ market-level greenium —the yield differential between green and conventional bonds —as an instrumental variable (IV) in a DID framework. The IV approach satisfies two key criteria: relevance and, arguably, exclusion restriction. Greenium, as the financial benefit of issuing green bonds, is intrinsically linked to the decision to issue green bonds, fulfilling the relevance condition. The exclusion restriction criterion is met because the greenium, particularly at the market-wide benchmark level, is shaped by market conditions and does not directly influence firm-level existing or planned GHG emissions —its impact is mediated solely through the issuance of green bonds. Plausible factors such as stakeholder climate awareness can affect a firm's decision to invest in green bonds and green projects and may affect greenium both through the supply and demand sides in the financial and real markets. However, coupled with market frictions such as the timely availability of green financial assets and green projects, the effect of public awareness on the level of market-level greenium is unclear. Regardless, to mitigate this concern, I control for public awareness of climate risks in the analysis. Additionally, as discussed by Duchin et al. (2022), there is a growing suspicion that issuers of labeled bonds might be using the strategy of divesting from GHG-intensive assets as a tactic to enhance their environmental performance without genuinely committing to green investments. Instead of transitioning to greener alternatives, these GHG-intensive assets are merely changing hands [3]. Nevertheless, it is less of a concern in the green bond market, as divestiture is more common in the oil and gas sectors, which are not primary players in green bond markets.

As long as green bond issuance results in the operation of green facilities, the impact on greenhouse gas emissions can persist. I conduct a more robust analysis by implementing an IV approach combined with a DID method, which controls for unobserved time-invariant factors, mitigates endogeneity concerns, and establishes a robust causal link between green bond issuance and GHG emissions, potentially yielding more accurate results and insights into the effectiveness of green bond issuance. Finally, I introduce an interaction term between the market-level greenium and firm size as an IV. This accounts for the varying propensities of firms of different sizes to participate in the green bond market, thereby capturing market participation heterogeneity. Despite the observed improvement in environmental performance linked to green bond issuance, my analysis does not substantiate the claim that such issuances significantly reduce firm-level GHG emissions. This is in line with earlier findings regarding the use of proceeds, which also showed no significant increase in investments funded by green bond proceeds compared to conventional bonds. Although this analysis is limited by the inability to link GHG emissions to the use of proceeds directly, the overall conclusion that green bonds do not cause incremental environmental benefits at the firm level still holds. However, as the

[3] Morenne B. How a Houston Oilman Confounded Climate Activists and Made Billions. WSJ. https://www.wsj.com/articles/wealthiest-oilman-houston-hildebrand-climate-activism-32bb8aec. Published July 11, 2023.

green bond market continues to evolve, the benefits of issuing green bonds become more apparent. The entry of marginal players into the green bond market could potentially lead to a causal impact on environmental outcomes in the future.

Leveraging a variety of data sources, I examine the causal impact of green bond issuance on greenhouse gas emissions (GHG), Environmental, Social, and Governance (ESG) scores, and green innovation. Nonetheless, no significant increase in green innovations is observed, implying that the issuance of green bonds may not necessarily stimulate the development of new environmentally friendly technologies, or it may simply require a longer time to bear fruit. Using data from S&P Trucost, I find that firms' overall ESG scores remain unchanged, indicating that green bond issuance may not broadly influence corporate sustainability performance. Considering the improved GHG emissions following their initial issuance, these findings pose an intriguing paradox. One possible explanation could be that these GHG changes are not effectively captured by the ESG scores. However, this explanation appears to contradict the prevailing belief that the primary motivation for issuing green bonds is to improve ESG scores. Alternatively, if that was indeed the aim, it seems to have been unsuccessful.

The paper concludes with questions about the efficiency and functioning of the green bond market by using an event study on stock reactions to green bond issuance. The findings show that the stock market responds positively only to the second and subsequent green bond issuance, suggesting that the first green bond issuance fails to serve as a credible signal for firms aiming to demonstrate responsible green activities. In the absence of a legal framework, the primary consequence for non-compliant issuing firms is the potential inability to return to the market. Consequently, a firm's return to the market acts as a credible signal, prompting positive stock market reactions. This mechanism drives firms to engage in green investments and achieve positive emission reductions, at least when planning to return to the market. This insight explains the effectiveness of the green bond market in promoting environmentally responsible behavior, even when operating on a voluntary basis.

The findings of this paper highlight three key insights about the green bond market. First, green bonds genuinely serve green investment purposes. There is no evidence to support the argument that green bonds are issued with the motivation to be used in non-green activity. Second, in the early stages of the green bond market, green bonds are primarily issued by environmentally conscious firms that would have made green investments (or had already undertaken such investments) anyway. Third, the aforementioned behavior represents a plausible equilibrium in a nascent, self-regulated market. Firms, especially those that are early issuers in the green bond market, tend to identify projects before issuing green bonds. This is because managers of earlier issuers face uncertainties about potentially tightened regulations, noncompliance consequences, and uncertainty regarding the approach to monitoring compliance. In conjunction with the potential risk of market exclusion due to noncompliance, funds are directed towards green investments, aligning with the core objectives of green bonds.

This paper contributes to the expanding literature on climate finance, with a particular emphasis on the green bond market. The current body of research on green bonds can be classified into two primary streams. The first stream investigates the pricing dynamics of green bonds compared to their conventional counterparts, often referred to as the "greenium". The existence, magnitude, and underlying drivers of this greenium have been subjects of extensive research. Studies by Larcker and Watts (2020), Flammer (2021), and Tang and Zhang (2020) found no evidence of a greenium, while Zerbib (2019) reported a positive greenium. Conversely, recent works by Caramichael and Rapp (2022), Baker et al. (2018), and Wang and Wu (2022) identified a negative greenium. Additionally, Wang and Wu (2022) posited that the investor-tastes model drives the greenium, Kapraun et al. (2021) emphasized the role of Green-credibility, and D'Amico et al. (2023) attempted to model the green spread that solely reflects investor's environmental preferences

The second stream focuses on firm-level outcomes, such as stock market reactions, ESG and environmental performance, and motivations for issuing green bonds. For instance, Tang and Zhang (2020) and Flammer (2021) documented positive stock market reactions following green bond issuance, Bhagat and Yoon (2022) observed a neutral response, and Aswani and Rajgopal (2022) reported a negative reaction. Moreover, Flammer (2021) highlighted improvements in ESG and GHG metrics, while Aswani and Rajgopal (2022) found no significant change in total GHG emissions four years post-issuance. It is worth noting that these studies incorporated financial firms in their samples, a sector that is intentionally excluded in this paper.Daubanes et al. (2021) shows theoretical modeling as signaling of the main motivations, which agrees with Flammer (2021).

This paper contributes to the ongoing discussion of the green bond by offering valuable insights into the effectiveness and real impact of green bond issuance on corporate environmental outcomes. It is among the first to provide micro-level evidence of the use of green bonds, which is pivotal for understanding the instrument designed as a use-of-proceeds bond. It is also among the first to assess the causal relationship between green bond issuance and greenhouse gas emissions. With Flammer (2021) being the most relevant work, Flammer (2021) also demonstrates a reduction in CO2 emissions (intensity) using a matching method, albeit her study includes financial firms. My research extends this by showing that while green bonds may fund these improvements, these projects would likely have been funded even without green bond issuance.

This paper also adds to the expanding literature that assesses the efficacy of financial instruments in addressing climate challenges, particularly emphasizing the cost of capital and financing channels within the wider framework of sustainable finance. My research provides empirical evidence that categorizes green bonds chiefly as signaling devices. This observation aligns with the theoretical conclusions drawn by Daubanes et al. (2021). However, I emphasize that the effectiveness of this signaling is contingent upon the issuer's ability to re-enter the market. Exploring other climate finance instruments, such as sustainability-linked bonds or loans where the coupon rate is linked to emissions performance, Du et al. (2022) indicates that sustainability-linked loans (SLLs) do not benefit from lower initial loan spreads. This suggests that the primary beneficiaries of these instruments are the lenders. Building on this, Kölbel and Lambillon (2022) argues that the issuance of the first Sustainability-Linked Bond is viewed by investors as a strong indication of a company's commitment to sustainability. Notably, the cost savings from the reduced cost of debt outweigh the potential penalties issuers may face if they fail to meet the defined sustainability performance targets.

Lastly, this research augments the literature on financing motivations by presenting empirical evidence on this novel bond type, thereby enriching the capital structure literature. While previous research by Kim and Weisbach (2008) and Huang and Ritter (2021) has established that firms typically utilize equity for long-term projects and debt for immediate capital needs, I find green bonds diverge from this pattern. Specifically, I demonstrate that the proceeds from green bonds are not allocated for immediate cash needs. Instead, these funds are deployed slowly and are not directed toward shareholder payouts, even though such payouts are often associated with value increases in the context of conventional bonds.

The remainder of the paper is organized as follows: Section 2 provides an overview of the green bond markets, while Section 3 outlines the hypotheses development related to the use of proceeds and GHG emissions. Section 4 elaborates on the sample construction process and the methods used for measurement. The allocation of proceeds from green bonds as opposed to conventional bonds is investigated in Section 5. Section 6 delves into the tangible impact on GHG emissions. A broader discussion of market dynamics and supplementary analyses on ESG and green innovation is presented in Section 7. Finally, Section 8 concludes the paper.

2 The Green Bond Market

In late 2007, a consortium of Swedish pension funds expressed interest in financing climate-positive initiatives. Consequently, the World Bank issued the first green bond in 2008, marking the creation of a new type of security tied to climate-related action. The market needed to evolve its own rules and procedures. Early Supranational, Sovereigns, and Agencies (SSA) green bond issuers, such as the World Bank, developed internal frameworks for selecting and managing green projects and established impact reporting practices. These early issuances and procedures paved the way for developing the Green Bond Principles. Vasakronan, a Swedish property company owned by four of the country's national pension funds, issued the inaugural corporate green bond in November 2013. The bond of SEK 1.3 billion was specifically designated for financing energy-efficient construction and refurbishment projects. In the same month, Électricité de France (EDF) issued its first green bond to finance renewable energy projects. Vasakronan and EDF's efforts initiated the corporate green bond market, prompting other firms to follow suit. The successful issuances of these bonds and the Green Bond Principle (GBP) establishment in 2014 accelerated the green bond market's growth, attracting a diverse range of corporate issuers and investors.

GBP is the foremost provider of guidance on the use of proceeds, project evaluation, selection, management of proceeds, and reporting. It was developed in 2014 by a consortium of investment banks, including Bank of America Merrill Lynch, Citi, Crédit Agricole Corporate and Investment Bank, and J.P. Morgan. As the founding members of the Green Bond Principles, they have been the major players in the green bond market and have acted as lead underwriters for numerous green bond issuances. In addition, third-party verification and certification processes, such as the Climate Bonds Initiative (CBI)[4], gained prominence to ensure that bonds adhered to environmental criteria.

The European Union (EU) is the first, and thus far only, governmental entity to release comprehensive regulations to shape the green bond compliance landscape. In January 2023, the European Commission, alongside the European Parliament and Council, instituted the European Green Bond Regulation with the aim of establishing a high-quality standard for green bonds. However, the EU has preserved the voluntary nature of these regulations. Corporations and public entities intending to finance their green investments through capital markets may choose to adopt the European Green Bond Standard (EUGBS) and obtain the EU green label. The choice of compliance ultimately rests with the issuers, even within leading regions of green finance.[5]

Despite 15 years of growth, the green bond market continues to operate without strict legal

[4] The Climate Bonds Initiative (CBI) is a not-for-profit organization that operates a voluntary certification initiative aligned with the Green Bond Principles. It provides sector-specific eligibility criteria for green projects.

[5] Prior to EUGBS, the EU released the EU Taxonomy in 2020, which defines criteria for economic activities that align with a net-zero trajectory by 2050 and broader environmental goals beyond climate. Mandatory for financial and non-financial companies subject to the Non-Financial Reporting Directive, the EU Taxonomy Regulation requires these companies to disclose information on how and to what extent their activities align with environmentally sustainable business activities. Starting in 2022, mandatory reporting under the EU Taxonomy Regulation will be limited to climate objectives: climate change mitigation and adaptation. Furthermore, effective from 10 March 2021, the EU implemented the Sustainable Finance Disclosure Regulation (SFDR), imposing mandatory ESG disclosure obligations for asset managers and other financial market participants, ensuring substantive adherence to the regulation.

enforcement. Bond covenants do not cover green framework compliance, and there is no mandatory framework for green bond issuance. Instead, the green bond market's evolving landscape has been shaping market norms and enforcement measures. Compliance is ensured through market mechanisms and a potential deterrent - exclusion from the market. Two notable controversies showcase this mechanism.

In 2014, Engie, a French utility company formerly known as GDF Suez, was one of the early issuers in the green bond market and issued the largest corporate green bond at the time. The controversy among investors and environmental groups stemmed from the allocation of a portion of the funds towards financing the contentious Jirau Dam project in Brazil.[6] Engie, in response, stated that it maintains ongoing monitoring of the dam's environmental impact, and auditors affiliated with the International Hydroelectric Association have provided positive feedback on the project's sustainability performance. Even though Engie was not excluded from the market and issued a second green bond in 2017 and more afterward, this event possibly deterred other companies from issuing bonds that could incite controversy. It also escalated the need for explicit criteria defining climate-friendly securities among investors and issuers. Without a uniform definition of what constitutes a green investment, issuers face uncertainty surrounding compliance costs, such as potential reputational damage when issuing a green bond. While green bonds may attract a diverse range of investors and enhance an issuer's reputation, investors might also seek penalties when disagreements on greenness arise.[7]. This event also discouraged large dam financing by green bond until 2021, when CBI issued guidance on selecting hydro-power green projects. Meanwhile, CBI has continually phased out criteria under the Climate Bond Standard for different sectors and is seeking public consultation.

In 2017, Repsol, an oil and gas company, issued the sector's first green bond with the intention of enhancing operational efficiency and reducing its carbon footprint. However, this move drew considerable controversy as many investors believed that funding an oil company contradicted the green bond's objectives. Consequently, Repsol's green bond was excluded from the CBI's internationally aligned green bond database, and the company never issued another green bond. Instead, Repsol issued Sustainability-Linked Bonds (SLBs) in 2021, a time when numerous polluting companies were issuing "transition bonds" to finance their shift towards more sustainable operations.

The examples above reflect the broader trend in the green bond market: The regulatory framework in the green bond market is largely driven by market norms, voluntary standards, and the threat of exclusion from the market rather than by stringent legal enforcement.

[6] The Jirau Dam flooded 362 square kilometers of rainforest and has been associated with labor rights violations, adverse impacts on indigenous communities, and habitat destruction.

[7] "Bond Market Asking 'What Is Green?' Curbs Climate-Friendly Debt", Bloomberg, https://www.bloomberg.com/news/articles/2016-03-07/bond-market-asking-what-is-green-curbs-climate-friendly-debt

3 Hypothesis Development

Firms face the challenge of addressing societal costs, such as greenhouse gas (GHG) emissions, often considered corporate negative externalities. Consequently, concerns about potential greenwashing in green bond markets have persisted. Agency problems and information asymmetry introduce further complexities, as managers may have private incentives or struggle to convey credible signals about their commitment to environmental objectives. This problem intensifies with green bonds, as green bonds are general obligation bonds backed by the firm's overall cash flow. This arrangement can result in a misalignment between the bond's repayment and the cash flow from the associated green investment. Firms remain obligated to repay the green bond even when the funded green project yields negative cashflows. This structure can motivate firms to redirect green bond proceeds toward high-yielding but non-environmentally-friendly projects, which raises the fungibility issue. It also creates a potential conflict of interest between green bondholders and issuers, particularly if green bondholders require environmentally beneficial outcomes from the bonds. Such a conflict between green bondholders and issuers is less likely if green bondholders view green bonds merely as conventional bonds with an environmental label. A potential market equilibrium of greenwashing arises where investors—perhaps just the intermediary investors—are simply looking for a green label to satisfy end-investor pressure but without any real commitment to green goals. Pressure and monitoring from the set of environmentally conscious investors can help alleviate concerns about the fungibility or greenwashing of green bond proceeds. However, the absence of a unified definition, legal recourse for green defaults, or government regulations in the green bond market casts doubt on the effectiveness of monitoring mechanisms and the possibility of market failures.

3.1 Hypotheses on Fungibility

Hypotheses in this subsection aim to investigate whether green bond issuers divert proceeds to non-green activities, especially given the potential incentives to do so.

A green bond and its conventional counterpart, issued by the same entity and with the same seniority, share several core attributes. First, the green bond covenants do not incorporate the green mandate; thus, violating the green framework does not lead to a default. Both types of bonds are subject to the same contractual obligations and terms agreed upon between the issuer and bondholders. Second, the credit risk of green and conventional bonds is identical as they are backed by firm-level cash flows and have the same credit ranking. Hence, the credit risk of both bonds is primarily determined by the issuing entity's ability to generate sufficient cash flows to meet its obligations, regardless of the bond's designation as green or conventional. Finally, the issuance process for green bonds mirrors their conventional counterparts. The underwriting, pricing, and allotment of bonds are executed identically for both types of bonds. Therefore, apart from the promised use of proceeds for environmentally friendly projects in the case of green bonds, these securities are structurally and operationally parallel to conventional bonds.

In a greenwashing equilibrium, as argued earlier, both issuers and green bondholders perceive the green bond market as a facade devoid of substantive environmental action. The utility function of green bondholders would then align with that of conventional bondholders. Under these circumstances, issuers would likely utilize green bond proceeds in the same manner as they would for conventional bonds, i.e., to maximize firm value, bearing all agency problems as given. Hence, if the issuance of green bonds merely reflects general financing preferences without a genuine commitment to environmental objectives, we would anticipate no difference in the use of proceeds compared to conventional bonds. On the other hand, if issuers genuinely intend to use green bonds for environmental purposes rather than merely maximizing firm value, we would expect a distinct pattern in the use of proceeds. This is because a green bond cannot be used to maximize firm value in the same manner a conventional bond does if it adheres to the green bond framework. By contrasting the fund allocation between green and conventional bonds, we can illuminate the issue of fungibility and assess whether a green bond issuance is essentially a conventional bond with a green label.

This attempt is relevant given the absence of a consistent reporting framework for green bond proceeds, the infeasibility of tracing the flow of green bond proceeds within a firm, and the current market design of the green bond market. In a perfect market scenario where green projects are prevalent, issuers could readily issue green bonds and seamlessly identify eligible green projects for investment. If, within this hypothetical scenario, we possessed the requisite mechanisms for direct observation, these allocations would predominantly manifest in tangible investments, such as capital expenditure, M&A, R&D, or working capital. Yet, real-world market dynamics and the security design of green bonds introduce inherent frictions, rendering the observation of such allocations impossible.

Delving deeper into the potential frictions, the bond market's cyclical behavior and the limited availability of green projects become evident. The relative cost advantage of issuing green bonds, i.e., the "greenium", is intrinsically linked to the cyclicality of the broader bond market. A significant misalignment arises between the green bond market and the actual market for eligible green projects. Specifically, when issuing green bonds is more cost-effective, green projects may be scarce in the real market, or such projects might be associated with higher costs. The prevailing green bond market structure, characterized by lenient regulations, refinancing options, and a two-year allocation deadline, provides issuers with a real option with green bond issuance. This real option involves investing in green projects using lower-cost green funds within a four-year window (two years for refinancing and two years for allocation). Issuers can opt to abandon this option, incurring the cost of the value of future real options and potential reputational damage, especially given the repeated game nature of the market. Hence, any deviation from the idealized 100% investment allocation could arise from several factors: refinancing existing green projects, the challenges associated with finding suitable green projects — which can be time-consuming — or non-compliance (fungibility). The observation of deviation, therefore, doesn't automatically indicate fungibility.

Hypothesis 1.a: Green bonds are designed and intended to finance environmentally sustainable projects. These projects often require substantial capital investment in sustainable infrastructure or green technology. This suggests a potential positive relationship between green bonds and capital investments, even when the precise "greenness" of the projects is arguable.

Null Hypothesis ($H_{0.1a}$): Whether firms are issuing green bonds or conventional bonds, there is no difference in their investments, specifically in capital expenditure, M&A, R&D, or working capital.

Alternative Hypothesis ($H_{1.1a}$): Proceeds from green bonds are more likely to be allocated toward investments than proceeds from conventional bonds.

Hypothesis 1.b: Green bond issuers, particularly those without pre-existing green projects, may require additional time to identify eligible initiatives for investment if they try to comply. Unlike conventional bonds, which are often allocated for immediate use, the disbursement of green bond proceeds may be more gradual. This delay in allocation could be less pronounced for issuers who frequently engage in green bond offerings, i.e., repeat issuers.

Null Hypothesis ($H_{0.1b}$): There is no significant difference in the amount of proceeds held in cash between green bonds and conventional bonds.

Alternative Hypothesis ($H_{1.1b}$): Green bonds have a significantly higher amount of proceeds held in cash compared to conventional bonds, and this effect is less pronounced for repeat issuers.

Hypothesis 1.c: While using green bond proceeds for equity payouts like dividends payouts or stock repurchases may increase value and alleviate free cash flow problems, as suggested by Jensen (1986), such uses contradict the environmental objectives of green bonds and effectively transfers value from green bondholders to shareholders.

Null Hypothesis ($H_{0.1c}$): Whether firms are issuing green bonds or conventional bonds, there is no difference in the use of proceeds for equity payouts, encompassing dividend payouts and stock repurchases.

Alternative Hypothesis ($H_{1.1c}$): Proceeds from green bonds are less likely to be used for equity payouts than those from conventional bonds.

Hypothesis 1.d: Recent literature[8] documents a "greenium" associated with issuing green bonds, implying favorable financial incentives for firms to issue them, given their often lower yields. Consequently, it is a positive NPV decision for issuers to replace existing, higher-yield debt if early repayment is feasible. This can be perceived as a reallocation of benefits from green bondholders to shareholders.

Null Hypothesis ($H_{0.1d}$): Whether firms are issuing green bonds or conventional bonds, there is no difference in the use of proceeds for debt repayments.

Alternative Hypothesis ($H_{1.1d}$): Proceeds from green bonds are more likely to be allocated toward debt repayments than those from conventional bonds.

Issuers, differentiated by their timing of initial market entry, frequency of participation, and financial constraints, may exhibit distinct behaviors, especially given the nascent and self-regulated nature of the market. The following hypotheses are formulated to test whether the market dynamics align with the discussions presented earlier.

Hypothesis 1.e: Repeat issuers, those who successfully re-enter the market, are likely to be the ones who have complied with the green bond framework at least once, i.e., completed the allocation. They are likely to have existing green projects to refinance or find it easier to identify them due to lower search costs.

Null Hypothesis ($H_{0.1e}$): Green bond issuers, irrespective of their frequency of participation, exhibit uniform behavior in the use of green bond proceeds. This suggests the absence of a repeated game or friction in identifying green projects.

Alternative Hypothesis ($H_{1.1e}$): If frictions in identifying green bond projects exist, repeat issuers, those who have exercised the real options of green bonds at least once, are more likely to allocate funds more rapidly, either for refinancing or new investments.

Hypothesis 1.f: High-yield issuers, likely facing financial constraints and having limited access to

[8] Wang and Wu (2022), Caramichael and Rapp (2022), Benincasa et al. (2022), Slimane et al. (2020), and Zerbib (2019)

the capital market, bear a higher cost of forgoing the value of real options if non-compliant. They are less likely to identify green projects and then refinance with green bonds due to the higher uncertainty they face in the capital market.

Null Hypothesis ($H_{0.1f}$): The pattern in the use of proceeds has no significant relation to the issuer's financial constraints or their access to the capital market.

Alternative Hypothesis ($H_{1.1f}$): If the dynamics of the repeated game don't enforce compliance, or if the market functions in the absence of an effective mechanism, high-yield issuers are more likely to divert the proceeds, leading to actions such as using green bond proceeds to replace more costly debt. Such differences wouldn't exist for high-yield issuers when comparing the use of conventional bonds.

3.2 Hypotheses on Additionality

A natural question that arises after identifying where capital is allocated is where the real impact lies. Consider a scenario where green bond issuers effectively direct proceeds towards projects that yield significant environmental benefits —projects that might otherwise go unfunded. In this case, issuing green bonds could catalyze environmental improvements, such as reductions in firm-level GHG emissions. This is particularly plausible for firms without prior green investments, as they may be incentivized by the lower cost of capital and broader investor base that green bonds offer. Alternatively, some firms may invest upfront in green projects, anticipating future opportunities to refinance using green bonds at favorable yields as permitted by the current green bond framework[9]. Both scenarios provide evidence of "additionality", where green bonds facilitate environmental impacts beyond what would have occurred otherwise.

On the other hand, if green bond issuance and green investments are driven by a firm's characteristics, such as stakeholder awareness of climate risk or foreseeable regulatory changes that a firm may face, the firm would likely undertake green projects regardless of green bond issuance. The improvements in environmental performance would occur irrespective of green bond issuance, suggesting correlation rather than causation.

Both of the above scenarios could co-exist empirically. Importantly, in neither case would the issuance of green bonds merely serve as greenwashing, given that their primary aim is to provide affordable financing for environmentally beneficial projects. Distinguishing between these scenarios is

[9] The refinancing and investment of green projects must occur within a two-year window.

challenging but also crucial for understanding how green bonds can contribute to combating climate risk and whether green financing can effectively address the problem. To empirically assess the real impact of green bonds on GHG emissions, I propose the following two hypotheses.

Null Hypothesis ($H_{0.2a}$): Issuing green bonds does not associate with a measurable change in GHG emissions compared to non-issuers.

Alternative Hypothesis ($H_{1.2a}$): Issuing green bonds is associated with a reduction in GHG emissions.

Null Hypothesis ($H_{0.2b}$): The issuance of green bonds does not causally lead to a reduction in GHG emissions, i.e., on average, there are no issuers doing green projects due to the issuance of green bonds.

Alternative Hypothesis ($H_{1.2b}$): The issuance of green bonds causally leads to a reduction in GHG emissions.

If Hypothesis *Hypothesis 2a* is not rejected, it would imply that the green label serves primarily to enhance a firm's reputation and attract investment, rather than to facilitate environmental improvements. Conversely, if *Hypothesis 2a* is rejected, it suggests that green bonds can effectively channel capital toward green projects or firms with positive environmental impacts. However, this outcome does not necessarily indicate additionality, or the generation of environmental benefits beyond what would have naturally occurred.

Furthermore, if *Hypothesis 2b* is also rejected, it provides evidence of additionality. In other words, the existence of a readily accessible green financing market entices some firms to make green investments at the margin. On the flip side, if *Hypothesis 2b* is not rejected, it suggests that while green bonds may not be mere window dressing, they do not incentivize additional green projects.

3.3 Hypotheses on Market Effectiveness

Insiders know about a firm's genuine commitment to environmental sustainability, while outsiders lack this information. Firms may use green bonds as a credible signal to communicate their dedication to environmental responsibility if there are costs associated with this signaling, as per Spence (1973). Compliance costs, such as ongoing reporting, are indeed one type of cost associated with green bond issuance. However, if firms believe the compliance costs outweigh the consequences of non-compliance, they may discontinue their compliance efforts. In this context, compliance cost alone cannot guarantee that green bond issuance serves as a credible signaling device. The regulatory landscape in the green bond market is characterized more by voluntary standards than stringent legal enforcement. Issuers have the discretion to select their preferred green bond framework. In addition, compliance with the chosen framework is not protected in the bond covenant. Thus, non-compliance does not result in a "green" default. Instead, the primary penalty for non-compliance is the potential exclusion from future participation in the market. This dynamic mirrors the principles of repeated game theory, where reputational concerns substitute as a form of enforcement in the absence of explicit regulation. Thus, a firm's successful re-entry into the market demonstrates its credible commitment to green intentions. As a result, we should expect positive abnormal returns on stocks in subsequent green bond issuance, as the market recognizes the firm's credible commitment to sustainability.

Null Hypothesis ($H_{0.3}$): Issuing green bonds does not serve as a credible signal of a firm's commitment to environmental objectives.

Alternative Hypothesis ($H_{1.3}$): If the issuance of green bonds serves as a signaling tool to indicate a firm's commitment to environmental objectives, then only the second and subsequent issuances would be credible. In such a case, I expect a positive announcement return in response to these issuances.

4 Data and Sample

4.1 Bond Level Data

I obtain bond-level data from Bloomberg and complement firm-level financial data sourced from COMPUSTAT North America and COMPUSTAT Global with information from Bloomberg, Refinitiv LPC, and the SDC Mergers and Acquisitions database. Beginning with all corporate bonds (active, inactive, and matured) labeled as green in the Bloomberg Fixed Income Search, I first exclude Supranational, Sovereigns, and Agencies (SSA) green bonds. Additionally, I eliminate green bonds issued by financial firms, hospitals, university endowments, special-purpose vehicles without traceable parent companies, local government financing vehicles, or entities wholly owned by governments. The rationale for excluding financial firms is that, unlike non-financial corporations, which directly allocate green proceeds to green activities, financial institutions allocate green proceeds through loan facilities and do not directly generate real impact.

I employ a series of checks to ensure the accurate matching of bonds and bond issuers. First, I utilize the "Issuer Equity Ticker" and "Bond to Equity Ticker" fields in Bloomberg to identify the issuer's ticker and the first parent company with available fundamental data. Next, I use the "Parent Relationship" and "Investor Institution Type" fields in Bloomberg to avoid using parent companies for indirect subsidiaries or portfolio companies. In such cases, the fundamental of the bond issuer is employed rather than the issuer's parent. This mapping is further validated by examining the International Securities Identification Number (ISIN), issue amount, and issue date of all green bond issuance announcements from the firm's investor relations page or green bond allocation reports, if available.

Bloomberg may display the same bond issuance as two bonds with distinct identifiers. For instance, in the US, issuers may choose to issue bonds registered with the Securities and Exchange Commission (SEC) or rely on two types of exemptions, Regulation S (RegS) or Rule 144A, and issue without registering under the Securities Act of 1933. RegS exempts securities sold outside the US to US and non-US Qualified Institutional Buyers (QIBs) from Section 5 of the Securities Act. Under Rule 144A, QIBs can trade debt securities without registration and SEC review. In another example, a bond issued in the Chinese market may have two identifiers on Bloomberg if it is traded on the inter-bank market and also listed on Chinese exchanges, Shanghai Stock Exchange (SSE) or Shenzhen Stock Exchange (SZSE). To address these nuances and avoid double counting, which may incorrectly inflate the size of green bond proceeds received by a firm, I meticulously review bond information on Bloomberg, annual reports, and green bond disclosures.

Moreover, bonds with tap terms, which allow the issuer to sell more bonds with the same terms in the future at prevailing market prices, may appear as a new fungible bond in Bloomberg. Based on my observations, the tapped issuance typically has a temporary identifier, and after a certain period (usually 40 days), it becomes fully fungible to the existing bond. After the fungible date, the existing bond displays an increased size of issuing and outstanding amounts, while the temporary identifier of the tapped bond shows zero outstanding balances. Since the amount and timing of the tapping bond are already considered in my sample by checking tapping history, I exclude fungible bonds created for tapping by detecting all bonds with zero balance that are neither matured nor called and have notes of fungible events on Bloomberg. Failing to address this issue would lead to double counting of the proceeds of tapped green bonds.

4.1.1 Bond Level Summary Statistics

Figure 1a presents the number of non-financial corporate green bonds (hereinafter referred to as corporate green bonds) issued, excluding tap issuance, while Figure 1b illustrates the US dollar amount of corporate green bond issuances up to December 31, 2021, which includes the amount from tap issuances. The inaugural non-financial corporate green bond was issued in 2013. Subsequently, 754 corporations across 55 countries and regions have issued 2,156 green bonds, among which 435 are public companies. The prevalence of green bond issuance among corporations has surged since 2016, exhibiting exponential growth in recent years. The volume of green bonds issued in 2021 doubled in comparison to 2020. Given that a mere six green bonds were issued before 2014, this study focuses on the sample of all corporate green bonds issued from January 2014 to December 2021.

[INSERT Figure 1]

Green bonds, as self-labeled financial instruments, incorporate a variety of voluntary practices to enhance transparency in their issuance, management, and utilization. By virtue of their voluntary nature, these bonds retain their green label, even without full compliance with these practices. Two crucial entities, the GBP and the CBI, offer guidelines that promote transparency, disclosure, and integrity within the green bond market. The GBP provides voluntary process guidelines for bond issuance, while the CBI issues the Climate Bonds Standard & Certification Scheme and provides a certification service [10]. To secure CBI certification, bond issuances must be reviewed and approved by Approved Verifiers[11], who deliver a formal assurance report. To obtain this third-party assurance, issuers must establish a green bond framework in alignment with the GBP, generate annual green bond reports, and implement a green project selection process. Green bond reporting necessitates that issuers regularly update the allocation of proceeds through financial reports, newsletters, and issuer websites. Meanwhile, the green bond project selection process, typically outlined in the issuer's Green Bond Framework or equivalent documentation and explains how the selected projects will meet environmental objectives as defined in the issuer's framework. Consequently, all CBI-certified green bonds feature green bond assurance, which includes green bond reporting and the project selection process.

Given that my sample includes all self-labeled green bonds, it becomes crucial to compare with CBI-certified green bonds, specifically regarding third-party assurance, green bond reporting, and project selection processes. Both the CBI certification and green bond reporting apply at the bond level. It's worth noting that early participants in the green bond market frequently did not pursue CBI certification for their initial issuances. This trend can primarily be attributed to the phased sector-wise rollout of certification by the CBI. Besides, bonds issued prior to 2016 frequently do not feature green bond reporting, reflecting the evolution of standards and practices over time. Accordingly,

[10] The CBI charges a minimum fee of $2,000 for issuers in developed countries and $1,000 for those in developing countries upon awarding the Certification label. Following issuing any certified bond, a variable fee is calculated at 1/10th of a basis point (0.00001) of the bond issuance amount. For instance, a $500 million bond would incur a certification fee of $5,000. https://www.climatebonds.net/certification/fee-policy

[11] The list of Green Bond Approved Verifiers from CBI https://www.climatebonds.net/certification/approved-verifiers

the presented statistics are at the bond level instead of the issuer level. Based on the number of issuances, 83% of self-labeled corporate green bonds feature green bond reporting, 77% engage green bond assurance providers, and 85% implement a green bond project selection process, as depicted in Table 1.

These ratios are higher for the sample encompassing all self-labeled corporate green bonds compared to the final sample, which solely includes bonds issued by public firms[12].

4.2 Issuer level data

4.2.1 Use of funding

After merging the datasets from COMPUSTAT North America and COMPUSTAT Global and supplementing them with financial data from Bloomberg, the final sample employed for the use of proceeds analysis consists of 1,222 green bonds. Out of these, 1,122 are new issues and 100 are tap issues, by 435 firms across 48 countries and regions.[13] The COMPUSTAT quarterly fundamental data is converted into semiannual data.

Upon securing financing, a firm can allocate the proceeds to bolster cash reserves or working capital[14], invest in capital expenditures, research and development (R&D), and mergers and acquisitions (M&A), distribute dividends and conduct stock repurchases for shareholders, repay loans, and repay bonds, including maturing bonds and those subject to early retirement. Data on cash change, working capital change, capital expenditure (capex), and dividend payout are sourced from COMPUSTAT. R&D data are obtained from Bloomberg, as COMPUSTAT Global only provides annual R&D expenses data. Data pertaining to stock repurchases are from Bloomberg, as COMPUSTAT displays net repurchase and raw repurchase data together in a single data item without a clear way to distinguish between the two, whereas this study is particularly interested in raw repurchases. Early bond repayments are manually collected from Bloomberg Corporate Action by searching for all bond calls, tender repurchase offers, and open market bond repurchase events involving green bond issuers from January 2014 to December 2021. For non-callable bonds, issuers are required to either repurchase from the open market or extend tender offers to bondholders. Data on effective dates, actual

[12] Prior to its acquisition by Tesla in 2016, SolarCity issued 153 green bonds from 2014 to 2016. None of these bonds committed to providing green bond reporting, engaged green bond assurance providers, or implemented a green bond project selection process.

[13] Advanced SolTech Sweden AB, a green issuer, is further excluded from the sample as it issued a 300 million SEK green bond in 2016 while possessing only 70 million SEK in assets. The book runner is a local bank.

[14] Cash and short-term debt are excluded from working capital in this paper, as both can serve as a source of funding rather than a use of funds.

repurchased/called back amounts (rather than intended/announced amounts), and prices paid are collected. If repurchase price information is unavailable, cash outlays are calculated using security prices on effective dates, although the actual cost basis may differ. Companies typically announce open market operations after implementation, mitigating information effect concerns. Stock prices and outstanding common share numbers are sourced from Bloomberg, as COMPUSTAT Global does not provide common stock prices. By excluding bonds repaid early, I collect funds used to repay maturing bonds in the data period. Loan financing and loan repayment data are from Refinitiv LPC. M&A transaction data is obtained from the SDC Mergers & Acquisitions database.

Merging with SDC is based on SEDOL, 6-digit historical CUSIP, and ticker codes. For firms with available SEDOL codes from COMPUSTAT, SEDOL is used for matching. For North American-listed firms, historical CUSIPs are retrieved from CRSP, with the first six digits used for matching with SDC. Tickers are employed for the remaining unmatched sample. Merging using tickers can be problematic due to potential ticker reuse, so I manually verify firm names, countries, and listed exchanges from both sources to ensure accurate ticker-based matching.

4.2.2 Source of funding

Apart from green bonds, firms can obtain financing through conventional bonds, equity issuance, corporate loans, the sale of PP&E, and internally generated cash flows from ongoing operations. Bond issuance data are sourced from Bloomberg Corporate Action's "Debt Offer Increase" for tap issues and "Debt Offer-New Issue" for new issues. Equity issuance and the sale of PP&E data are acquired from Bloomberg. Proceeds from green and conventional bonds are calculated by multiplying the issued amount by the issue price. Corporate loan funding data are collected from Refinitiv LPC; however, it is crucial to acknowledge that actual cash flows from revolving loans remain unobservable in this data source. I have to assume that firms utilize the revolving loan from the beginning and repay it at maturity. Operating funds are sourced from COMPUSTAT.

4.2.3 Summary Statistics

Table 2 displays the summary statistics of the sample at the firm-semiannual level.

Panel A pertains to periods involving the issuances of green bonds, conventional bonds, equity, or corporate loans. Its objective is to reveal the relative size and frequency of each financing type. Additionally, it displays firm size and funds from operations throughout the entire sample period.

The panel offers both the raw amount and the amount scaled by the total assets of the firm from the preceding period, effectively accounting for firm size.

Among conventional financing methods, firms most frequently issue conventional bonds, trailed by loans and equity offerings. Equity financing, though less common, typically involves larger amounts in absolute terms and relative to firm size compared with conventional or green bond financing. This pattern aligns with the Pecking Order Theory proposed by Myers and Majluf (1984), asserting that firms tend to prefer internal over external financing, and when external financing is required, they favor bond issuance over equity due to information asymmetry. Moreover, the substantial fixed costs associated with equity financing often result in larger equity offerings.

As an emerging financing tool, green bonds are issued more frequently than equity but less frequently than other methods. Green bonds are, on average, one-third the size of conventional bonds - with green bonds averaging at $413.437 million, while conventional bonds average at $1,271.50 million. However, their relative size in proportion to the firm size is comparable to that of conventional bonds.

Panel B provides a summary of the utilization of funds over all periods. These variables, which are cumulative, begin from the issuing period (T=1) and continue up to a year after the end of the issuing period (T=3). Use of funds variables can be naturally categorized into two types: changes from the previous 6-month period, specifically ΔCash, ΔTA (total asset), and ΔWC (working capital), and the spending amounts, which comprise the remainder.

It is evident that certain variables, namely spending variables, do not conform to a normal distribution. They are non-negative and have a significant mass at 0. Once adjusted for total assets, these variables are capped at 1, justifying the use of fractional response regressions for the spending variables.

Data pertaining to stock repurchases, sourced from Bloomberg, represents an increase in capital stock. As such, this variable is consistently positive, unlike the corresponding data from COMPUSTAT. Certain variables exhibit skewness, including stock repurchases, dividend payouts, R&D, loan repayments, and bond repayments. These activities are not common occurrences, given that firms do not engage in these transactions every period. Capital expenditure (Capex) emerges as the most substantial corporate spending category. In contrast, spending on M&A exhibits the smallest mean, reflecting not their relative size but their infrequency.

[INSERT Table 2]

Table 3 illustrates the geographic distribution of issuers' incorporation within the sample. Approximately 70% of issuers are incorporated in the European Union, Japan, China, the United States, and South Korea. Notably, 30% of green bond issuers are located in Europe, with one-third of European issuers based in Sweden.

[INSERT Table 3]

[INSERT Table 4]

I present the industry distribution of issuers, as determined by the Global Industry Classification Standard in Table 5. A significant portion, 50%, of issuers operate within real estate [15], electric utilities, renewable electricity, independent power producers, construction & engineering, or environmental & facilities service subgroups. These industries have a substantial number of eligible green projects, as defined by the GBP.

[INSERT Table 5]

5 Use of Proceeds

In this section, I investigate how green issuers use green bond proceeds and conventional bond proceeds over time.

5.1 Specification

To estimate the uses of proceeds raised from green bond issuances, I employ a specification based on Kim and Weisbach (2008) that allows for different sources of funding to enter separately. Kim and Weisbach (2008) utilizes one plus with logarithms to address the issue of outliers; however, I opt for winsorizing all variables, except for dummies, by 1%. Omitting logarithms has no significant effect on regression results, and the outcomes are more readily interpretable. As previously discussed, the distribution of spending variables may not conform to normality. Accordingly, I also estimate these variables using fractional response regressions as proposed by Papke and Wooldridge (2008), as presented in the Appendix. Additionally, I include control variables for firm leverage, size, and Tobin's Q. I also account for funding from various sources, such as proceeds from conventional bonds, equity offerings, corporate loans, the sale of PP&E, and net funds from operations. If the estimation spans multiple periods, proceeds from green bonds in subsequent periods are also controlled. Both

[15] Real estate operating companies(REOCs) are companies that invest in real estate properties and generate income through the operations of these properties, unlike Real Estate Investment Trusts (REITs), REOCs can reinvest their earnings into business growth rather than distributing them to shareholders.

the source of funds and the use of funds variables are deflated by lagged total assets.

Financing instruments are often substituted for one another; for instance, during periods when a firm issues green bonds or equity offerings, it may issue fewer or no conventional bonds. There exists a negative correlation between the various funding sources, which is more pronounced when the sample size is smaller. Including the entire panel in the sample results in less multicollinearity than focusing solely on green issuance periods. An ideal test would be to observe the allocation of green bond proceeds by identical firms with varying green bond financing sizes. Consequently, I control for firm characteristics and employ firm-fixed effects to account for firm-specific unobserved variables over time. As the sample is global, foreign exchange fluctuations can inflate or deflate the change variables; thus, year-fixed effects are also implemented. The specification is presented in Equation 1. The primary interest lies in the estimates of β_1 and β_2, which measure the proportion of proceeds raised in green/conventional bond issuances allocated to increase each use of funds.

$$\begin{aligned}\sum_{t=1}^{T} Y_{i,t} =& \beta_1 \left[\frac{\text{Green Bond Proceeds}_{i,t}}{\text{Total Asset}_{i,0}}\right] + \beta_2 \left[\frac{\text{Conventional Bond Proceeds}_{i,t}}{\text{Total Asset}_{i,0}}\right] \\ &+ \beta_3 \sum_{t=1}^{T} \left[\frac{\text{Other Funds}_{i,t}}{\text{Total Asset}_{i,0}}\right] + \beta_4 \text{Leverage}_{i,t} + \beta_5 \text{Tobin's Q}_{i,t} + \beta_6 \text{Size}_{i,t} \\ &+ \text{Firm Fixed Effects} + \text{Year Fixed Effects} + \epsilon_{i,t}\end{aligned} \tag{1}$$

Where $\sum_{t=1}^{T} Y_{i,t} = (V_{i,t} - V_{i,0})/\text{Total Asset}_0$ for $V_{i,t}$ = cash, working capital, and total asset, and $\sum_{t=1}^{T} Y_{i,t} = \sum_{t=1}^{T} V_{i,t}/\text{Total Asset}_)$ for $V_{i,t}$ = early bond repayment, bond rollover, loan repayment, capital expenditure, dividend payout, stock repurchase, mergers and acquisitions (M&A), and research and development (R&D). Leverage is calculated as the sum of the book value of long-term debt and debt in short-term liability divided by the market value of total assets. The fiscal half-year preceding the green bond issuance is denoted as $t = 0$, while t represents the number of half-years following $t = 0$. The variable Other Funds includes funding from equity issuance, corporate loans, the sale of PP&E, and funds from operations. When the parameter T is greater than 1, which implies our focus is on the use of green/conventional bond proceeds issued at $t = 0$ over multiple periods, the funds from Conventional/Green bonds issued in subsequent periods are also included in the other funds variable. For instance, to estimate the use of green bonds issued at $t = 0$ over the following one year, green proceeds at $t = 2$ will also be controlled. As such, β_1 and β_1 will be estimated by two separate regressions when T exceeds 1. Tobin's Q is the ratio of the market value to the book value of total assets. Firm size is the logarithm of lagged total assets.

5.2 Results

One crucial element to consider when interpreting the use of funds results and other findings is the refinancing feature of green bonds. Refinancing, in the context of green bonds, involves using the proceeds from a newly issued green bond to repay or replace debt from a previous green bond or a conventional bond, as well as other sources of funding that funded environmental-friendly projects. According to the current green bond framework, issuers must complete the allocation within 24 months (or 36 months in earlier versions), and they can refinance eligible projects dating back to 24 months, which will be referred to as the refinancing backdate hereafter in this paper.

Figure 2 visualizes the allocation of $1 of green/conventional bond proceeds in a pie chart format. Due to unobservable activities in revolving loans and potential measurement errors, I have included an additional category to balance the distribution, which accounts for cash flow to uses other than those listed.

For brevity, Table 6 presents estimates of β_1 and β_2 in Equation 1 for $T = 1$ to $T = 3$, indicating contemporaneous half-year usage and cumulative usage up to one and half-year periods following the issuance of green/conventional proceeds. The spending on stock repurchases and dividends is aggregated into a single variable, equity payouts, to capture the overall allocation of funds towards shareholder returns. In addition to the nine measures of potential green proceeds usage, I also estimate the change in total assets as a data integrity check. For every $1 of green proceeds in the issuing period, firms allocate 50 cents to cash reserves, 4.7 cents in working capital, 7.72 cents to refinancing existing bonds, 2 cents to rolling over bonds, 0.59 cents to repay corporate loans, 5.9 cents to capital expenditures, 2.09 cents to M&A, and 3.7 cents to research and development. Proceeds used for bond rollover, working capital, loan repayment, and equity payout are insignificant. For every $1 of conventional bond proceeds, firms allocate 32.9 cents to cash reserves, 3.29 cents to working capital, 5.53 cents to refinancing existing bonds, 5.97 cents to bond rollover, 8.14 cents to capital expenditures, 0.06 cents to equity payouts, 1.4 cents to M&A, and 0.5 cents to R&D. Proceeds used in loan repayments, equity payouts, and R&D are insignificant.

When compared to conventional bonds, green bonds show a distinct pattern in the allocation of proceeds within the first 6-month window. Specifically, they allocate significantly more funds to cash reserves and less to bond rollover. However, they channel funds into capital expenditure and M&A at a similar rate as conventional bonds. Interestingly, green bonds are more likely to be used for refinancing rather than for equity payout. When the observation window is extended to 18 months, these differences in the use of funds become less pronounced, with the only significant variations being less allocation to bond rollover and more to refinancing. It's important to note that as the observation window expands, the sample size decreases due to the exclusion of more recent issuers, which could potentially affect the statistical power of the analysis.

It is useful to compare the allocation of proceeds from green and conventional bonds in a regression framework where the coefficients sum to 1. This approach helps to mitigate differences that could be attributed to measurement errors. The results obtained using seemingly unrelated regressions with constraints, are presented in Table 7. These findings are also depicted in pie charts in Figure 3a and Figure 3b. The regressions employ strict assumptions and account for the correlated covariance matrix in the use of funds. Issuers of green bonds allocate more funds to cash reserves and less to bond rollover and M&A activities. When categorizing the usage into broader buckets—such as cash, debt repayments (including repayments to bonds and loans), equity payouts, and investments (comprising Capital Expenditure, M&A, Working Capital, and R&D), regression results that are not tabulated indicate that green bond proceeds are 6 cents less used for investments and 12 cents more allocated to cash while being less used for equity (2 cents) and debt repayments (4 cents).

Green bond issuers pledge to manage green bond proceeds separately and allocate all funds for green activities, creating the impression that funds will be directed toward real investments (capital expenditure, R&D, or M&A). Approximately 50% of green bond proceeds are held in cash during the issuance half-year, and 34% remains in cash over one year, decreasing to 18% in a year and a half. These figures are significantly higher than those for conventional bonds, where only 14% of proceeds are in cash after a year, further dropping to 12% in the following half-year. The observation that green bond proceeds remain in cash for extended periods suggests that the allocation of funds from green bonds occurs at a slower pace compared to conventional bonds. This could be due to a lack of readily available green activities. As further evidenced by the tests in Section 5.3, these repeat issuers, likely having more experience in identifying eligible projects, tend to invest more quickly and substantially. Green bond proceeds can be applied to reimburse ongoing or past green projects, provided the expenditure occurs within 24 months of the bond issuance. This reasoning also explains why green bond proceeds are used for early bond repayment or rollovers, which are not green, per se, but could represent the replacement of conventional financing of recent green projects.

The observation that green bond proceeds tend to be held in cash for extended periods aligns with the common practice among issuers of utilizing separate or restricted cash accounts to manage green bond proceeds. The following exemplifies common languages in the Green Bond frameworks issued by firms: "The proceeds from the issuance of Green Bonds will be segregated into separate accounts within the company's finance and reporting system"[16]; "Only in the event that proceeds cannot be allocated directly, they will temporarily be held in any form of cash or bank deposits until full allocation to Eligible Green Capital Expenditures of the Eligible Green Portfolio."[17]. This, in turn, challenges the fungibility perspective.

Theoretically, in the absence of value-enhancing activities and debt repayments, a one-dollar bond could increase total assets by one. The fact that brown issuers' change in total assets is much smaller than green issuers' (and is smaller than one), is consistent with the observation that brown issuers use more of the proceeds to roll over existing debts.

Returning to the testable hypotheses outlined in Section 3, the usage of green bond proceeds aligns with that of conventional bonds 18 months after issuance. This alignment is consistent with the 24-month allocation window defined by the green bond framework. In the year following issuance, green bonds show a more gradual allocation compared to conventional bonds, evidenced by the fact that more green bond proceeds remain in cash. This observation effectively rejects *Hypothesis 1.b.* Even though an increase in capital expenditure is noted after the initial 6-month window, there is no discernible difference in the amount of proceeds used for investments between green and conventional bonds, failing to reject *Hypothesis 1.a.* As issuers allocate no green bond proceeds to equity payouts, no value is transferred to shareholders in this manner, leading to the rejection of *Hypothesis 1.c.* However, there is evidence of debt refinancing using green bonds, justified by the refinancing term. Specifically, green bond proceeds are more often used to actively replace existing debt and less for rollovers, rejecting *Hypothesis 1.d.* Overall, these findings underscore distinct motivations for issuing green bonds compared to conventional ones. Consistent with Huang and Ritter (2021), conventional bond issuers appear more attuned to immediate cash needs, such as working capital and show a propensity to use proceeds for bond rollovers and dividend payments.

Although green bonds are not as heavily allocated towards investments as one might expect based on their intended design, this could be attributed to the refinancing option, which allows issuers to refinance previous green projects. Given the evolving landscape of environmental compliance, managers may be incentivized to initially identify green projects and then refinance them later. The acceleration in the pace of investment in later periods indicates that it may take time for some green bond issuers to identify and invest in new projects that meet green eligibility criteria. While it's formidable to assess the greenness of these investments or to track a firm's internal cash management, the above findings lend credence to the notion that green bonds are not merely conventional bonds

[16] Green Bond Framework (2020). Green Finance Framework. https://www.btsgroup.co.th/en/sustainability/green-bond

[17] Volkswagen Group (2022). Green Finance Framework. https://www.volkswagen-group.com/en/green-finance-15752

with a green label. Rather, they signify a potentially genuine commitment to sustainability and a distinct financing strategy prioritizing long-term investment projects over immediate financial needs.

5.3 Firm Characteristics

Along with the basic specification, I also explore whether green issuers exhibit different behavior depending on the timing of their first issuance, whether they are repeat issuers, or whether they are high-yield issuers. I classify an issuance as high-yield if it is not rated as investment-grade by S&P, Moody's, or Fitch. It is possible for a firm to issue green bonds with different credit ratings over the sample period. I calculate a ratio of high-yield green proceeds over total green proceeds for a firm throughout the entire sample period. If the ratio exceeds 0.5, the issuer is considered a high-yield issuer. Green bond volume doubled in 2021, potentially reflecting stronger market demands or different investor monitoring practices since then. In this case, the issuer will be classified as a late issuer if their first green bond is issued after January 1, 2021. A repeat issuer is one who has issued in more than one period (half-year) during the sample period. Multiple issuances during the same 6-month period or tap bonds do not count towards repeat issuers. Figure 4 displays a Venn diagram of issuers with the mentioned characteristics.

My sample includes 435 distinct green issuers after matching with COMPUSTAT. High-yield, repeat, or late issuers make up 90% of the sample, leaving only 44 firms (10%) that do not fall into any of the above categories. Including all three dummies and interactions in the regressions may erroneously result in insignificant coefficients of β_1. Thus, I employ two strategies. First, I estimate specifications with interactions separately. Second, I use the whole sample in the regression. In my sample, 69% of the issuers are high-yield issuers, 30% are repeat issuers, and 41% are late issuers.

Accordingly, I also estimate these variables using fractional response regressions as proposed by Papke and Wooldridge (2008), as presented in the Appendix.

$$
\begin{aligned}
\sum Y_{i,t} =& \beta_0 \left[\frac{\text{Green Bond Proceeds}_{i,t}}{\text{Total Asset}_{i,0}}\right] + \beta_1 \text{Issuer Characteristics}_i \times \left[\frac{\text{Green Bond Proceeds}i,t}{\text{Total Asset}_{i,0}}\right] \\
&+ \beta_2 \sum_{t=1}^{T} \left[\frac{\text{Other Funds}_{i,t}}{\text{Total Asset}_{i,0}}\right] + \beta_3 \text{Leverage}_{i,t} + \beta_4 \text{Tobin's Q}_{i,t} + \beta_5 \text{Size}_{i,t} \\
&+ \text{Industry Fixed Effects} + \text{Year Fixed Effects} + \epsilon_{i,t}
\end{aligned} \tag{2}
$$

Where Issuer Characteristics is late, high-yield, or repeat.

Table 9 presents the regression results with firm characteristics interactions with green bond proceeds. For brevity, it only reports the coefficients on β_1.

In the initial 6-month window, repeat issuers significantly allocate 9 cents more per dollar of green proceeds to repaying existing bonds and 7 cents more to rolling over bonds compared to one-time issuers. They also allocate 17 cents more to capital expenditures while holding 22 cents less in cash reserves. Those faster allocations show that repeat issuers are more likely to be the issuers who experience fewer frictions in finding eligible projects. It, therefore, effectively rejects *Hypothesis 1.e.* Frictions exist in arranging green projects, and the magnitude of these frictions varies across issuers. This pattern is consistent with the observation that repeat issuers often operate in sectors where green projects are more readily available. As shown in Table 8, half of these repeat issuers come from sectors involved in renewable energies, green building, or environmental facility initiatives. These issuers are likely to have pre-existing projects that align with the ICMA green bond principles or green projects that are lined up to be financed right after the issuance, and have demonstrated their commitment to sustainability by re-entering the market multiple times.

High-yield and investment-grade issuers show little difference in how they allocate green bond proceeds, except that high-yield issuers spend 11 cents less towards roll-over loans. As the actual cash flow of the revolving loans is not observable, the origination and maturity dates of the loans are used as proxies. Even when taken at face value, high-yield issuers do not utilize the proceeds in the most profitable manner for fungibility, specifically to replace high-cost debt. In Table 10, I examine the use of conventional bonds by high-yield issuers who have issued green bonds. These issuers exhibit a preference for utilizing fewer conventional bonds for refinancing existing bonds while allocating more towards rolling over bonds and less towards M&A activities compared with investment-grade issuers. This pattern aligns with the notion that high-yield issuers face greater financial constraints. Altogether, the evidence suggests that some market mechanisms are at play in the green bond market, thereby rejecting the hypothesis *Hypothesis 1.f.*

To understand the evolution in the market's participants, I also examine the differences between late and early issuers. Late issuers refinance 8.6 cents less and rollover 6 cents less compared to their earlier counterparts. However, they allocate a higher portion of funds to equity payouts. It remains ambiguous whether this action contravenes the green bond framework. We cannot definitively say that late issuers, on average, aren't refinancing a project with 5.3% of the green bond proceeds, which would imply they have an existing green project equivalent to 5.37% of the bond size.

The above findings suggest the presence of market frictions that prevent us from observing an idealized high proportion of investment. One potential source of this friction could be the misalignment between the conditions in the green bond market and the actual market for green projects. However, certain market mechanisms appear to deter green bond issuers from complete fungibility. These mechanisms likely stem from the repeated game nature of the market and the associated costs of forgoing the value of future real options. This will be further discussed in Section 7.

6 Real Impact

In this section, I examine the real impact of green bond issuance, primarily focusing on GHG emissions. The discussion begins with a descriptive analysis tracing the temporal evolution of GHG emissions among green bond issuers, followed by a causal analysis employing an instrumented difference-in-differences approach augmented with control samples. Assessing the real impact of green bond issuance is not merely a logical next step after understanding how the proceeds are used. It also provides crucial insights into the potential role that financial instruments can play in facilitating a transition to a more sustainable economy, especially since reducing greenhouse gas emissions is pivotal to mitigating climate risks.

6.1 Greenhouse Gas Emissions

I sourced Greenhouse Gas (GHG) emissions data from Bloomberg, starting from the year 2010 when the platform began offering comprehensive coverage. The sample includes 324 non-financial firms that had issued green bonds up to December 31, 2021, and 527 firms that have never issued green bonds. The control group, including all firms within the country-industry segments of the treatment sample, is sourced from COMPUSTAT Global and COMPUSTAT North America. It's important to recognize that a firm could be incorporated and headquartered in different countries, and as a result, it might face regulations, public pressure, and climate risks from both of these countries. Consequently, combinations of incorporation and headquarters locations are considered as the "country" when selecting the control firms. For instance, consider a green issuer incorporated in Canada, headquartered in the US, and with a 4-digit SIC code of 4911. All firms with the same 4-digit SIC code of 4911, incorporated in Canada and headquartered in the US in COMPUSTAT, will be selected as the control sample to match this specific firm in the treated group.

Bloomberg collects GHG emissions data directly from companies' annual or sustainability reports when available. Similar to another widely-used dataset, S&P Global Trucost, Bloomberg employs model-based estimates to approximate the emissions in cases where such data is not disclosed. GHG emissions are categorized into three scopes based on their source and the level of control exerted by the reporting entity. Scope 1 emissions are direct emissions originating from sources owned or controlled by the organization, such as combustion in boilers. Scope 2 emissions are indirect and result from the generation of purchased electricity, heat, or steam consumed by the organization. These emissions occur at facilities owned by another entity but are a consequence of the organization's energy consumption. Scope 3 emissions are also indirect but encompass a broader range of activities, including supply chain emissions, employee commuting, and waste disposal. For the purpose of this study, the focus will be on the total of Scope 1 and Scope 2 emissions, because these emissions are directly influenced by the organization's operational choices and energy consumption, making them most relevant for assessing the impact of green bond issuance.

Scope 2 GHG emissions are further divided into Market-based and Location-based measures. Market-based Scope 2 emissions are calculated based on the specific electricity organizations purchase. Location-based Scope 2 emissions use grid-average emission factors to calculate emissions based on the average carbon intensity of the regional or national electricity grid where energy consumption occurs. Since Market-based Scope 2 data is more relevant and offers better coverage, this analysis will primarily report results using Scope 1 + Market-based Scope 2 data. However, the results remain consistent when using Scope 1 + Location-based Scope 2 data.

I first visualize the evolution of GHG intensity in Figure 5. GHG intensity is defined as GHG emissions per unit of assets. This metric is expressed in thousands of tonnes of GHG emissions per million dollars of assets. The graph is indexed to the timing of each firm's inaugural issuance of green bonds.

The sample spans from -4 to +4 years relative to the inaugural issuance, and two crucial cutoff dates are highlighted in the graph: refinancing backdate and allocation deadline. They are 24 months before the issuance and 24 months after the issuance, respectively, marking when firms can begin allocating funds and when they must complete the allocation. To be included in the constant component group, the firm must have data 3 years before and 2 years after the inaugural issuance. This smaller, constant component dataset includes around 100 issuers, primarily those that entered the market in its early stages. There is a noticeable decrease in GHG emissions from two years before issuance, continuing after issuance, during the financing period, and extending beyond the allocation period. A comparable pattern is also shown in the entire sample. The key distinction between the whole sample and the subsample is the observed increase in GHG emissions after issuance. Comparing this with the constant sample suggests that data availability drives this difference: firms that persist until year +3 are those that entered the market earlier and appear to be more GHG-intensive.

The observed patterns are statistically robust, presented in Table A4. Since the commencement of the eligible allocation period, GHG intensity has a significant decline of roughly 10%, a trend that continued for 24 months post-issuance, with a further reduction of 25%. The regression analysis highlights substantial emission cutbacks both from the onset of the allocation and after the allocation. It also exhibits a considerable reduction when comparing emissions before and after issuance. There is a significant decrease between the refinancing and financing periods. This could indicate the positive impact stemming from green investment financing after the issuance, i.e., financing new green projects.

It is noticeable that the GHG reduction trends begin four years before the issuance. One possible explanation is that managers are more likely to identify green projects initially and then issue green bonds if compliance uncertainty is high, particularly at the market's early stages [18], to avoid the risk of greenwashing allegations. Greenwashing can jeopardize the credibility of green assets, deter SRI investment, and subject firms to reputational costs. Consequently, some managers may choose not to issue green bonds unless they possess clear and verifiable proof of green projects or improved environmental performance. This is supported by the argument that firms use green bonds to signal their efficiency in addressing the energy transition in Daubanes et al. (2021). Another possibility is that there is a common trend in the economy to shift to energy efficiency. In other words, the trend should be observed even in the absence of green bond issuance.

Given these complexities, isolating the marginal impact of green bonds while accounting for alternative explanations becomes challenging. To address this, I employ Difference-in-Differences (DID) with Two-Way Fixed Effects (TWFE), Event-Study DID, and Instrumented DID approaches in the subsequent subsections.

6.2 TWFE DID and Event-study DID

The central research question concerns whether the reduction in carbon emissions can be attributed to the issuance of green bonds. This inquiry addresses the "additionality" issue, which posits whether these green initiatives would have remained unfunded in the absence of green bonds. Answering this question presents challenges, such as accounting for omitted variables and addressing selection bias. Numerous factors can influence both green bond issuance and GHG reduction, including the firm-level stakeholder's public awareness of climate risk, which can affect firms' and investors' actions. Firms may reduce emissions in response to increased awareness of climate risks, while investors might encourage firms to issue green bonds. Selection bias arises when treatment and control groups exhibit

[18] Anecdotal evidence are the controversies surrounding Repsol and Engie, as discussed in Section 2.

systematic differences, resulting in biased estimates of the treatment effect. Firms opting to issue green bonds might inherently differ from those that do not in various ways, including a stronger commitment to environmental sustainability, operating in industry sectors with different levels of exposure to GHG emissions, having different sizes or financial resources, and experiencing distinct regulatory environments or pressures. These inherent differences create challenges in determining whether GHG emission reductions result from green bond issuance or the unique characteristics of the firms that choose to issue them.

I first employ a DID approach with TWFE to examine the changes in GHG emissions between the treatment and control groups, both before and after the issuance of green bonds. Since GHG intensity is strictly positive, logarithmic transformation is employed to account for the non-normality. As suggested by Cohn et al. (2022), Poisson regression is also used for the TWFE DID. The regression analysis includes controls for firm size, leverage, and a dummy variable for divestiture. The inclusion of a divestiture variable is supported by the findings of Duchin et al. (2022), which shows that firms may strategically sell off GHG-intensive plants to appear more environmentally friendly. However, it's worth noting that divestiture is less of a concern for green bond issuers compared to sustainability-linked bonds for two reasons: first, divestiture of GHG-intensive plants is more prevalent in the oil and gas industry, and second, green bonds do not have a specific GHG reduction target and less incentive to do so. In untabulated tests, there is no evidence to suggest that firms are more inclined to issue green bonds following a divestiture and firms do not appear to be more likely to engage in divestitures after issuing a green bond. The DID with TWFE approach accounts for time-invariant differences between firms and year-specific factors that each firm faces. To further refine the analysis, I also employ an event-study DID approach with the same set of controls to explore heterogeneous effects, utilizing the method provided by de Chaisemartin and D'Haultfœuille (2020).

Figure 7 illustrates the dynamic treatment effect following a firm's inaugural green bond issuance. Specifically, the treatment effect is estimated relative to the GHG intensity at T=0, the calendar year corresponding to the first issuance. The event-study DID serves dual purposes: it elucidates the dynamic effects and acts as a statistical test for the parallel trends assumption. Figure 6 reveals relatively parallel trends in GHG intensity between the control and treated groups prior to the first issuance, particularly given that the majority of issuers entered the market post-2020. However, it is less clear given the staggered nature of the treatment. It is further validated by the placebo effects for years -3 to -1 and a joint nullity test with a p-value of 0.386, as indicated in Table 11.

The DID with TWFE results are presented in the first two columns of Table 12, using both logarithm transformation and Poisson regressions. Across all tests, an 8% reduction in GHG emissions is observed post-issuance compared to control firms, effectively rejecting the null hypothesis of **Hypothesis.2a**. This suggests that green bond issuers do indeed reduce their emissions post-issuance, and this reduction is not caused by divestiture.

6.3 Instrumented DID

It's important to note that the decision to issue a green bond is not random. Although the green bond market is available to all firms with capital market access, control firms are, on average, significantly smaller, less GHG-intensive, and emit fewer total GHGs. The earlier results do not directly address *Hypothesis 2b*, as the issuers may be firms that would have undertaken green projects regardless of green bond issuance. To further enhance causal inference and address *Hypothesis 2b*, I employ a two-stage least squares (2SLS) estimation, utilizing an instrumental variable (IV): greenium, which is used to instrument the decision to issue a company's first green bond. Greenium is the yield spread between green bonds and their conventional counterparts. By applying the instrument in the first stage of the 2SLS estimation, I can predict firms' propensity to issue green bonds. In the second stage, the impact of green bond issuance on GHG emissions is estimated based on the predicted propensity from the first stage. This approach helps address concerns regarding omitted variable bias and selection issues.

Greenium serves as a robust Instrumental Variable (IV) for this analysis. It satisfies two key criteria for a valid IV: it captures the financial incentives for firms to issue green bonds, and it is unlikely to directly relate to firm-level carbon emissions, except through its influence on green bond issuance. A more negative greenium indicates greater financial incentives for companies to issue green bonds, potentially allowing them to raise funds at lower costs than conventional bonds.

Greenium reflects the pricing difference between green and conventional bonds, primarily driven by investor preferences and market conditions. It is unlikely that greenium would directly affect a firm's GHG intensity without going through the green bond issuance channel, thus satisfying the exclusion restriction. This is further substantiated by Figure 8 and Figure 9, which show that estimated market-level greenium does not trend with estimated public awareness of climate risk. Neither of them trends with the GHG intensity of the sample in Figure 6.

Conceptually, the awareness of climate risk, especially of firm stockholders, could indeed lead to green investment by firms. That is also why public awareness of climate risk fails as a valid instrument for this task. However, greenium is hardly driven by public awareness only. It is determined by the market's demand and supply of green bonds, which can be influenced by a variety of factors in both the financial and real markets. Awareness of climate risk could lead to an increase in the supply of green bonds and also an increase in demand for green bonds. The exact direction is unknown, ex-ante. Besides, the supply of green bonds is determined both by the finance market and the real market in a general equilibrium framework. The need for green financial assets and green real assets funded by green projects do not always meet each other. The frictions between markets lead to the fluctuation of greenium. This effect is more pronounced in the supranational bonds market, where supranational banks issue green bonds based on countries' funding needs for green projects. While it is impossible to rule out concerns about the exclusion restriction entirely, greenium serves as a robust and justifiable IV for this study. To capture the firm-level benefit of issuing a green bond, the interaction of market-level greenium and firm size is also used as an IV.

6.3.1 Greenium Estimation

Similar to Larcker and Watts (2020), Flammer (2021), greenium is calculated as the yield at issuance difference between a green bond and its conventional counterpart, using the nearest neighbor matching method that employs Mahalanobis distance. Bond data is sourced from Dealogic to avoid the survivorship bias in Bloomberg, as Bloomberg removes bond pricing data after bonds become inactive. The data is further cross-validated with Bloomberg to ensure accuracy. The sample is meticulously selected to include only fixed-coupon bonds that lack callable or puttable features. The sample excludes dual-currency bonds, bonds with coupons linked to any index, and bonds with step-up or floating coupons. Bonds subject to floor or cap conditions, Payment-In-Kind (PIK) bonds, hybrid futures and bonds with unique features, such as Islamic bonds, are also omitted. Additionally, labeled bonds such as sustainability-linked or social bonds are not part of the sample. This stringent selection criteria ensures a homogeneous set of bonds.

The matched pairs are carefully selected to meet specific criteria: they must be issued by the same issuer, denominated in the same currency, carry the same credit rating, be priced in the same month, have the same seniority within the firm, and belong to the same market category (public vs. private, domestic vs. global). Pairs are then matched using nearest-neighbor matching with Mahalanobis distance, on years to maturity, bond coupon, and issue size within a 0.2 caliper. The difference in years to maturity must be less than two years. This rigorous matching process results in 110 matched pairs of bonds across all markets.

A significant portion of the matched samples comes from the supranational markets, a major source of green bond suppliers. Supranational bonds are often issued in response to countries' funding needs, reducing the likelihood that greenium influences both the corporate and supranational green bond markets simultaneously while still providing a benchmark for corporations entering the green bond market. The greenium is then aggregated at the annual level.

Due to data limitations, there are some caveats to consider in estimating greenium. While the stringent matching method addresses some concerns, it cannot fully account for the heterogeneous effects of different features on greenium, such as years to maturity and issue size. However, the primary objective of this task is not to measure the size or direction of greenium. Rather, the focus is on the relative variation in greenium, which captures the relative financial benefits of issuing green bonds. The estimated aggregate level of greenium falls within a range of -10 bps to 15 bps, which is consistent with existing literature. Larcker and Watts (2020) show average zero greenium in the municipal green bond market. In contrast, Caramichael and Rapp (2022) reports a -8 bps, Baker et al. (2018) notes -6 bps, and Wang and Wu (2022) identifies -5 bps. On the other hand, Zerbib (2019) shows a positive 2 bps greenium. Figure 8 depicts the temporal trend of the estimated greenium. Unlike GHG emissions, greenium does not show a clear downward trend, nor does it exhibit an upward trend similar to that of public awareness.

6.3.2 Awareness of Climate Risk Estimation

The estimation of public awareness regarding climate risk is derived from the Climate Change in the American Mind: National Survey Data on Public Opinion (2008-2022), a dataset provided by the Yale Program on Climate Change Communication (YPCCC). This dataset is comprised of 26 survey cycles, each designed to be representative of U.S. adults aged 18 and older, and spans from 2008 to 2022. It includes a range of variables, such as public attitudes and beliefs about global warming, risk perceptions, preferences for policy interventions, and behaviors related to information acquisition. Individual responses are averaged across these categories and then aggregated over the survey waves using the provided weighting scheme. A higher value indicates a greater level of concern about climate risk. A discernible upward trend in this concern is evident, as depicted in Figure 9. It's worth noting that public awareness may vary by region and industry. Therefore, this estimate primarily captures temporal variations in public concern about climate risk.

6.3.3 Results

The estimated greenium or the pricing benefit for issuing green bonds is a benchmark faced by all firms. The green bond market is open to all firms, and a firm's participation in this market is also shaped by its own characteristics, including its accessibility to the capital market. If we were to solely utilize the greenium as the instrumental variable (IV), we would be unable to incorporate year-fixed effects to exclude time-specific factors. Therefore, I also use an interaction term of greenium and firm size as the IV.

I incorporate the instrumental variable in a difference-in-differences setting with panel data to account for the fact that the impact of the green project may persist once in operation. For similar reasons, the post-period is defined as the period following the issuance of the first green bond. The data is across multiple regions worldwide and various time periods, which helps control for unobserved time-invariant factors that could cause reverse causalities, such as investor preferences or regulatory environments. Controlling for factors such as firm size, leverage, dummy for divestiture, and public awareness does not change the point estimate.

The specification is defined as follows: First stage:

$$\begin{aligned} \text{PT}_{i,t} =& \text{Greenium}_t \times \text{size}_{i,t} + \gamma_2 \text{leverage}_{i,t} + \gamma_3 \text{size}_{i,t} + \gamma_4 \text{Divestiture}_{i,t} \\ &+ \gamma_5 \text{Public Awareness}_i + \text{Firm fixed Effects} + \text{Year fixed Effects} + \epsilon_{i,t} \end{aligned} \tag{3}$$

Second stage:

$$\begin{aligned} \text{Log(GHG Intensity)}_{i,t} =& \alpha + \lambda_0 \hat{\text{PT}}_{i,t} + \lambda_1 \text{leverage}_{i,t} + \lambda_2 \text{size}_{i,t} + \lambda_3 \text{Divestiture} \\ &+ \lambda_4 \text{Public Awareness}_i + +\text{Firm fixed Effects} + \text{Year fixed Effects} + \epsilon_{i,t} \end{aligned} \tag{4}$$

Where PT is an indicator variable for the period after the first green bond issuance, which is always 0 for the control group. The divestiture variable is a dummy variable, with 1 for the year that a firm has divestiture activity and 0 otherwise. The size variable represents the natural logarithm of total assets. The GHG variable includes both scope 1 and market-based scope 2 emissions. The dependent variable, GHG Intensity, represents GHG emissions deflated by the firm's total assets. Standard errors are robust to heteroskedasticity and clustered at the firm level to mitigate the impact of unobserved firm-specific factors and account for correlated error terms across observations within each firm. Standard errors are clustered at the firm level.

The regression results are reported in Table 12. Columns 1-2 in Table 12 are for the TWFE DID regression. Column 1 uses the log-transformed model, while column 2 uses a Poisson regression. Columns 3-6 represent the first and second stages in 2SLS regressions. The IV passes the weak instrument test, with Kleibergen-Paap rk Wald F statistics greater than 10. As anticipated, a significant negative correlation exists between green bond issuance and the greenium. Firms facing a more negative greenium are more likely to enter the market. Larger-sized and less-leveraged firms are more inclined to issue green bonds under the same greenium. This pattern continues when I employ the interaction of greenium and firm size as the IV in columns 5-6.

When using greenium as an instrumental variable (IV) without incorporating a year-fixed effect, the data suggests an 81% reduction in GHG intensity due to the issuance of green bonds. However, this significant effect becomes statistically insignificant when an interaction term is used as the IV and a year-fixed effect is added. This suggests that the earlier results may be driven by temporal changes, indicating that aggregate GHG intensity tends to decrease when market-level greenium gets more negative.

It's worth noting that these results could be limited by the short time series available for analysis. Additionally, this is not direct evidence of the impact of green bonds on GHG emissions, as the use of the funds is not explicitly tied to GHG performance. More robust inferences could be drawn with more heterogeneous greenium data or more frequent GHG or greenium data as the market expands and data quality improves. As it stands, the more robust analysis does not support the conclusion that green bonds lead to the funding of green projects with incremental GHG reduction that would otherwise go unfunded. However, firms issuing green bonds do show improved GHG intensity when compared to those that do not issue such bonds.

6.4 ESG Scores

This study further investigates the impact of green bond issuance on ESG scores using a difference-in-differences regression approach. Data for this analysis is sourced from the S&P Global ESG dataset, beginning in 2013 when the dataset was first introduced. The control sample consists of all firms covered by this dataset that never issued green bonds.

Testing the impact of green bond issuance on environmental performance using ESG scores incorporates a dual hypothesis: whether the ESG score genuinely reflects environmental performance and whether green bonds truly enhance environmental performance. If green bonds genuinely contribute to improved environmental performance and the ESG score genuinely reflects environmental performance, a correlation should exist between green bond issuance and enhancements in ESG scores or at least enhancements in Environmental (E) scores. On the other hand, observing this relationship would indicate either a legitimate use of green bond proceeds towards environmental improvements or an attempt at greenwashing that successfully inflates ESG scores. A lack of correlation between green bond issuance and ESG scores could either indicate an ineffective greenwashing attempt that doesn't fool the ESG score providers or a potential deficiency in the ESG score's ability to capture genuine environmental improvements accurately. Meanwhile, if GHG reductions are observed without corresponding improvements in ESG scores, this would raise questions about the completeness and accuracy of ESG disclosure practices, especially when mandatory disclosure requirements on GHG emissions exist for large corporations worldwide.

To interpret these regression results, it is essential to distinguish between raw and modeled ESG scores. Raw ESG scores represent unadjusted values of a company's environmental, social, and governance performance, calculated using a set of predetermined indicators that can vary among ESG rating agencies. Conversely, modeled ESG scores are derived from raw scores through adjustments and transformations that account for industry-specific factors, company size, regional differences, and other relevant aspects. Modeled ESG scores aim to provide a more accurate and comparable assessment of a company's ESG performance, considering each organization's unique context and challenges.

In line with the methodology proposed by Cohn et al. (2022), this study employs Poisson regressions with firm and year fixed-effects, given that ESG scores are non-negative count variables. This approach assumes that the dependent variable follows a Poisson distribution conditional on covariates. Poisson regressions yield estimates with valid semi-elasticity interpretations, so the results should be interpreted as the percentage change in ESG scores following the issuance of green bonds. Table 13 presents the results of difference-in-differences regression analyses, assessing the impact of green bond issuance on various ESG dimensions, including overall ESG, environmental, social, and governance factors, as well as specific sub-categories within the environmental dimension. While there is no significant change in total ESG scores, a significant decrease of 0.057% in raw Environmental scores is observed. The modeled ESG scores suggest a decline in Environmental Reporting and Product Stewardship. In contrast, raw ESG scores indicate a significant increase in Environmental Policy & Management Systems, Electricity Generation, and Biodiversity and significant decreases in Environmental Reporting, Operational Eco-Efficiency, and Climate Strategy.

Interpreting these results is challenging due to S&P's continual adjustments to the weights and components of the Corporate Sustainability Assessment (CSA), which contribute to the E, S, and G scores, as evidenced by the number of observations in each regression. These components also vary across different industries. The dependent variables shown in Table 13 are those with sufficient data points for the green bond issuers. Specifically, in 2023, Emissions were first introduced as a new component in the CSA by S&P. As a result, we do not observe an increase in the E score, despite that I show a decrease in GHG emissions after green bond issuance. However, when comparing CSAs under the Environmental category between raw and modeled scores, it appears that some changes may be due to changes in the industry methodology, as these disappear after industry adjustment. The consistent decrease in Environmental Reporting in both raw and modeled ESG is puzzling, as firms typically associate the issuance of green bonds with improved reporting.

It's important to note the results presented in this section should not be interpreted as causal inferences. The decision to issue green bonds is often an endogenous voluntary choice made by companies rather than an exogenous, random event. Therefore, there may be underlying factors affecting both the decision to issue green bonds and the observed ESG scores, potentially confounding the interpretation of the observed relationships.

Furthermore, there is no universally accepted ESG score. The practices vary across different ESG providers. Bhagat and Yoon (2022) finds a marginal increase in E scores using MSCI ESG scores but no overall ESG change, while Flammer (2021) finds an increase in the ASSET4 ESG score after green bond issuance. Nevertheless, this study concludes that issuing green bonds does not substantially improve ESG scores, as provided by S&P.

Testing the impact of green bond issuance on environmental performance using ESG scores embeds a joint hypothesis: whether the ESG score accurately reflects environmental performance and whether green bonds genuinely enhance environmental performance. Given the current data, reaching a definitive conclusion is challenging. It's possible that green bond issuance does indeed improve environmental performance, but the ESG score fails to capture this improvement. Alternatively, it could be that green bond issuance does not actually enhance environmental performance.

6.5 Green Innovation

Green innovation refers to a diverse array of intellectual properties designed to reduce ecological damage and optimize the utilization of natural resources. The interest in exploring the impact of green bond issuance on green innovation arises from three main reasons. First, green innovation is a potential avenue for firms to utilize green bond proceeds, effectively translating financial resources into tangible environmental benefits. Second, compared to other types of green investments, green innovation can have a more enduring impact by fostering the development of sustainable technologies and practices that can continue to generate positive environmental outcomes over time. Third, it's important to note that cash-based measurements for R&D are unavailable, requiring additional analysis to gain a more comprehensive understanding of how proceeds are allocated towards green innovation.

The patent data utilized in this study is sourced from the United States Patent and Trademark Office (USPTO). Green patent classifications are obtained from the World Intellectual Property Organization (WIPO) IPC Green Inventory which is recognized by the United Nations Framework Convention on Climate Change (UNFCCC), comprises a range of Environmentally Sound Technologies (ESTs) across various categories, including Alternative Energy Production, Energy Conservation, Nuclear Power Generation, Transportation, Waste Management, Agriculture Forestry, and Administrative, Regulatory, and Design Aspects. Patents classified as Design Aspects are excluded from the analysis, as they do not directly contribute to generating a positive environmental impact.

A notable limitation of the data arises from the time required for patents to be granted, as they are not incorporated into the dataset until the grant is issued. As depicted in Figure 10a, there is a disproportionate decrease in the number of patents in 2010 and 2021. Consequently, the data is confined to the period between 2011 and 2020, leading to a substantial reduction in the sample size, which contains 74 firms.

Figure 10b displays a histogram comparing the proportions of green patents before and after a firm's first green bond issuance. I investigate the influence of the first green bond issuance, mainly because its impact can be more precisely evaluated. In contrast, for subsequent issuance, it becomes challenging to disentangle their effects from those of earlier issuance. A t-test reveals no significant difference in the distribution of green patents.

The sample in this study includes all green bond issuers who have ever applied for patents at the United States Patent and Trademark Office (USPTO). If two issuers collaborate on a patent, it will be counted for both issuers. For each issuer, the percentage of green innovations out of all patents is calculated. I employ a simple specification in Equation 5 to test the change in green innovations filed before and after the green bond issuance.

The linear model can be expressed as follows:

$$\text{Green Patent Percent}_{i,t} = \beta_1 \text{After}_{i,t} + \beta_3 \text{Size}_{i,t} + \beta_3 \text{Tobin's Q}_{i,t} + \text{Firm Fixed Effects} \quad (5)$$

where Green Patent Percent$_i$ represents the proportion of green patents over the total number of patents filed by a firm within a calendar year; After$_i$ is a dummy variable, which equals 1 if it is after the issuance (or refinancing backdate) and zero otherwise.

Given the constrained nature of the dependent variable *Green Patent Percent*$_{i,t}$ within the range

[0, 1], I utilize fractional probit regressions and incorporate controls for the average of time-variant variables, i.e. $\overline{Size}_{i,t}$ and $\overline{Tobin's\ Q}_{i,t}$, as recommended by Papke and Wooldridge (2008). This approach helps address the issue of biased fixed effects when the number of entities (N) surpasses the number of time periods (T). Table 14 presents the results. Additionally, I report the average partial effects (APEs), which are the partial effects averaged across the population. Moreover, I convey the findings through the log transformation of the green patent percentage. However, this alteration eliminates observations that are zero.

Column 1 reports the regression results based on the refinancing backdate, which is two years prior to the issuance of green bonds, while Column 2 displays the regression results based on the green bond issuance date. The analysis indicates no significant differences in the portion of green innovations filed before and after the issuance, regardless of whether the issuance date or the refinancing start date is used as the cutoff. Columns 3 and 4 present the results using logarithm transformation. In summary, I observed no substantial impact on green innovation, which could be attributed to the limitations inherent in the data.

This result could indicate one of two possibilities: either the R&D efforts are not particularly targeted towards eco-friendly initiatives, or these investments require a more extended time to yield noticeable outcomes, underscoring the need for a lengthier observation period to discern their impact. The lack of impacts in green innovation also resonates with the findings of Cohen et al. (2023), which demonstrates that oil, gas, and energy-producing firms — often not prominent in the green bond market or typically excluded by ESG investors — are pivotal innovators in the U.S. green patent landscape."

7 Discussion

In the absence of a stringent legal framework, one may question what ensures that green bond issuance comes with a reduction in GHG intensity and prevents issuers from misusing the capital. Firstly, non-profit self-regulated organizations such as the Green Bond Principles and the Climate Bonds Initiative have established requirements for the framework, allocation reporting, and third-party verification for the allocation of green bonds. Secondly, if firms violate the green requirements ("green default"), they face not only reputational costs but also the risk of being excluded from the green bond market, as evidenced by anecdotal examples. In this section, I aim to discuss one of the monitoring mechanisms exerted by investors and shed light on this by studying the stock market reaction following green bond issuance announcements.

Furthermore, the impact of green bond issuance on ESG scores and green innovation will be explored in subsequent subsections. This will provide a more comprehensive view of how green financing mechanisms like green bonds can influence a firm's overall sustainability performance and commitment to eco-friendly innovation.

7.1 Stock market reactions to the issuance of green bonds

I investigate stock return reactions following green bond issuance announcements using the event-study methodology in this subsection. Flammer (2021) reports a positive announcement return, while Bhagat and Yoon (2022) find insignificant stock price reactions. Distinct from other literature that examines stock return reactions, the sample in this study excludes financial issuers and tap issuances. This exclusion is due to financial issuers' unique regulatory environment, business models, and indirect environmental impact, as well as the fact that the issuance size of tap issues is generally not comparable to the original issue size.

Three critical dates are associated with bond issuance: the announcement, pricing, and issue dates. Although not required, some lead book-runners may choose to announce the bond mandate[19] to disclose the new issue's details, including green aspects, to institutional investors. This mandate appoints banks as lead managers to underwrite the bond, and the mandated bank may choose to announce this appointment, which is referred to as the announcement date. This is typically followed by a three-to-five-day roadshow. The bond offering's price and amount are determined on the pricing date. For bonds without a mandate announcement, known as drive-by deals, the announcement date aligns with the pricing date. The offering is settled on the settlement date or issue date, during which investors exchange cash or assets with the issuers for bond certificates. Consequently, the issue date is used in the use of proceeds analysis. In most cases, the announcement date is either identical to the pricing date or precedes it by less than 14 days. However, in extreme and rare cases in my sample, the announcement date may occur six months prior to the pricing date. Since the announcement date is when information about the bond issuance is publicly disclosed, it is used as the event date.

Stock return data is sourced from Datastream, while stock index data comes from Bloomberg. Abnormal returns for each issuance are calculated using the market model. The most representative stock index for each country is selected as the market index and displayed in Table A1 in the Appendix. Equation 6 is estimated using daily returns from 220 trading days prior to the event until 21 days before the event date.

[19] Mandate is a letter of instruction and authorization given to a lead manager by the issuer of a bond, typically including basic bond terms

$$R_{i,t} = \alpha_i + \beta_i \times R_{m,t} + \epsilon_{i,t} \tag{6}$$

Where $R_{i,t}$ is the stock return of issuer i on day t, $R_{m,t}$ is the return of the market index on day t. The abnormal return is calculated as $AR_{i,t} = R_{i,t} - \hat{R}_{i,t}$. The cumulative abnormal return for each time interval is calculated by adding up the abnormal returns within each time frame, and the average values are reported for $[-1, 1]$, $[-2, 2]$, $[-5, 5]$, and [-5,10].

After merging with the Datastream, the sample includes 371 issuers with 823 issuances. Among them, 742 are original (non-tap) issues, and 113 issuers issue more than once. Table 15 reports the event study results. The sample is separated into all issuance, first-time green issuance, and non-first-time issuance. Only the [-1,1] CAR for non-first issuance is significant at the 5% level with CARs of 0.32%. Stock responds positively to an experienced green issuer (but not to its first issuance). Contrary to Flammer (2021), which reports a 0.49% CAR for the event window [-5,10], no significance is observed for longer windows in this analysis. The disparity in findings compared to Flammer (2021) could be attributed primarily to differences in sample selection. Specifically, Flammer (2021) utilizes a sample that extends until the end of 2018, whereas my study includes data up until the end of 2021. Additionally, I have deliberately excluded issuers from financial institutions.

Existing literature[20] indicates that the stock market generally does not exhibit significant responses to conventional bond issuance, especially straight bond issuance. Positive reactions after conventional bond issuance could happen if there is increased leverage instead of cash holdings following the bond issuance as suggested by the free cashflow theory by Jensen (1986), for example, stock repurchase (Dann (1981)) or dividend payments (Lang and Litzenberger (1989)).

Green bond issuance presents several effects. First, it increases leverage, which may enhance the firm's value. Second, green bond proceeds are allocated gradually and at the manager's discretion for green projects. These funds cannot be utilized for dividend payments or stock repurchases unless they refinance existing green projects, potentially exacerbating agency problems. Third, green bonds are linked to a greenium, which can lower the cost of capital. Lastly, the issuance of green bonds signals a company's commitment to environmental sustainability, which may be perceived positively by investors (Flammer (2013), Klassen and McLaughlin (1996), Krüger (2015)). These four effects could potentially offset one another, resulting in no significant overall impact on stock prices. The first two effects cancel out, as shown in conventional bonds. If greenium is the main driver, we should see positive CAR for all green bond issuance. This evidence of positive stock reaction after

[20] Bayless and Chaplinsky (1996), Shyam-Sunder (1991), Hansen and Crutchley (1990), Eckbo (1985), Mikkelson and Partch (1986),Jung et al. (1996), and Howton et al. (1998)

the second issuance implies that the fourth effect plays a role and, specifically, commitment to green actions is more credible when a firm issues green bonds multiple times. This rejects *Hypothesis 3* and suggests that green bonds serve as a signaling tool to indicate a firm's commitment to environmental objectives, and only the second and subsequent issuances are credible. This, in return, confirms the mechanism of a repeated game in enforcing compliance.

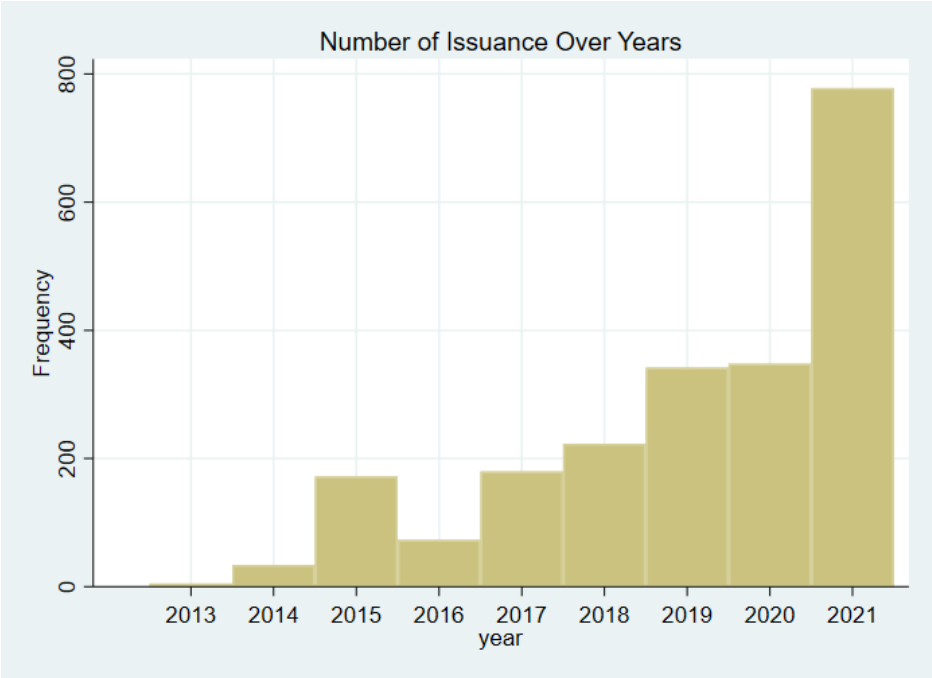
8 Conclusion

This paper reveals a distinct motivation for issuing green bonds compared to conventional bonds. Proceeds from green bonds remain as cash for longer periods, largely owing to the time required to identify eligible projects. Contrary to the notion of fungibility, my results indicate that they neither lead to more new investments than conventional bonds nor are used in apparent green-washing. When combined with the results examining issuers with different characteristics and market reactions, it becomes evident that the repeated game serves as a market mechanism to enforce compliance. The time required to locate green projects contributes to the non-observability of new investments.

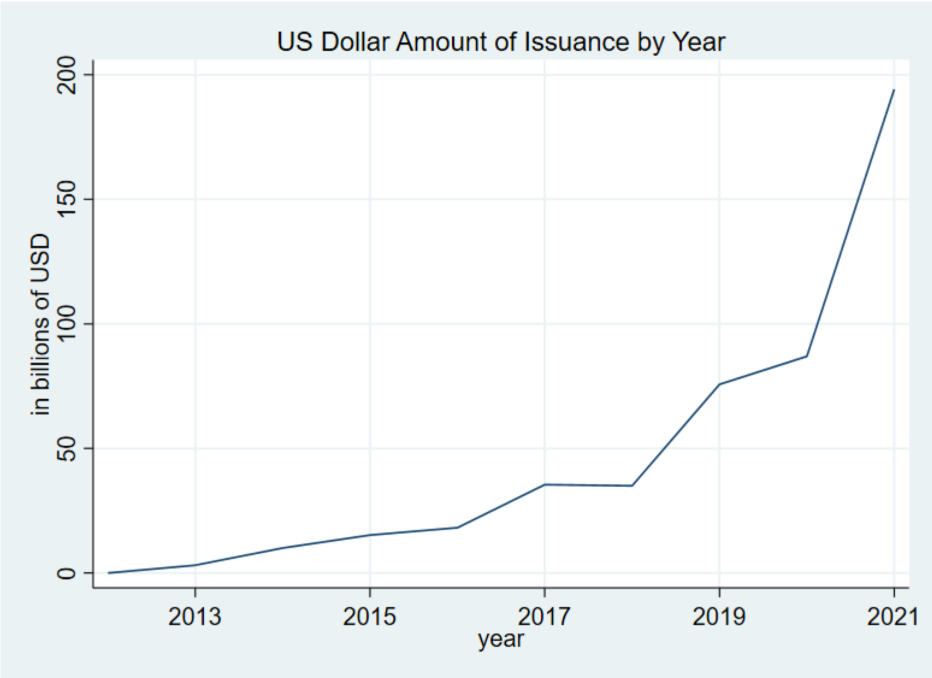
Concomitantly, firms issuing green bonds show improved environmental performance, particularly in the reduction of GHG intensity. However, this improvement appears not to stem from incremental green investments facilitated by green bonds but rather from issuers that would have pursued green initiatives regardless. Such firms take advantage of the lower cost of capital associated with green bonds to signal their commitment to sustainability, especially by reentering the market. Green bonds do provide funds to firms with green improvements. However, at this stage in the market's development, evidence for additionality or incremental green investments remains scarce. The current market landscape for green bonds may not sufficiently support players who could yield the highest marginal improvements due to evaluated information asymmetry, such as oil and gas companies, who are currently more involved in the "transition" labeled bonds market, such as sustainability-linked bonds. Furthermore, firms with green intentions but higher uncertainty in compliance may find the existing framework less accommodating. It highlights the need for green instruments with clearer regulation and enforcement mechanisms. Given that many environmental policies frequently target GHG emissions, the insights gained from this study may hold relevance for various stakeholders, including, but not limited to, policymakers, investors, and the public at large.

Nevertheless, it's imperative to note the limitations of this study, such as the emphasis on first-time issuances and data constraints. The greenium could be better estimated and used to assess the causal impact as the market matures and more data becomes available. As the green bond market evolves, the conclusions drawn here may also evolve, particularly as the benefits of issuing green bonds become more evident and as more marginal players enter the market. Therefore, while the study contributes to ongoing discussions on sustainable finance, it also opens avenues for future research to further refine our understanding of the real impact of green bonds.

9 Figures and Tables

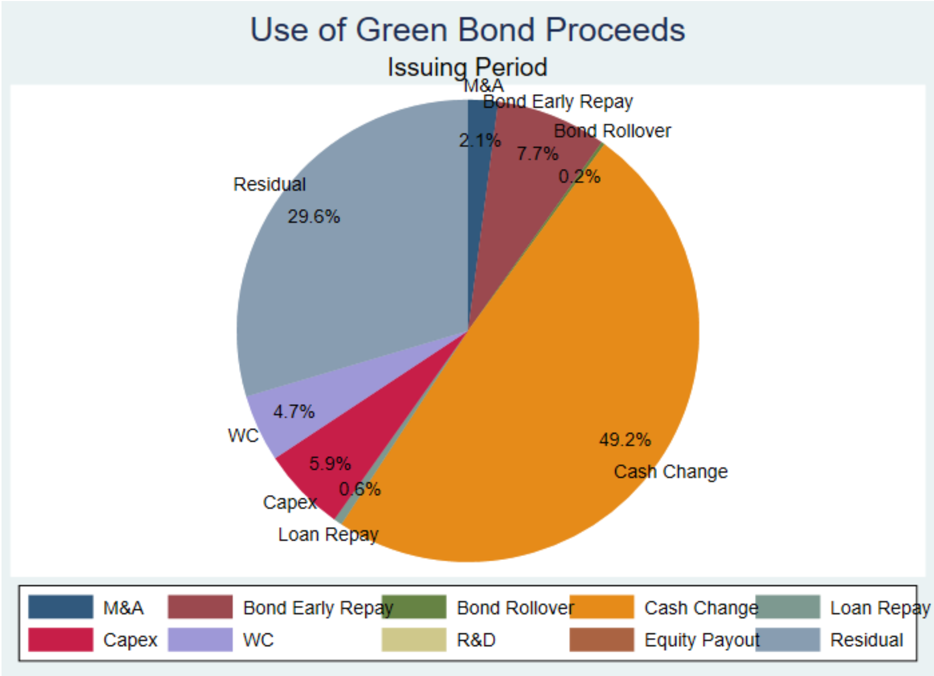


(a) Number of Issuances by Year

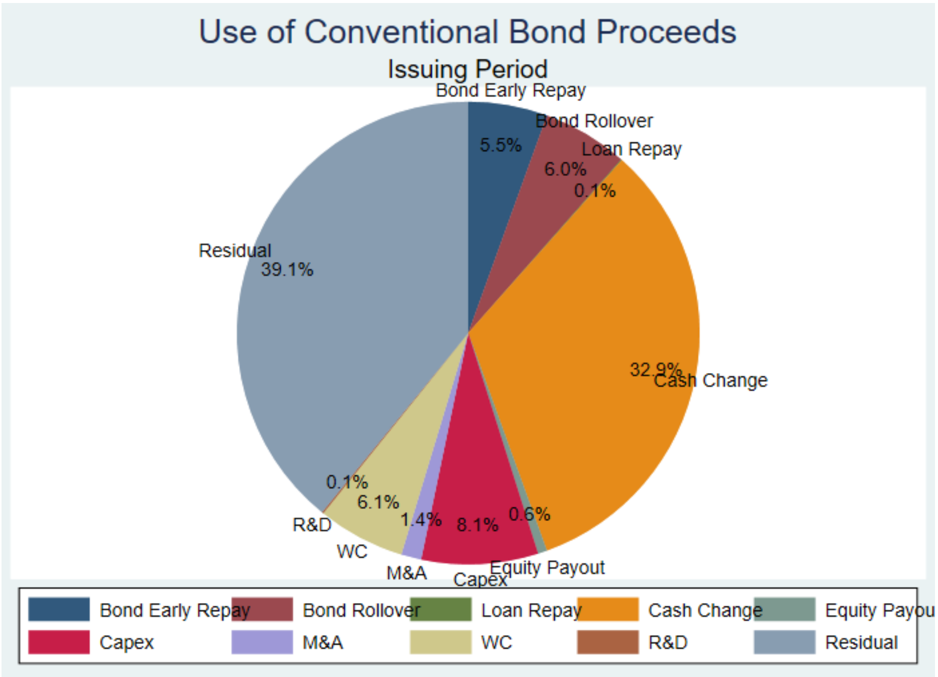


(b) Issuance Amount in Millions of US Dollars

Figure 1: Green Bonds Market over Years Panel A displays the annual count of corporate green bond issuances from 2013 through 2021. Panel B exhibits the issuance volume of corporate green bonds in millions of USD for the years 2013 to 2021.

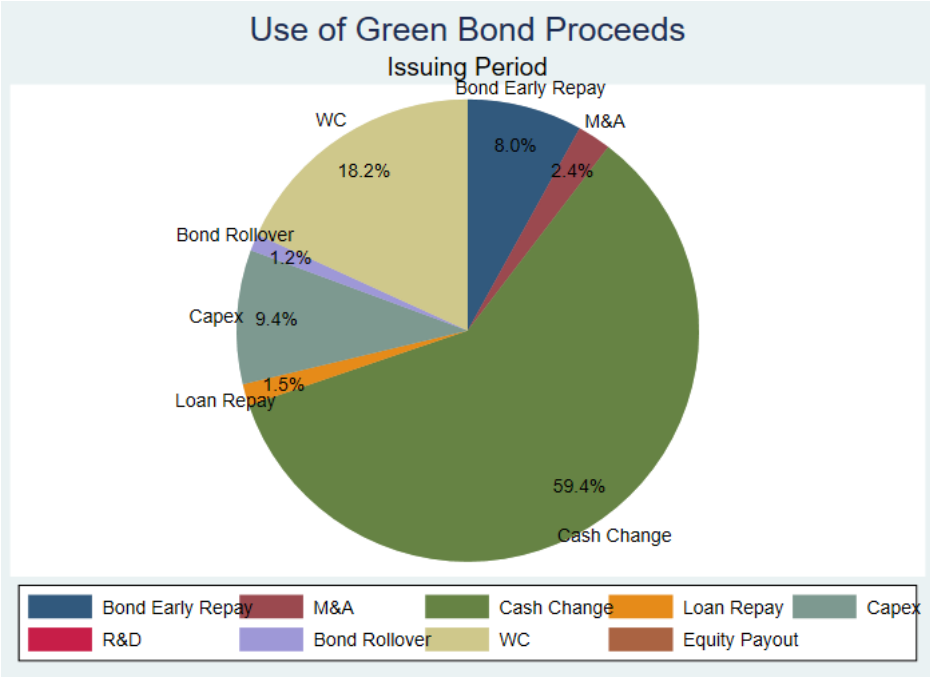


(a) Use of Green Bond Proceeds

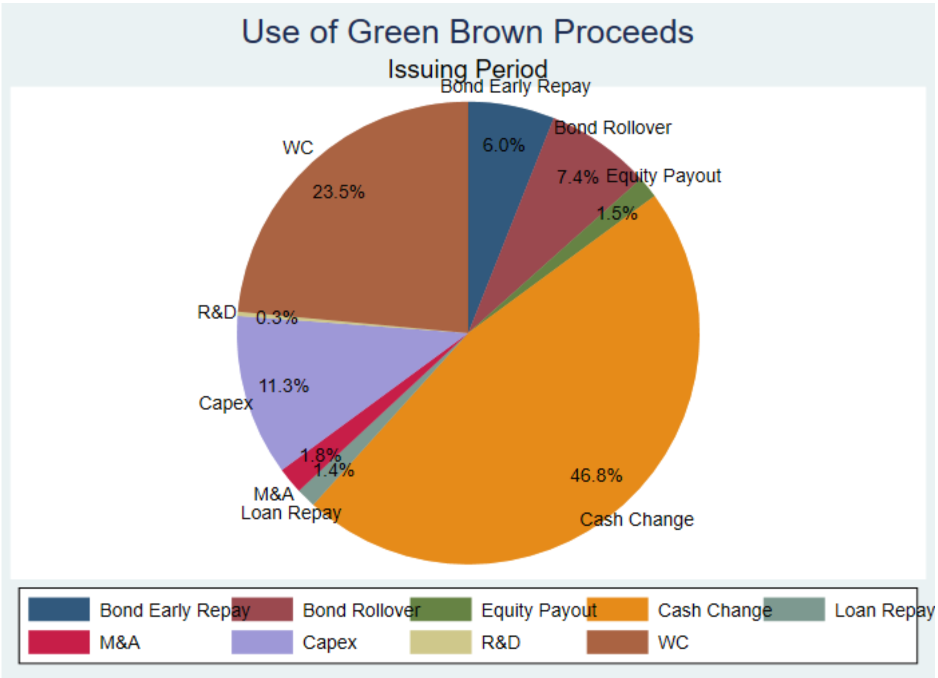


(b) Use of Conventional Bond Proceeds

Figure 2: Use of Proceeds This pie chart illustrates the allocation of each $1 of green/conventional bond proceeds within the sample from 2014 to 2021.



(a) Use of Green Bond Proceeds: Regressions with Constraints



(b) Use of Conventional Bond Proceeds: Regressions with Constraints

Figure 3: Use of Proceeds This pie chart illustrates the allocation of each $1 of green/conventional bond proceeds within the sample from 2014 to 2021 when using seemingly unrelated regressions and constrain β_1/β_2 adding up to 1.

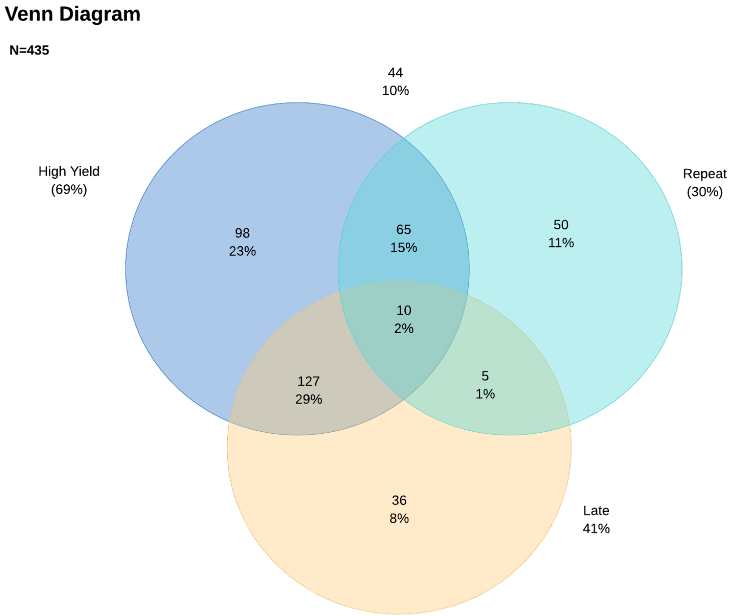
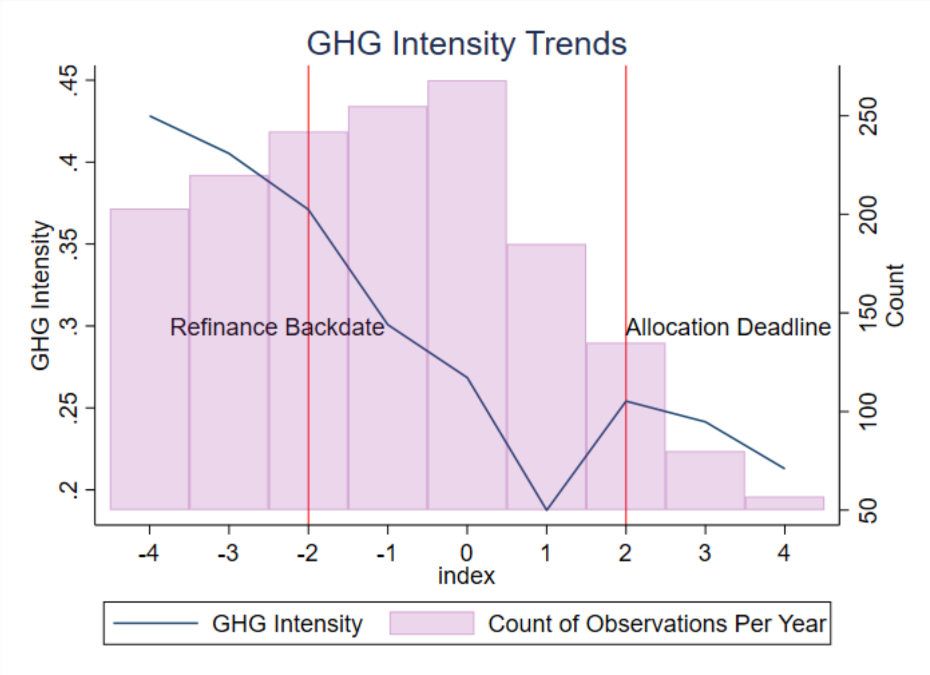
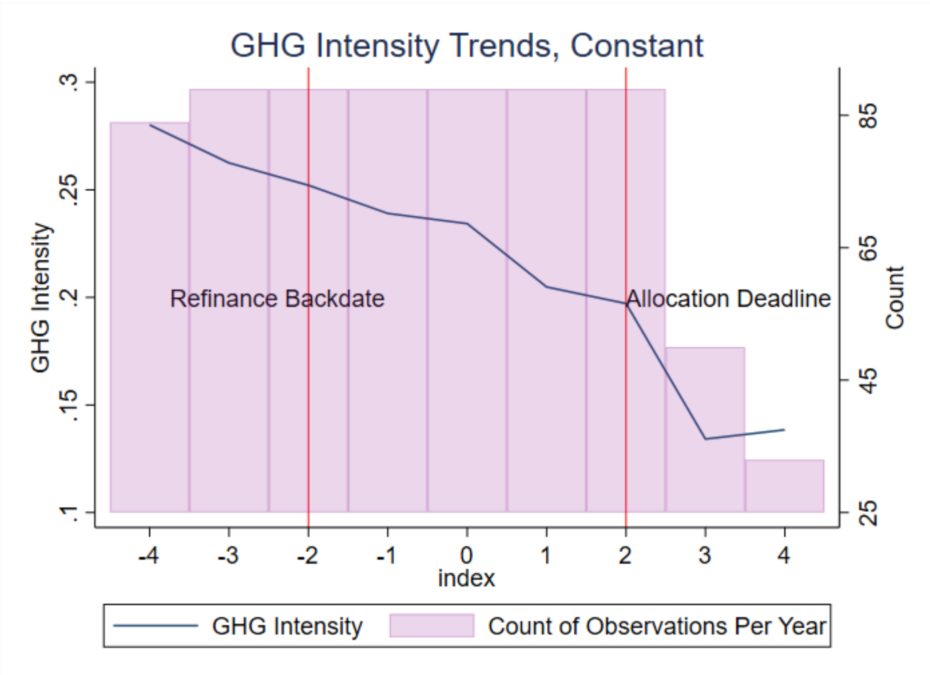


Figure 4: Green Bond Issuers: Venn Diagram This figure showcases a Venn Diagram illustrating issuer characteristics within the sample timeframe of 2014 to 2021. Late issuers refer to those who issued their initial green bond following December 31, 2020. For the entire sample period, a firm's high-yield green proceeds ratio to total green proceeds is determined. Issuers with a ratio exceeding 0.5 are categorized as high-yield issuers. Additionally, repeat issuers are defined as those who have issued green bonds across multiple periods (half-year intervals) during the sample.



(a) GHG Intensity, Whole Sample



(b) GHG Intensity, Constant Sample

Figure 5: This graph illustrates the GHG intensity trajectory, defined as greenhouse gas emissions normalized by a firm's total assets. Figure A encompasses the entire sample, whereas Figure B is restricted to a constant sample—comprising firms with data available from three years prior to two years after their initial green bond issuance. The timeline spans from four years before to four years after a firm's first green bond issuance. Serving as a temporal anchor, the index is aligned with the timing of each firm's inaugural green bond issuance. A pink bar chart within the graph indicates the number of observations along this index, while a blue line represents the aggregate level of emissions. Two key dates are highlighted: the Refinance Backdate, which marks the earliest point at which a firm can refinance its green projects, and the Allocation Date, the deadline by which a firm must complete its allocations.

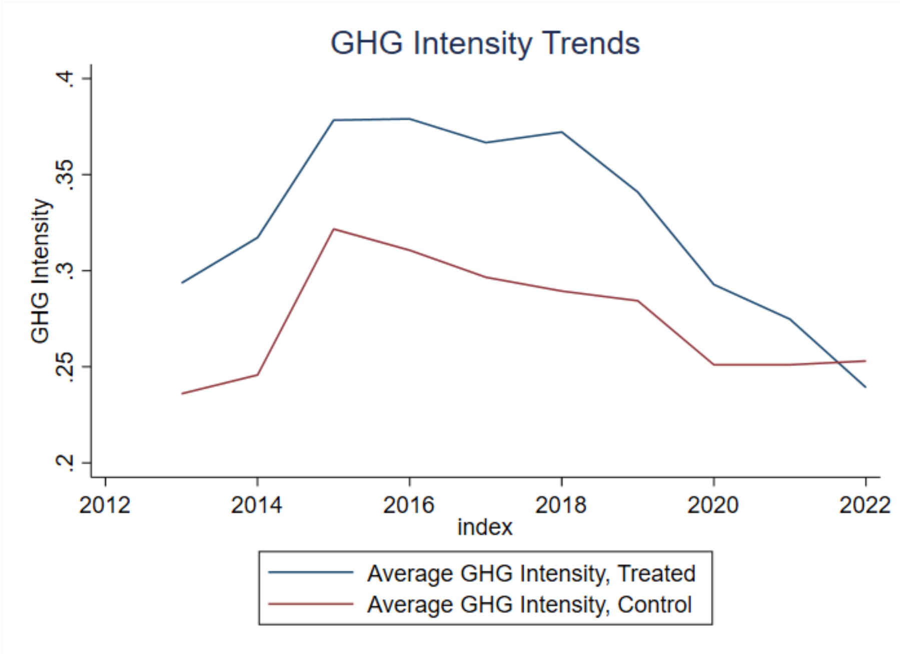


Figure 6: GHG time trend

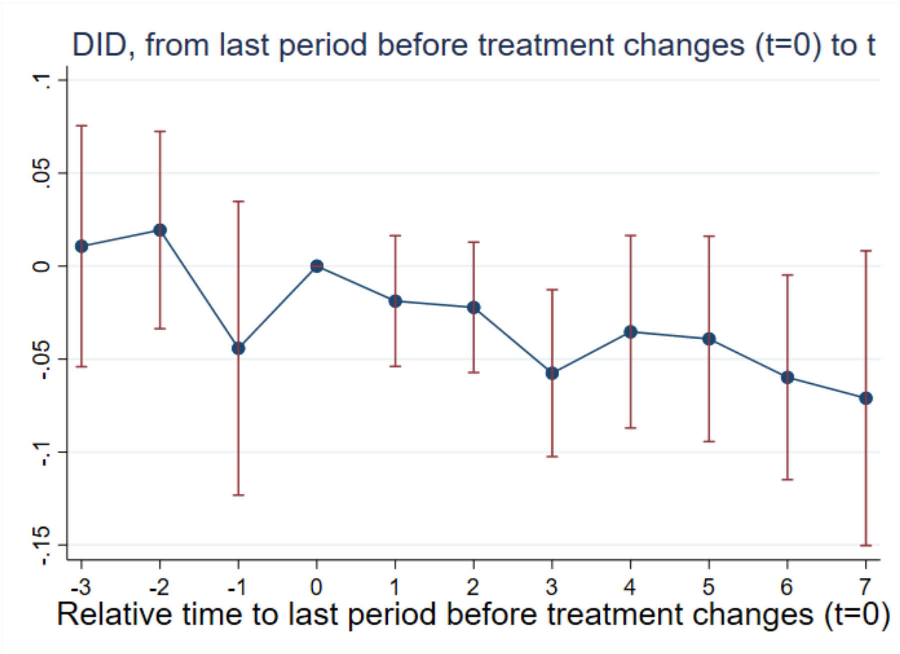


Figure 7: This graph visualizes the heterogeneous effects using a stacked DID approach. Time zero represents the year in which a firm issues its inaugural green bond. All changes are measured relative to the GHG intensity level at time zero. The graph displays the treatment effects annually, extending up to year 7. Additionally, it presents the placebo effects for up to three years prior to issuance.

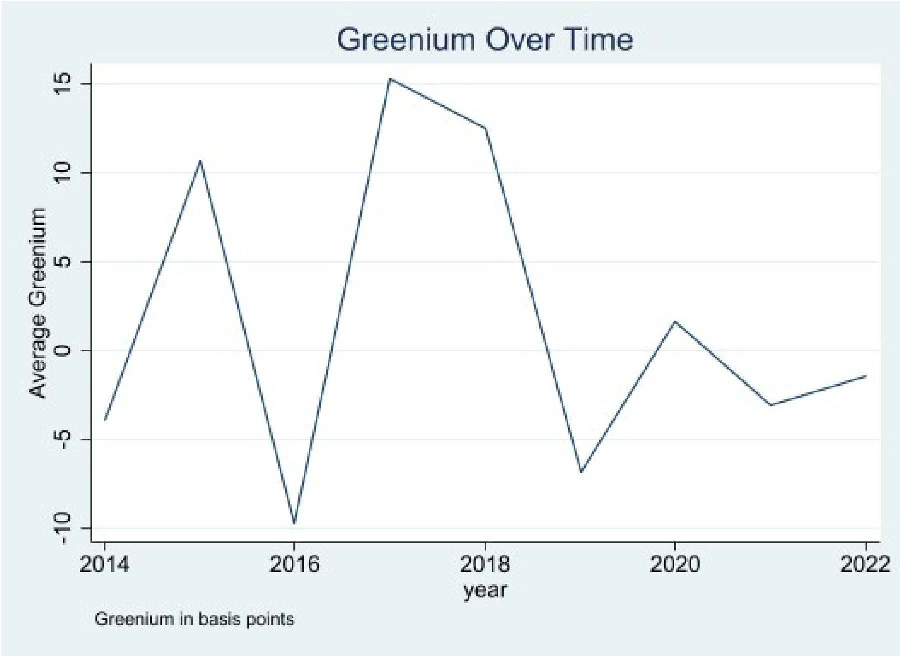


Figure 8: This graph depicts the temporal trend of the estimated greenium.

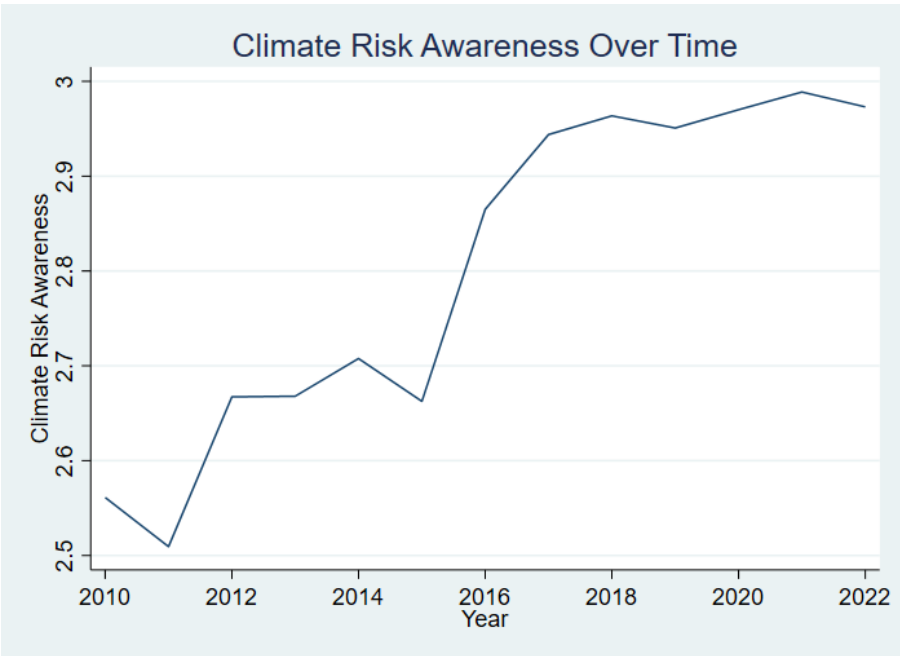
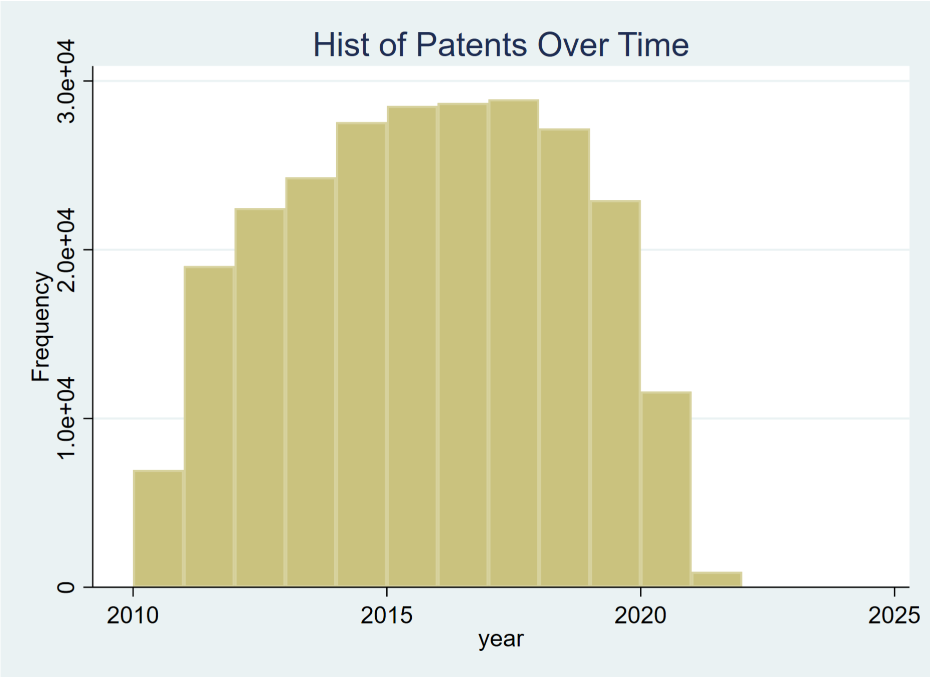
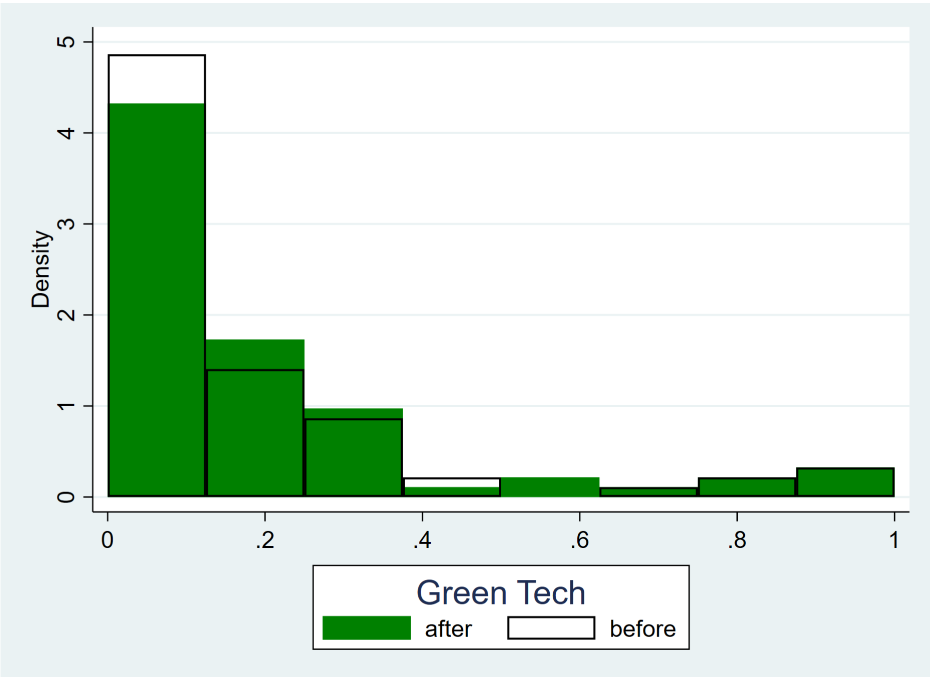


Figure 9: This graph depicts the temporal trend of the awareness of climate risk.



(a) Histogram showing the distribution of patents by green bond issuers



(b) Histogram of green tech before vs after green bond issuance.

Figure 10: Figure A shows the progression of the number of patents by green bond issuers over time. Figure B presents a histogram comparing the relative proportions of firm-level green patents to total patents before and after the issuance of green bonds

Table 1. Green Bond Certifications

This table displays the distribution of Green Bond Certifications. The table is divided into three panels: Panel A focuses on Green Bond Reporting, Panel B on Green Bond Assurance Providers, and Panel C on the Green Bond Project Selection Process. The left section of the table represents all green bonds issued from 2013 to 2021, while the right section is exclusive to the sample used in this study. Data for this table are sourced from Bloomberg.

Panel A: Green Bond Reporting							
All Bonds	Freq.	Percent	Cum.	In Sample	Freq.	Percent	Cum.
N	85	3.95	3.95	N	37	3.05	3.05
N/A	271	12.6	16.56	N/A	181	14.9	17.94
Y	1,794	83.44	100	Y	997	82.06	100
Panel B: Green Bond Assurance Provider							
All Bonds	Freq.	Percent	Cum.	In Sample	Freq.	Percent	Cum.
N	328	15.26	15.26	N	242	19.92	19.92
N/A	160	7.44	22.7	N/A	65	5.35	25.27
Y	1,662	77.3	100	Y	908	74.73	100
Panel C: Green Bond Project Selection Process							
All Bonds	Freq.	Percent	Cum.	In Sample	Freq.	Percent	Cum.
N	61	2.84	2.84	N	27	2.22	2.22
N/A	264	12.28	15.12	N/A	179	14.73	16.95
Y	1,825	84.88	100	Y	1,009	83.05	100
Total	2,150	100		Total	1,215	100	

Note: N/A indicates data not available on Bloomberg.

Table 2. Sample Summary Statistics

This table presents the summary statistics for the variables used in the uses of proceeds analysis. Panel A exhibits the summary statistics pertaining to the sources of funds, with figures conditioned on the presence of these sources during a six-month fiscal period, in order to compare various sources of funding. Panel A includes both the dollar amount and the amount scaled by the total assets of the firm from the preceding period, to adjust for firm size. Panel B presents summary statistics for the use of proceeds spanning periods of half a year, one year, and one-and-a-half years denoted as T=1, T=2, and T=3, respectively. All variables in Panel B are firm-size adjusted.

	N	T	Mean	Median	Standard Deviation	Minimum	Maximum
Panel A: Source of funds							
Green Bond Proceeds	698		413.4	230.2	482.1	0.1541	3384.8
Green Bond Proceeds/Total Asset$_0$	695		0.0323	0.0231	0.0269	0.0002	0.0806
Conventional Bond Proceeds	1967		1271.5	338.9	11855.2	0.0097	500297.9
Conventional Bond Proceeds/Total Asset$_0$	1960		0.0353	0.0227	0.0340	0.0000	0.1333
Equity Offering Proceeds	421		569.4	204.5	1003.9	0.0026	10000
Equity Offering Proceeds/Total Asset$_0$	414		0.0572	0.0413	0.0457	0.0000	0.1234
Loan Proceeds	786		1280.3	2669.2	444.4	6.5147	26559.2
Loan Proceeds/Total Asset$_0$	783		0.0405	0.0290	0.0345	0.0003	0.1070
Fund from Operations	6342		922.3	218.3	2827.9	-9118.5	62744
Fund from Operations/Total Asset$_0$	6305		0.0314	0.0308	0.0390	-0.1020	0.1678
Total Asset	6436		25025.6	8929.2	50868.7	3.2606	613136.1
Panel B: Use of funds							
$\sum \Delta$ Cash/Total Asset$_0$	6277	1	0.0059	0.0009	0.0430	-0.1073	0.2124
	6246	2	0.0116	0.0024	0.0571	-0.1339	0.2980
	6193	3	0.0173	0.0035	0.0715	-0.1464	0.3722
$\sum \Delta$ WC/Total Asset$_0$	6090	1	0.0023	0.0009	0.0436	-0.1556	0.1877
	6046	2	0.0050	0.0010	0.0534	-0.1670	0.2460
	5982	3	0.0073	0.0020	0.0708	-0.2374	0.3203
$\sum$ Early Repay/Total Asset$_0$	6365	1	0.0021	0.0000	0.0087	0.0000	0.0546
	6306	2	0.0048	0.0000	0.0157	0.0000	0.0917
	6253	3	0.0075	0.0000	0.0223	0.0000	0.1303
$\sum$ Rollover Bond/Total Asset$_0$	6365	1	0.0071	0.0000	0.0156	0.0000	0.0781
	6306	2	0.0144	0.0000	0.0267	0.0000	0.1341
	6253	3	0.0217	0.0031	0.0377	0.0000	0.1946
$\sum$ Loan Repay/Total Asset$_0$	6365	1	0.0024	0.0000	0.0103	0.0000	0.0657
	6306	2	0.0058	0.0000	0.0189	0.0000	0.1109
	6253	3	0.0101	0.0000	0.0305	0.0000	0.1855
$\sum$ Capex/Total Asset$_0$	6291	1	0.0280	0.0204	0.0309	0.0000	0.1905
	6240	2	0.0587	0.0437	0.0633	0.0000	0.3918
	6168	3	0.0909	0.0673	0.0985	0.0000	0.6197
$\sum$ Dividend/Total Asset$_0$	6291	1	0.0083	0.0046	0.0110	0.0000	0.0623
	6240	2	0.0174	0.0121	0.0187	0.0000	0.1047
	6168	3	0.0269	0.0187	0.0289	0.0000	0.1675
$\sum$ MA/Total Asset$_0$	6365	1	0.0007	0.0000	0.0055	0.0000	0.0487
	6306	2	0.0024	0.0000	0.0141	0.0000	0.1113
	6253	3	0.0048	0.0000	0.0252	0.0000	0.1998
$\sum$ RD expense/Total Asset$_0$	6365	1	0.0024	0.0000	0.0058	0.0000	0.0326
	6306	2	0.0041	0.0000	0.0118	0.0000	0.0670
	6253	3	0.0062	0.0000	0.0177	0.0000	0.1016
$\sum$ Stock Repurchase/Total Asset$_0$	6333	1	0.0008	0.0000	0.0033	0.0000	0.0230
	6274	2	0.0018	0.0000	0.0065	0.0000	0.0445
	6221	3	0.0030	0.0000	0.0101	0.0000	0.0696
$\sum \Delta$TA/Total Asset$_0$	6292	1	0.0487	0.0263	0.1273	-0.1907	0.7210
	6262	2	0.1021	0.0545	0.2274	-0.2553	1.4000
	6210	3	0.1616	0.0880	0.3331	-0.3105	2.1111

Table 3. Issuer Geography by Incorporation

This table presents the geographic distribution of issuers in the analysis, arranged in descending order based on the frequency of issuance between 2013 and 2021.

Country Incorporation	Count of Issuers	Percentage	Cumulative Percentage
European Union	134	30.80	30.80
Japan	55	12.64	43.45
China	49	11.26	54.71
United States	36	8.28	62.99
South Korea	31	7.13	70.11
Cayman Islands	22	5.06	75.17
Hong Kong	11	2.53	77.70
Brazil	10	2.30	80.00
United Kingdom	10	2.30	82.30
Norway	10	2.30	84.60
Bermuda	9	2.07	86.67
Taiwan	9	2.07	88.74
Thailand	7	1.61	90.34
Canada	6	1.38	91.72
Switzerland	5	1.15	92.87
New Zealand	4	0.92	93.79
Chile	3	0.69	94.48
India	3	0.69	95.17
Malaysia	3	0.69	95.86
Mexico	3	0.69	96.55
Philippines	3	0.69	97.24
Singapore	2	0.46	97.70
Turkey	2	0.46	98.16
Australia	1	0.23	98.39
Colombia	1	0.23	98.62
Estonia	1	0.23	98.85
Indonesia	1	0.23	99.08
Jersey	1	0.23	99.31
Marshall Islands	1	0.23	99.54
Mauritius	1	0.23	99.77
Saudi Arabia	1	0.23	100.00
Total	435		

Table 4. European Issuers

This table presents the geographic distribution of European issuers in the analysis, arranged in descending order based on the frequency of issuance between 2013 and 2021.

Country Incorporation	Count of Issuers	Percentage	Cumulative Percentage
Sweden	42	31.34	31.34
Spain	15	42.54	11.19
Germany	14	52.99	10.45
France	12	61.94	8.96
Finland	8	67.91	5.97
Italy	8	73.88	5.97
Netherlands	6	78.36	4.48
Austria	5	82.09	3.73
Belgium	5	85.82	3.73
Denmark	3	88.06	2.24
Greece	3	90.30	2.24
Poland	3	92.54	2.24
Republic of Ireland	2	94.03	1.49
Lithuania	2	95.52	1.49
Luxembourg	2	97.01	1.49
Portugal	2	98.51	1.49
Hungary	1	99.25	0.75
Malta	1	100.00	0.75
Total	134		

Table 5. Issuer Industry

This table presents the industry distribution of issuers, representing the top 80%, in the analysis, arranged in descending order based on the frequency of issuance between 2013 and 2021, with industry specification according to GICS sub-industry classification.

GICS Sub-Industry	Count of Issuers	Percent	Cumulative Percent
Real Estate Operating Companie	46	10.6	10.6
Electric Utilities	44	10.2	20.8
Renewable Electricity	36	8.3	29.1
Real Estate Development	32	7.4	36.5
Independent Power Producers &	26	6.0	42.5
Construction & Engineering	21	4.8	47.3
Environmental & Facilities Ser	15	3.5	50.8
Diversified Real Estate Activi	11	2.5	53.3
Semiconductors	10	2.3	55.7
Multi-Utilities	9	2.1	57.7
Automobile Manufacturers	8	1.8	59.6
Industrial Machinery	8	1.8	61.4
Industrial Conglomerates	7	1.6	63.0
Oil & Gas Refining & Marketing	7	1.6	64.7
Packaged Foods & Meats	7	1.6	66.3
Railroads	7	1.6	67.9
Commodity Chemicals	6	1.4	69.3
Marine	6	1.4	70.7
Trucking	6	1.4	72.1
Water Utilities	6	1.4	73.4
Electrical Components & Equipm	5	1.2	74.6
Gas Utilities	5	1.2	75.8
Heavy Electrical Equipment	5	1.2	76.9
Integrated Telecommunication S	5	1.2	78.1
Auto Parts & Equipment	4	0.9	79.0
Construction Machinery & Heavy	4	0.9	79.9
Homebuilding	4	0.9	80.8

Table 6. Use of Proceeds Green vs Conventional

This table displays the estimate of β_1 and β_2 in Equation 1 pertaining to the use of the proceeds section. Panel A presents the results corresponding to the contemporaneous fiscal half-year during which the firm issues green bonds, while Panels B and C depict the cumulative usage over a one-year and one-and-a-half-year period, respectively. Additionally, each panel provides the T-test results for comparing the use of proceeds between green and conventional bonds. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Δ Cash	Δ WC	Early Bond Repay	Rollover Bond	Loan Repay	Capital Expenditures	M&A	Equity Payout	R&D Expense	Δ Total Asset
Green	**0.4918*** **	0.047	**0.0772*** **	0.0023	0.0059	**0.0589* **	**0.0209** **	-0.01	-0.0021	**1.2576*** **
P-Value	0.0000	0.3886	0.0000	0.8408	0.6475	0.0918	0.0166	0.3340	0.2186	0.0000
Conventional	**0.3292*** **	**0.0611** **	**0.0553*** **	**0.0597*** **	0.0006	**0.0814*** **	**0.0141** **	0.0064	0.0011	**0.9177*** **
P-Value	0.0000	0.0439	0.0000	0.0000	0.9311	0.0000	0.0274	0.3807	0.2957	0.0000
Diff	**0.1625** **	-0.0141	0.0219	**-0.0573*** **	0.0053	-0.0225	0.0069	-0.0164	-0.0032	**0.3399* **
P-Value	0.0326	0.8053	0.2322	0.0019	0.7379	0.5293	0.5244	0.1840	0.1040	0.0889
Observations	5721	5627	5746	5746	5746	5732	5746	5700	5746	5734
Panel B: Issuing Period and the following half-year										
Green	**0.3422*** **	0.0329	**0.0961*** **	0.0235	-0.004	**0.1409*** **	**0.037** **	-0.0039	-0.0016	**1.5168*** **
P-Value	0.0000	0.6410	0.0002	0.2511	0.8011	0.0025	0.0384	0.7552	0.7103	0.0000
Conventional	**0.1418*** **	**0.0819** **	**0.0487*** **	**0.0951*** **	0.0093	**0.1425*** **	**0.0365** **	**0.0186** **	**0.004** **	**0.9856*** **
P-Value	0.0015	0.0466	0.0002	0.0000	0.4365	0.0001	0.0263	0.0284	0.0471	0.0000
Diff	**0.2004** **	-0.0489	**0.0474* **	**-0.0715** **	-0.0133	-0.0016	0.0005	-0.0225	-0.0056	**0.5312* **
P-Value	0.0161	0.4932	0.0704	0.0178	0.5426	0.9712	0.9828	0.1465	0.2391	0.0796
Observations	5700	5593	5721	5721	5721	5696	5721	5664	5721	5714
Panel C: Issuing Period and the following year										
Green	**0.182** **	-0.0356	**0.0989*** **	**0.0596** **	0.0114	**0.1817*** **	**0.0708** **	-0.0038	0.004	**1.591*** **
P-Value	0.0159	0.7120	0.0012	0.0423	0.6406	0.0087	0.0198	0.8606	0.5543	0.0000
Conventional	**0.1185** **	**0.0965* **	**0.0404** **	**0.1313*** **	**0.0414* **	**0.1991*** **	**0.0947*** **	**0.0311*** **	**0.0065** **	**1.2672*** **
P-Value	0.0240	0.0600	0.0168	0.0000	0.0572	0.0010	0.0011	0.0048	0.0339	0.0000
Diff	0.0635	-0.1321	**0.0584* **	**-0.0717* **	-0.03	-0.0174	-0.0239	-0.035	-0.0024	0.3238
P-Value	0.5126	0.2219	0.0903	0.0866	0.3676	0.8114	0.5460	0.1665	0.7384	0.4267
Observations	5663	5546	5685	5685	5685	5639	5685	5607	5685	5678
Model	Linear									
Estimation method	Year and Firm Fixed Effects									

*** p< 0.01, ** p< 0.05, * p< 0.1

Table 7. Use of Proceeds, Regressions with Constraints

This table displays the estimate of β_1 and β_2 in Equation 1 pertaining to the use of the proceeds section using seemingly unrelated regressions, with constraints that β_1/β_2 adding up to 1. Year and firm fixed effects are included. all Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Δ Cash	Δ WC	Early Bond Repay	Rollover Bond	Loan Repay	Capital Expenditures	M&A	Equity Payout	R&D Expense
Green	**0.5969*** **	**0.1828*** **	**0.0808*** **	0.0119	0.0152	**0.0942*** **	**0.0237*** **	-0.0044	-0.001
P-Value	0.0000	0.0000	0.0000	0.3698	0.1429	0.0000	0.0001	0.6291	0.6064
Conventional	**0.4678*** **	**0.2352*** **	**0.0603*** **	**0.0737*** **	**0.0138** **	**0.1127*** **	**0.0185*** **	**0.015*** **	**0.0029** **
P-Value	0.0000	0.0000	0.0000	0.0000	0.0305	0.0000	0.0000	0.0076	0.0128
Diff	**0.1291*** **	-0.0524	**0.0205** **	**-0.0619*** **	0.0014	-0.0185	0.0052	**-0.0195* **	**-0.0039* **
P-Value	0.0023	0.1840	0.0355	0.0000	0.9046	0.4125	0.4573	0.0644	0.0748
Observations					5730				

*** p< 0.01, ** p< 0.05, * p< 0.1

Table 8. Repeat Issuers: Issuer Industry

This table presents the top 80% industry distribution of repeated issuers.

GICS Sub-Industry	Count of Issuers	Percent	Cumulative Percent
Renewable Electricity	23	17.83	17.83
Independent Power Producers &	14	10.85	28.68
Electric Utilities	13	10.08	38.76
Environmental & Facilities Ser	10	7.75	46.51
Real Estate Operating Companie	8	6.20	52.71
Construction & Engineering	7	5.43	58.14
Real Estate Development	6	4.65	62.79
Water Utilities	6	4.65	67.44
Heavy Electrical Equipment	4	3.10	70.54
Automobile Manufacturers	3	2.33	72.87
Integrated Telecommunication S	3	2.33	75.19
Paper Products	3	2.33	77.52
Diversified Real Estate Activi	2	1.55	79.07
Food Retail	2	1.55	80.62
Multi-Utilities	2	1.55	82.17
Oil & Gas Storage & Transporta	2	1.55	83.72

Table 9. Use of Green Proceeds: Firm Characteristics

This table displays the estimate of β_1 in Equation 2 pertaining to the use of the proceeds section. Panel A displays the results for the concurrent fiscal half-year during which the firm issues green bonds. Panels B and C show the cumulative usage over one year and one-and-a-half years, respectively. Repeat, High Yield, and Late are indicator variables that represent specific firm characteristics associated with green bond issuance. The Repeat variable is assigned a value of 1 if the firm issues more than one green bond, excluding cases where multiple tranches are issued at the same time or the bond is tapped. The High Yield variable is set to 1 if a firm issues over 50% of its green bonds as high yield, as rated by S&P, Fitch, and Moody's. Finally, the Late variable is given a value of 1 if a firm issued its first green bond after the end of 2020. Standard errors are clustered at the firm level. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Δ Cash	Δ WC	Early Bond Repay	Rollover Bond	Loan Repay	Capital Expenditures	M&A	Equity Payout	R&D Expense	Δ Total Asset
Late × *Green Fund*	0.1455	0.1488	**-0.087*** **	**-0.0643** **	0.0027	-0.0997	-0.0076	**0.0537***	0.0102	0.037
P-Value	0.3022	0.3135	0.0081	0.0182	0.9059	0.2794	0.6403	0.0868	0.1530	0.9246
Observations	5733	5639	5757	5757	5757	5744	5757	5712	5757	5746
High Yield × *Green Fund*	-0.0139	0.1304	-0.0043	-0.0024	**-0.1158*** **	0.034	-0.0066	-0.0246	0.0121	0.1765
P-Value	0.9055	0.1884	0.9106	0.9406	0.0040	0.7195	0.7236	0.3710	0.1172	0.5676
Observations	5733	5639	5757	5757	5757	5744	5757	5712	5757	5746
Repeat × *Green Fund*	**-0.2164***	-0.1649	**0.0911*** **	**0.0737** **	-0.0106	**0.1711***	0.013	-0.0009	0.0032	-0.1271
P-Value	0.0712	0.1163	0.0081	0.0210	0.6607	0.0684	0.4340	0.9643	0.5958	0.7166
Observations	5733	5639	5757	5757	5757	5744	5757	5712	5757	5746
Panel B: Firm Charatersitcs: From T to T+1										
Late × *Green Fund*	0.0643	0.0575	**-0.1742*** **	**-0.0799***	0.0103	-0.1183	0.021	**0.0794***	0.0242	-0.1558
P-Value	0.6899	0.7438	0.0005	0.0937	0.7632	0.5209	0.6198	0.0869	0.1118	0.7973
Observations	5713	5607	5733	5733	5733	5706	5733	5674	5733	5727
High Yield × *Green Fund*	0.0655	0.1459	0.003	0.0305	**-0.1124** **	0.0798	0.0261	**-0.0721***	0.0252	0.4292
P-Value	0.6236	0.2652	0.9665	0.5628	0.0438	0.6755	0.4372	0.0946	0.1250	0.4924
Observations	5713	5607	5733	5733	5733	5706	5733	5674	5733	5727
Repeat × *Green Fund*	-0.1454	**-0.2388***	**0.1605*** **	**0.1196** **	-0.0223	0.2696	0.0081	-0.0046	-0.0027	0.3991
P-Value	0.3165	0.0897	0.0066	0.0380	0.5324	0.1381	0.8200	0.8917	0.8363	0.5083
Observations	5713	5607	5733	5733	5733	5706	5733	5674	5733	5727
Model	Linear									
Estimation method	Year and Industry Fixed Effects									

*** p< 0.01, ** p< 0.05, * p< 0.1

Table 10. Use of Conventional Bond Proceeds: High Yield

This table displays the regression results pertaining to the use of conventional bonds by high-yield issuers as opposed to non-high-yield issuers. The standard errors are clustered at the firm level. The analysis employs two methods: linear regressions with year and industry fixed effects and pooled quasi-maximum likelihood estimations for variables that reside within the [0,1] interval. Panel A presents the results for the issuing period, while Panel B exhibits the results for both the issuance period and the subsequent half-year. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Δ Cash	Δ WC	Early Bond Repay	Rollover Bond	Loan Repay	Capital Expenditures	M&A	Equity Payout	R&D Expense	Δ Total Asset
Panel A: Issuing Period										
High Yield ×*Conventional Bond*	-0.0086	0.047	**-0.0772*** **	**0.1464*** **	-0.0261	-0.0487	**-0.0213***	0.0197	**-0.0188** **	-0.2367
P-Value	0.9044	0.3308	0.0011	0.0007	0.1375	0.6339	0.0769	0.2316	0.0243	0.3519
Model	Linear									
Estimation method	Year and Industry Fixed Effects									
High Yield ×*Conventional Bond*	0.0741	0.0947	**-0.0651*** **	0.0654	-0.038	-0.0552	**-0.0575** **	-0.0077	-0.0259	-0.7664
P-Value	0.3945	0.2679	0.0016	0.2251	0.2805	0.5421	0.0101	0.8903	0.2312	0.1652
Model	Linear		Fractional probit							Linear
Estimation method	Fixed Effects		Pooled QMLE							Fixed Effects
Panel B: Issuing Period and the following half-year										
High Yield ×*Conventional Bond*	-0.0086	0.047	**-0.0354** **	0.0441	-0.0175	0.0024	-0.0109	0.0142	-0.0082	-0.2367
P-Value	0.9044	0.3308	0.0042	0.1115	0.2825	0.9321	0.2395	0.3689	0.4133	0.3519
Model	Linear									
Estimation method	Year and Industry Fixed Effects									
High Yield ×*Conventional Bond*	0.0741	0.0947	**-0.122** **	**0.27*** **	-0.0438	-0.1569	**-0.0865** **	0.0182	**-0.0405** **	-0.7664
P-Value	0.3945	0.2679	0.0143	0.0009	0.2088	0.4580	0.0363	0.5846	0.0268	0.1652
Model	Linear		Fractional probit							Linear
Estimation method	Fixed Effects		Pooled QMLE							Fixed Effects

*** p< 0.01, ** p< 0.05, * p< 0.1

Table 11. DID Event-study Estimators

This table summarizes the dynamic treatment effects using a DID Event-study approach. All treatment effects are evaluated relative to the GHG intensity level at time zero, defined as the year of issuance. The placebo effects compare the outcome trajectories of switchers and their respective controls prior to the first change in switchers' treatment. Under the assumptions of parallel trends and no anticipation, the expected value of the placebo effects is zero. Both year and firm fixed effects are controlled for in the analysis. Standard errors are clustered at the firm level. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Estimate	SE	T-stat	P Value	N	Number of Switchers
Effect at T=1	-0.0188	0.0179	-1.0487	0.2943	3994	170
Effect at T=2	-0.0222	0.0179	-1.2428	0.2140	3149	109
Effect at T=3	-0.0576**	0.0229	-2.5151	0.0119	2444	63
Effect at T=4	-0.0353	0.0264	-1.3371	0.1812	1869	39
Effect at T=5	-0.0391	0.0282	-1.3894	0.1647	1386	23
Effect at T=6	-0.0598**	0.0281	-2.1317	0.0330	969	11
Effect at T=7	-0.071*	0.0404	-1.7572	0.0789	614	7
Average Total Effect	-0.0862**	0.0391	-2.2048	0.0275	4322	422
Placebo Year -1	-0.0442	0.0403	-1.0971	0.2726	3475	158
Placebo Year -2	0.0194	0.0271	0.7166	0.4736	2453	93
Placebo Year- 3	0.0107	0.0331	0.3229	0.7467	1759	51
Test of joint nullity of the placebos : p-value = .385						

Table 12. Greenhouse Emission: Instrumented Diff-in-Diff

This table presents the regression results assessing the causal impact of green bond issuance on greenhouse gas (GHG) emissions. Columns 1 and 2 report results from a difference-in-differences (diff-in-diff) regression analysis, employing log-linear and Poisson models, respectively. Columns 3 to 6 utilize an instrumental variables (IV) approach within a diff-in-diff framework. Either the greenium or the interaction between greenium and firm size serves as the instrumental variable for firms issuing their inaugural green bond. Columns 3 and 5 report the first-stage regression results, while Columns 4 and 6 present the second-stage regression findings. Firm and year-fixed effects are included. GHG Intensity is defined as the firm-level GHG emissions volume per million units of the firm's total assets. Controls include firm size, calculated as the logarithm of total assets, public awareness of climate risk, and a dummy variable for firm-level divestiture. Standard errors are robust to heteroskedasticity and are clustered at the firm level. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%

	(1)	(2)	(3) First-Stage	(4) Second-Stage	(5) First-Stage	(6) Second-Stage
	Log(GHG Intensity)	GHG Intensity	Post × *Treatment*	Log(GHG Intensity)	Post × *Treatment*	Log(GHG Intensity)
Greenium			-0.206***			
			(0.0282)			
Greenium × *Size*					-0.0573***	
					(0.016)	
Size	-0.484***	-0.650***	0.151***	-0.418***	0.0390	-0.416***
	(0.0601)	(0.0871)	(0.0266)	(0.0739)	(0.0276)	(0.0777)
Leverage	0.00114**	0.00203***	-0.000179	0.00101**	-0.000213	0.000991**
	(0.000454)	(0.000477)	(0.000161)	(0.000446)	(0.000161)	(0.000479)
Post × *Treatment*	**-0.0834***	**-0.105***		**-0.815****		**-0.771**
	(0.0491)	**(0.0581)**		**(0.292)**		**(0.687)**
Pucblic Awareness			0.476***	-0.0743	-2.033*	2.739
			(0.0481)	(0.173)	(1.214)	(2.689)
Divestiture	-0.0511**	-0.0367*	0.0125	0.0101	0.00873	0.00976
	(0.0207)	(0.0198)	(0.0119)	(0.0208)	(0.0115)	(0.0220)
Constant	1.538***	5.822***				
	(0.542)	(0.789)				
Observations	6,233	6,233	4,845	4,845	4,845	4,845
R-squared	0.956			-0.014		0.005
Kleibergen-Paap rk Wald F			53.536		12.786	
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	No	Yes	Yes
Method	Linear	Poisson	Linear	Linear	Linear	Linear

Robust standard errors in parentheses
*** p< 0.01, ** p< 0.05, * p< 0.1

Table 13. ESG Score

The table displays regression results for the effect of green bond issuance on ESG performance. It specifically scrutinizes the eight-year impact, extending from four years before to four years after the initial issuance. All firms in the S&P Trucost ESG database are included in the sample. Panel A presents the individual Environmental, Social, and Governance scores, as well as their ESG scores, while Panel B focuses on the scores within the Environmental Dimension. Both panels include raw and industry-adjusted modeled ESG scores. A staggered difference-in-differences analysis for a constant treatment effect is employed. The Treatment variable is assigned as 1 following the issuance of initial green bonds and 0 otherwise. The regressions utilize the Poisson model with year and firm fixed-effect. The standard deviation is clustered at the firm level.

Panel A: S&P Global ESG						
	Raw Score			Modelled		
	Treatment	Standard Error	Observations	Treatment	Standard Error	Observations
Environmental Dimension	**-0.0574****	(0.0274)	52,209	-0.00314	(0.0268)	44,166
Social Dimension	-0.0430	(0.0278)	56,352	-0.0260	(0.0232)	44,166
Economic Governance Dimension	0.0286	(0.0247)	57,077	0.00627	(0.0170)	44,166
S&P Global ESG Score	-0.00564	(0.0252)	57,072	0.00790	(0.0194)	44,166

Panel B: S&P Global CSA Criterion under Environmental Dimension						
	Raw Score			Modelled		
	Treatment	Standard Error	Observations	Treatment	Standard Error	Observations
Environmental Policy & Management Systems	**0.0556****	(0.0266)	46,990	0.00915	(0.0284)	40,225
Environmental Reporting	**-0.177*****	(0.0249)	42,151	**-0.188*****	(0.0506)	35,706
Operational Eco-Efficiency	**-0.199*****	(0.0353)	44,722	-0.00445	(0.0482)	44,097
Climate Strategy	**-0.0762****	(0.0364)	36,297	0.0344	(0.0253)	41,945
Water Related Risks	**-0.192****	(0.0868)	5,664	-0.0348	(0.0539)	8,284
Biodiversity	**0.289*****	(0.0892)	7,752	0.0284	(0.0535)	7,836
Product Stewardship	0.00921	(0.0641)	11,281	**-0.0880****	(0.0370)	11,239
Transmission & Distribution	0.131	(0.0988)	1,512	0.0627	(0.0696)	1,248
Electricity Generation	**0.133***	(0.0754)	1,541	0.0494	(0.0645)	1,122

Robust standard errors in parentheses
*** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$

Table 14. Green Innovation

This table presents the regression results of green bond issuance on the percentage of green patents filed by firms at the year-firm level. Fractional probit regressions are employed in Column 1 and Column 2 to estimate the population average effect. Column 1 presents the regression results based on the refinancing backdate, which is two years prior to the issuance of green bonds. Column 2 is based on the actual date of green bond issuance. Columns 3 and 4 report the regression using linear models with year and firm fixed effects, where the dependent variable is the logarithm of the percentage of patents. Robust standard errors and the average partial effects are reported. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	(1)	(2)	(3)	(4)
	Green Patent Percentage	Green Patent Percentage	log(Green Patent Percentage)	log(Green Patent Percentage)
Allocation period	0.0706		0.0833	0.0625
	(0.152)		(0.0924)	(0.0779)
Issuance		0.0661		
		(0.179)		
Size	0.151	0.159	0.128	0.134
	(0.129)	(0.127)	(0.108)	(0.105)
Tobin'Q	0.00582	0.00559	0.00656	0.00695
	(0.00513)	(0.00531)	(0.0141)	(0.0146)
$\overline{\text{Size}}$	-0.116	-0.125		
	(0.162)	(0.158)		
$\overline{\text{Tobin'Q}}$	-0.0109**	-0.0106**		
	(0.00449)	(0.00454)		
Constant	-1.219	-1.210	-3.273***	-3.340***
	(0.794)	(0.789)	(1.106)	(1.069)
Observations	674	674	526	526
R-squared			0.840	0.84
Average partial effects	0.0195092	0.018364		
Method	Pooled QMLE	Pooled QMLE	Linear with FE	Linear with FE

Standard errors in parentheses
*** p< 0.01, ** p< 0.05, * p< 0.1

Table 15. Stock Reaction to Green Bond Issuance

This table displays the event study results for the impact of green bond issuance announcements on the issuer's stock return. Panel A includes all announcements except for tapped bonds, Panel B focuses on first-time green bond issuances, and Panel C presents the results for subsequent issuances. Cumulative abnormal returns (CAR), standard errors, T-statistics, and P-values are reported for each panel. Standard errors are calculated using the J-1 method. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	CAR	Standard Error	T-stat	P-value
		Panel A: All		
$[0, 0]$	0.0806%	0.0700%	1.1512	0.2496
$[-1, 1]$	0.1360%	0.1221%	1.1145	0.2651
$[-2, 2]$	0.1502%	0.1584%	0.9487	0.3428
$[-3, 3]$	0.0937%	0.1885%	0.4969	0.6193
$[-4, 4]$	0.1520%	0.2162%	0.7033	0.4819
$[-5, 5]$	0.1857%	0.2406%	0.7720	0.4401
$[-5, 10]$	0.1428%	0.2940%	0.4856	0.6273
		Panel B: First-Time		
$[0, 0]$	0.0126%	0.1051%	0.1198	0.9046
$[-1, 1]$	-0.0545%	0.1831%	-0.2980	0.7657
$[-2, 2]$	0.1098%	0.2377%	0.4618	0.6442
$[-3, 3]$	0.0749%	0.2824%	0.2654	0.7907
$[-4, 4]$	0.1951%	0.3248%	0.6008	0.5479
$[-5, 5]$	0.1272%	0.3627%	0.3508	0.7257
$[-5, 10]$	0.3612%	0.4436%	0.8143	0.4155
		Panel C: Non-first		
$[0, 0]$	0.1456%	0.0930%	1.5663	0.1173
$[-1, 1]$	**0.3193%****	0.1624%	1.9660	0.0493
$[-2, 2]$	0.1889%	0.2104%	0.8976	0.3694
$[-3, 3]$	0.1117%	0.2511%	0.4450	0.6563
$[-4, 4]$	0.1110%	0.2870%	0.3867	0.6990
$[-5, 5]$	0.2407%	0.3185%	0.7559	0.4497
$[-5, 10]$	-0.0611%	0.3893%	-0.1570	0.8753

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

References

Aswani, J., & Rajgopal, S. (2022). Rethinking the Value and Emission Implications of Green Bonds. https://doi.org/10.2139/ssrn.4215882

Baker, M. P., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). Financing the Response to Climate Change: The Pricing and Ownership of U.S. Green Bonds. https://doi.org/10.2139/ssrn.3275327

Bayless, M., & Chaplinsky, S. (1996). Is There a Window of Opportunity for Seasoned Equity Issuance? [Publisher: [American Finance Association, Wiley]]. *The Journal of Finance*, *51*(1), 253–278. https://doi.org/10.2307/2329309

Bena, J., Ferreira, M. A., Matos, P., & Pires, P. (2017). Are foreign investors locusts? The long-term effects of foreign institutional ownership. *Journal of Financial Economics*, *126*(1), 122–146. https://doi.org/10.1016/j.jfineco.2017.07.005

Benincasa, E., Fu, J., Mishra, M., & Paranjape, A. (2022). Different Shades of Green: Estimating the Green Bond Premium using Natural Language Processing. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4198065

Bhagat, S., & Yoon, A. (2022). Corporate Green Bonds: Market Response and Corporate Response, 48.

Caramichael, J., & Rapp, A. C. (2022). The Green Corporate Bond Issuance Premium. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4194858

Cohen, L., Gurun, U. G., & Nguyen, Q. (2023). The ESG - Innovation Disconnect: Evidence from Green Patenting. https://doi.org/10.2139/ssrn.3718682

Cohn, J. B., Liu, Z., & Wardlaw, M. I. (2022). Count (and count-like) data in finance. *Journal of Financial Economics*, *146*(2), 529–551. https://doi.org/10.1016/j.jfineco.2022.08.004

D'Amico, S., Klausmann, J., & Pancost, N. A. (2023). The Benchmark Greenium. https://doi.org/10.2139/ssrn.4128109

Dann, L. Y. (1981). Common stock repurchases: An analysis of returns to bondholders and stockholders. *Journal of Financial Economics*, *9*(2), 113–138. https://doi.org/10.1016/0304-405X(81)90010-6

Daubanes, J. X., Mitali, S. F., & Rochet, J.-C. (2021). Why Do Firms Issue Green Bonds? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3996238

de Chaisemartin, C., & D'Haultfœuille, X. (2020). Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects [arXiv: 1803.08807]. *American Economic Review*, *110*(9), 2964–2996. https://doi.org/10.1257/aer.20181169

Du, K., Harford, J., & Shin, D. ((2022). Who Benefits from Sustainability-linked Loans? https://doi.org/10.2139/ssrn.4260717

Duchin, R., Gao, J., & Xu, Q. (2022). Sustainability or Greenwashing: Evidence from the Asset Market for Industrial Pollution. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4095885

Eckbo, B. E. (1985). Valuation Effects of Corporate Debt Offerings. Retrieved September 12, 2023, from https://papers.ssrn.com/abstract=1490081

Flammer, C. (2013). Corporate Social Responsibility and Shareholder Reaction: The Environmental Awareness of Investors [Publisher: Academy of Management]. *The Academy of Management Journal*, *56*(3), 758–781. Retrieved September 12, 2023, from https://www.jstor.org/stable/43589942

Flammer, C. (2021). Corporate green bonds [Publisher: Elsevier B.V.]. *Journal of Financial Economics*, (40). https://doi.org/10.1016/j.jfineco.2021.01.010

Hansen, R. S., & Crutchley, C. (1990). Corporate Earnings and Financings: An Empirical Analysis [Publisher: University of Chicago Press]. *The Journal of Business*, *63*(3), 347–371. Retrieved September 12, 2023, from https://www.jstor.org/stable/2353154

Howe, P. D., Mildenberger, M., Marlon, J. R., & Leiserowitz, A. (2015). Geographic variation in opinions on climate change at state and local scales in the USA [Number: 6 Publisher: Nature Publishing Group]. *Nature Climate Change*, *5*(6), 596–603. https://doi.org/10.1038/nclimate2583

Howton, S. D., Howton, S. W., & Perfect, S. B. (1998). The Market Reaction to Straight Debt Issues: The Effects of Free Cash Flow [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1475-6803.1998.tb00681.x]. *Journal of Financial Research*, *21*(2), 219–228. https://doi.org/10.1111/j.1475-6803.1998.tb00681.x

Huang, R., & Ritter, J. R. (2021). Corporate Cash Shortfalls and Financing Decisions (D. Denis, Ed.). *The Review of Financial Studies*, *34*(4), 1789–1833. https://doi.org/10.1093/rfs/hhaa099

Jensen, M. C. (1986). Agency costs of free cash flow, corporate finance, and takeovers. *The American Economic Review*, *76*, 11–16. Retrieved November 28, 2022, from https://www.jstor.org/stable/1818789

Jung, K., Kim, Y.-C., & Stulz, R. (1996). Timing, investment opportunities, managerial discretion, and the security issue decision. *Journal of Financial Economics*, *42*(2), 159–185. https://doi.org/10.1016/0304-405X(96)00881-1

Kapraun, J., Latino, C., Scheins, C., & Schlag, C. (2021). (In)-Credibly Green: Which Bonds Trade at a Green Bond Premium? https://doi.org/10.2139/ssrn.3347337

Kim, W., & Weisbach, M. S. (2008). Motivations for public equity offers: An international perspective. *Journal of Financial Economics*, 27.

Klassen, R. D., & McLaughlin, C. P. (1996). The Impact of Environmental Management on Firm Performance [Publisher: INFORMS]. *Management Science*, *42*(8), 1199–1214. Retrieved September 12, 2023, from https://www.jstor.org/stable/2634452

Kölbel, J. F., & Lambillon, A.-P. (2022). Who Pays for Sustainability? An Analysis of Sustainability-Linked Bonds. https://doi.org/10.2139/ssrn.4007629

Krüger, P. (2015). Corporate goodness and shareholder wealth. *Journal of Financial Economics*, *115*(2), 304–329. https://doi.org/10.1016/j.jfineco.2014.09.008

Lang, L. H. P., & Litzenberger, R. H. (1989). Dividend announcements: Cash flow signalling vs. free cash flow hypothesis? *Journal of Financial Economics*, *24*(1), 181–191. https://doi.org/10.1016/0304-405X(89)90077-9

Larcker, D. F., & Watts, E. M. (2020). Where's the greenium? *Journal of Accounting and Economics*, *69*(2), 101312. https://doi.org/10.1016/j.jacceco.2020.101312

Mikkelson, W. H., & Partch, M. M. (1986). Valuation effects of security offerings and the issuance process. *Journal of Financial Economics*, *15*(1), 31–60. https://doi.org/10.1016/0304-405X(86)90049-8

Myers, S. C., & Majluf, N. S. (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics*, *13*(2), 187–221. https://doi.org/10.1016/0304-405X(84)90023-0

Papke, L. E., & Wooldridge, J. M. (2008). Panel data methods for fractional response variables with an application to test pass rates. *Journal of Econometrics*, *145*(1), 121–133. https://doi.org/10.1016/j.jeconom.2008.05.009

Shyam-Sunder, L. (1991). The Stock Price Effect of Risky Versus Safe Debt [Publisher: Cambridge University Press]. *The Journal of Financial and Quantitative Analysis*, *26*(4), 549–558. https://doi.org/10.2307/2331411

Slimane, M. B., Mahtani, V., & Fonseca, D. D. (2020). Facts and Fantasies about the Green Bond Premium [Publisher: Unpublished]. https://doi.org/10.13140/RG.2.2.19600.84486

Spence, M. (1973). Job Market Signaling*. *The Quarterly Journal of Economics*, *87*(3), 355–374. https://doi.org/10.2307/1882010

Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds? *Journal of Corporate Finance*, *61*, 101427. https://doi.org/10.1016/j.jcorpfin.2018.12.001

Wang, L., & Wu, J. ((2022). Deciphering Greenium: The Role of Investor Demand. https://doi.org/10.2139/ssrn.4136605

Wooldridge, J. M. (2019). Correlated random effects models with unbalanced panels. *Journal of Econometrics*, *211*(1), 137–150. https://doi.org/10.1016/j.jeconom.2018.12.010

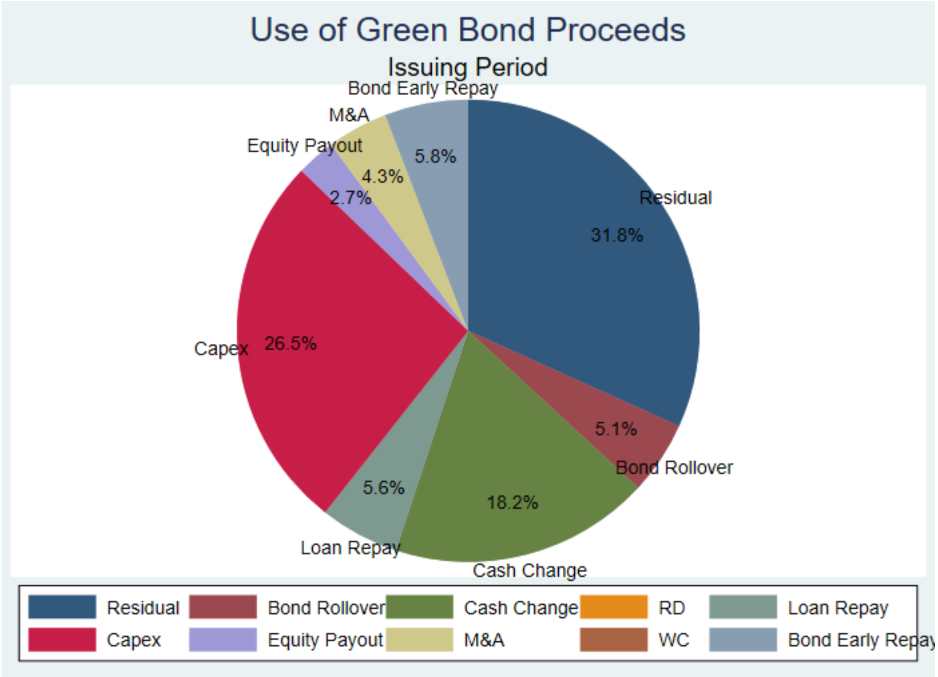
Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, *98*, 39–60. https://doi.org/10.1016/j.jbankfin.2018.10.012

10 Appendix

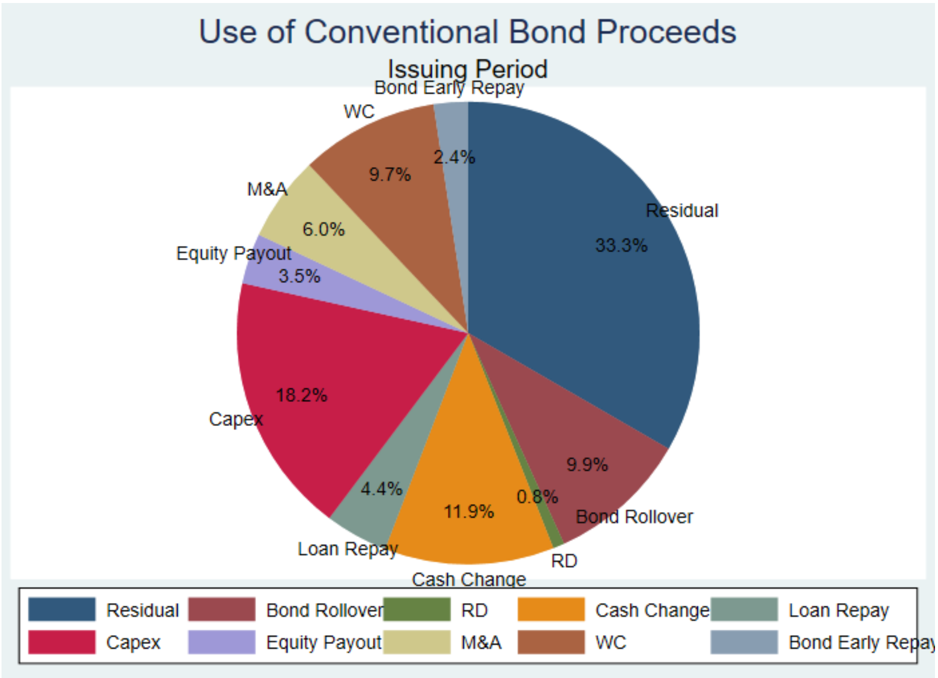
In this section, I present the results of utilizing fractional probit regression in panel analysis to examine the use of proceeds. This approach is suggested by Papke and Wooldridge (2008) for the common occurrence of having a large number of firms compared to the number of time periods (N >> T) in finance data where using fixed effects in probit can lead to biased estimates. To address this concern of time-invariant difference across firms, I control for the average of time-varying data following Papke and Wooldridge (2008). Following Wooldridge (2019), I also include average year dummies as covariates as this panel dataset is not balanced,

The change variables, including the change in cash, change in working capital (WC), and change in total assets (TA), are still modeled using linear regressions with year and firm fixed effects. Instead of presenting the coefficients, the average partial/marginal effect is reported at the median level of green and conventional bonds for fractional regressions. The detailed results can be found in Table A2 and Table A3. A pie chart depicting the results is also displayed in Figure 11.

In general, the results show minimal differences compared to the linear regression findings. However, there are a few notable distinctions. Firstly, green bonds are more commonly utilized for refinancing purposes compared to conventional bonds. Additionally, there is a relatively higher allocation of conventional bonds in R&D activities.



(a) Use of Green Bond Proceeds



(b) Use of Conventional Bond Proceeds

Figure 11: Use of Proceeds This pie chart illustrates the allocation of each $1 of green/conventional bond proceeds within the sample from 2014 to 2021, reflecting the regression results from Table A2.

Table A1. Stock Index

This table lists the market index chosen for the event-study analysis of stock market reactions to green bond issuance conducted in Section 7 . For each country where the stock of the green bond issuer is listed, the most representative stock index is selected.

Country	Market Index
Australia	EURO STOXX Total Market Index
Austria	EURO STOXX Total Market Index
Belgium	EURO STOXX Total Market Index
Brazil	BOVESPA Index
Canada	S&P/TSX Composite Index
Switzerland	EURO STOXX Total Market Index
China	Shanghai Composite Index
Chile	The S&P IPSA
Colombia	MSCI COLCAP Index
Germany	EURO STOXX Total Market Index
Denmark	EURO STOXX Total Market Index
Spain	EURO STOXX Total Market Index
Finland	EURO STOXX Total Market Index
France	EURO STOXX Total Market Index
Hungary	EURO STOXX Total Market Index
UK	EURO STOXX Total Market Index
Indonesia	Jakarta Stock Exchange Composite Index
Ireland	EURO STOXX Total Market Index
Greece	EURO STOXX Total Market Index
Hong Kong	Hang Seng Composite Index
India	S&P BSE Sensex Index
Lithuania	EURO STOXX Total Market Index
Italy	EURO STOXX Total Market Index
Japan	Nikkei 225
Netherlands	EURO STOXX Total Market Index
Korea	KOSPI Index
Mexico	MEXICO IPC (BOLSA) index
Malaysia	FTSE Bursa Malaysia KLCI Index
Poland	EURO STOXX Total Market Index
Portugal	EURO STOXX Total Market Index
Saudi Arabia	Tadawul All Share Index
Norway	EURO STOXX Total Market Index
South Africa	FTSE/JSE Africa Indexes
New Zealand	EURO STOXX Total Market Index
Philippines	Philippine Stock Exchange All Shares Index
Sweden	EURO STOXX Total Market Index
Taiwan	Taiwan Capitalization Weighted Stock Index
Singapore	Straits Times Index
Turkey	BIST All Shares Index
Thailand	FTSE Thailand index
United States	CRSP Value-Weighted Index

Table A2. Use of Proceeds Green vs Conventional

This table displays the estimate of β_1 and β_2 in Equation 1 pertaining to the use of the proceeds section. Panel A presents the results corresponding to the contemporaneous fiscal half-year during which the firm issues green bonds, while Panels B and C depict the cumulative usage over a one-year and one-and-a-half-year period, respectively. Additionally, each panel provides the T-test results for comparing the use of proceeds between green and conventional bonds. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Δ Cash	Δ WC	Early Bond Repay	Rollover Bond	Loan Repay	Capital Expenditures	M&A	Equity Payout	R&D Expense	Δ Total Asset
Green	**0.4918*****	0.047	**0.0578*****	0.0165	0.0233	**0.0797*****	**0.0211*****	-0.0022	**-0.0071***	**1.2576*****
P-Value	0.0000	0.3886	0.0000	0.2722	0.1136	0.0074	0.0003	0.8440	0.0922	0.0000
Conventional	**0.3292*****	**0.0611****	**0.0343*****	**0.0453*****	**0.0031**	**0.0743*****	**0.0085****	0.0079	0.0013	**0.9177*****
P-Value	0.0000	0.0439	0.0000	0.0000	0.7069	0.0000	0.0100	0.2488	0.3238	0.0000
Diff	**0.1625****	-0.0141	**0.0236***	**-0.0288***	0.0202	0.0054	0.0127	-0.0102	**-0.0084***	**0.3399***
P-Value	0.0326	0.8053	0.0703	0.0765	0.2900	0.9023	0.1329	0.4327	0.0582	0.0889
Observations	5721	5627	5757	5757	5757	5744	5757	5712	5757	5734
Panel B: Issuing Period and the following half-year										
Green	**0.3422*****	0.0329	**0.0632*****	0.0361	0.0274	**0.1764*****	**0.0304****	0.0134	**-0.0144***	**1.5168*****
P-Value	0.0000	0.6410	0.0000	0.1486	0.1443	0.0000	0.0240	0.3639	0.0836	0.0000
Conventional	**0.1418*****	**0.0819****	**0.0296*****	**0.0743*****	0.0181	**0.1353*****	**0.0267*****	**0.0242*****	**0.0063*****	**0.9856*****
P-Value	0.0015	0.0466	0.0000	0.0000	0.1200	0.0000	0.0014	0.0037	0.0034	0.0000
Diff	**0.2004****	-0.0489	**0.0337****	-0.0382	0.0093	0.0411	0.0037	-0.0108	**-0.0207****	**0.5312***
P-Value	0.0161	0.4932	0.0215	0.1604	0.7175	0.3945	0.9048	0.5314	0.0199	0.0796
Observations	5700	5593	5733	5733	5733	5706	5733	5674	5733	5714
Panel C: Issuing Period and the following year										
Green	**0.182****	-0.0356	**0.0583*****	0.051	**0.0556****	**0.2655*****	0.0427	0.0272	**-0.026****	**1.591*****
P-Value	0.0159	0.7120	0.0002	0.1446	0.0361	0.0000	0.1049	0.2679	0.0379	0.0000
Conventional	**0.1185****	**0.0965***	**0.024*****	**0.0987*****	**0.044*****	**0.1821*****	**0.0595*****	**0.0353*****	**0.008****	**1.2672*****
P-Value	0.0240	0.0600	0.0079	0.0000	0.0050	0.0002	0.0000	0.0009	0.0278	0.0000
Diff	0.0635	-0.1321	**0.0343***	-0.0477	0.0116	0.0834	-0.0168	-0.008	**-0.034****	0.3238
P-Value	0.5126	0.2219	0.0824	0.2242	0.7663	0.2674	0.4825	0.7649	0.0110	0.4267
Observations	5663	5546	5694	5694	5694	5649	5694	5617	5694	5678
Model	Linear		Fractional probit							Linear
Estimation method	Fixed Effects		Pooled QMLE							Fixed Effects

*** p< 0.01, ** p< 0.05, * p< 0.1

Table A3. Use of Green Proceeds: Firm Characteristics

This table displays the estimate of β_1 and β_2 in Equation 2 pertaining to the use of the proceeds section. Panel A displays the results for the concurrent fiscal half-year during which the firm issues green bonds. Panels B and C show the cumulative usage over one year and one-and-a-half years, respectively. Repeat, High Yield, and Late are indicator variables that represent specific firm characteristics associated with green bond issuance. The Repeat variable is assigned a value of 1 if the firm issues more than one green bond, excluding cases where multiple tranches are issued at the same time or the bond is tapped. The High Yield variable is set to 1 if a firm issues over 50% of its green bonds as high yield, as rated by S&P, Fitch, and Moody's. Finally, the Late variable is given a value of 1 if a firm issued its first green bond after the end of 2020. Significance levels are denoted as follows: * for 10%, ** for 5%, and *** for 1%.

	Δ Cash	Δ WC	Early Bond Repay	Rollover Bond	Loan Repay	Capital Expenditures	M&A	Equity Payout	R&D Expense	Δ Total Asset
Panel A: Firm Characteristics: Issuing Period										
Late $\times$ *Green Fund*	0.1455	0.1488	-0.0189	**-0.067****	-0.0197	-0.0916	-0.0087	**0.065****	-0.0069	0.037
P-Value	0.3022	0.3135	0.3823	0.0280	0.6081	0.2363	0.5345	0.0197	0.1861	0.9246
Observations	5733	5639	5757	5757	5757	5744	5757	5712	5757	5746
High Yield $\times$ *Green Fund*	-0.0139	0.1304	0.0004	0.0066	**-0.1312*****	-0.0001	-0.013	-0.029	0.0099	0.1765
P-Value	0.9055	0.1884	0.2571	0.9249	0.0002	0.9079	0.9240	0.2614	0.4050	0.5676
Observations	5733	5639	5757	5757	5757	5744	5757	5712	5757	5746
Repeat $\times$ *Green Fund*	**-0.2164***	-0.1649	0.0054	**0.1249*****	0.0021	**0.1643****	0.0153	-0.0147	0.0043	-0.1271
P-Value	0.0712	0.1163	0.2337	0.0002	0.9770	0.0376	0.1456	0.5230	0.6130	0.7166
Observations	5733	5639	5757	5757	5757	5744	5757	5712	5757	5746
Panel B: Firm Characteristics: From T to T+1										
Late $\times$ *Green Fund*	0.0643	0.0575	-0.0401	**-0.1408****	-0.0487	-0.1236	0.02	**0.0888****	**-0.0207***	-0.1558
P-Value	0.6899	0.7438	0.2328	0.0127	0.3378	0.4418	0.6468	0.0375	0.0895	0.7973
Observations	5713	5607	5733	5733	5733	5706	5733	5674	5733	5727
High Yield $\times$ *Green Fund*	0.0655	0.1459	0.0068	0.0509	**-0.1395****	0.0117	0.0135	**-0.077***	0.015	0.4292
P-Value	0.6236	0.2652	0.4045	0.4505	0.0094	0.9711	0.4152	0.0618	0.4801	0.4924
Observations	5713	5607	5733	5733	5733	5706	5733	5674	5733	5727
Repeat $\times$ *Green Fund*	-0.1454	**-0.2388***	0.0022	**0.2188*****	0.005	**0.2795***	0.0016	-0.017	0.0023	0.3991
P-Value	0.3165	0.0897	0.4877	0.0003	0.9156	0.0548	0.7131	0.6346	0.7804	0.5083
Observations	5713	5607	5733	5733	5733	5706	5733	5674	5733	5727
Model	Linear		Fractional probit							Linear
Estimation method	Fixed Effects		Pooled QMLE							Fixed Effects

*** p< 0.01, ** p< 0.05, * p< 0.1

Table A4. Greenhouse Gas: Constant Component Sample

This table presents the regression results of GHG intensity among firms issuing green bonds. Panel A is confined to a constant sample, i.e. to be included in the sample, firms must have data available from three years before to two years after their first green bond issuance. Panel B encompasses the entire sample. The variable I_{After} functions as an indicator variable, taking a value of 1 after a date of interest and 0 otherwise. Column 1 examines the change in GHG intensity from two years pre-issuance to the end of the green bond proceeds allocation period, which ends two years post-issuance. Column 2 investigates whether there is a further reduction in GHG emissions following the end of the allocation period (two years after issuance). Column 3 evaluates the levels of GHG emissions pre- and post-issuance, whereas Column 4 contrasts emissions during the refinancing period (from -2 to 0 years) with those in the financing period (from 0 to 2 years). Firm size, calculated as the logarithm of total assets, is controlled for in the analysis. Firm fixed-effect is employed. Significance levels are denoted as follows:* for 10%, ** for 5%, and *** for 1%.

Panel A: Constant Sample

	(1) GHG Intensity Before vs Allocation	(2) GHG Intensity Allocation vs After	(3) GHG Intensity Before vs After Issuance	(4) GHG Intensity Refinance vs Finance
Size	-0.278	-0.401***	-0.299**	-0.436***
	-0.283	-0.108	-0.134	-0.159
$I_{\textbf{After}}$	**-0.104***	**-0.201*****	**-0.190*****	**-0.101****
	-0.0586	-0.0462	-0.0585	-0.0484
Constant	0.112	1.428	0.292	1.591
	-2.74	-1.044	-1.3	-1.552
Observations	529	528	701	445
R-squared	0.975	0.976	0.969	0.98
Firm FE	Yes	Yes	Yes	Yes

Panel B: Whole Sample

	(1) GHG Intensity Before vs Allocation	(2) GHG Intensity Allocation vs After	(3) GHG Intensity Before vs After Issuance	(4) GHG Intensity Refinance vs Finance
Size	-0.487***	-0.535***	-0.377***	-0.525***
	-0.122	-0.0978	-0.0898	-0.112
$I_{\textbf{After}}$	**-0.0890****	**-0.154*****	**-0.183*****	**-0.115*****
	-0.0375	-0.0428	-0.042	-0.0397
Constant	1.821	2.168**	0.722	1.976*
	-1.156	-0.917	-0.855	-1.063
Observations	1,350	1,190	1,618	1049
R-squared	0.971	0.976	0.971	0.977
Firm FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1