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Professor Caroline Flammer and Professor Stefano Giglio
NBER PhD Student Workshop on Climate Finance
1050 Massachusetts Avenue
Cambridge, MA 02138 USA

03.08.2025
Application for the PhD Student Workshop on Climate Finance

Dear Professors Flammer and Giglio,

I am writing to express my interest in the NBER PhD Student Workshop on Climate Finance, to be held on October 9, 2025, in Cambridge. As a doctoral student in Climate Finance at the University of Augsburg, I am currently working toward a cumulative dissertation focused on the role of policy signals in shaping climate-related financial outcomes. I expect to complete my degree by December 2026. My supervisors—Professor Dr. Sebastian Utz and Dr. Florian Habermann—are available to provide a reference.

Prof. Dr. Sebastian Utz
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Dr. Florian Habermann
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Research Agenda and Interests
My dissertation centers on how distinct policy signals—ranging from explicit financial incentives to implicit political narratives—reshape climate finance markets, capital allocation, and ultimately the pace of climate adaptation and mitigation. I explore how financial markets respond to government interventions and political shifts, and how these responses influence the development of sustainable finance instruments and firm-level outcomes.

—**Paper 1**: "Plug and Play Policy Tool for Green Financial Market Development? Insights from Japan's Green Bond Subsidy Program"
This paper provides quasi-experimental evidence on the effects of Japan's green bond subsidy program. Using a synthetic control approach, the analysis shows that the subsidy significantly increased green bond issuance, market volume, and issuer diversity, underscoring its effectiveness in deepening market participation. However, the average issuance size declined post-subsidy implementation, raising concerns about the programs efficiency. Complementary firm-level analyses reveal limited short-term effects on stock market valuation and CO_2 emissions, pointing to a disconnect between financial uptake and environmental outcomes and highlighting the potential need for additional policy measures to enhance real-economy impact.

—**Paper 2**: "The Influence of Right-Wing Populism on the Sustainable Finance Market"
This project examines how the entry of right-wing populist parties into government influences sustainable finance. Combining regression discontinuity and staggered difference-in-differences designs, the study analyzes stock market reactions, firm-level environmental outcomes, and green bond issuance patterns. Preliminary evidence suggests that shifts in political ideology can reprice climate risk, slow environmental progress, and dampen the supply of labelled green finance.

My future work will explore how climate- and nature-related risks are priced, transmitted, and acted upon across financial markets and corporate decision-making. I aim to better understand how policy signals and institutional contexts shape the allocation of capital in the face of environmental uncertainty. The goal is to identify when financial instruments and market structures enable—or obstruct—the transition to a more resilient and low-carbon economy, thereby generating policy-relevant insights.

A complete draft of Paper 1 is attached for review.

I would appreciate the opportunity to present my research and receive feedback. The workshop offers a valuable setting to engage with ongoing work in the field and to strengthen connections within the climate finance research community.

Thank you for considering my application.

Sincerely,
Felix Stolze

Felix Stolze

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EDUCATION

Doctoral Researcher at the Chair of Climate Finance, University of Augsburg — **Augsburg, DE**, since 08.2023
- Supervised by Prof. Dr. Sebastian Utz and Dr. Florian Habermann
- 1st paper: Plug and Play Policy Tool for Green Financial Market Development? Insights from Japan's Green Bond Subsidy Program
- 2nd paper: The Influence of Right-Wing Populism on the Sustainable Finance Market

M. Sc. in Business Administration at Catholic University Eichstätt-Ingolstadt — **Ingolstadt, DE**, 04.2021 - 07.2023
- Grade: 1.4 with focus on Finance, Accounting, Controlling & Taxation
- Master-Thesis: "Net zero and the role of banks: An investigation of sustainability-linked-loans and shareholder reactions as well as disclosure quality" (Grade 1.0)

B. Sc. in Business Administration at Catholic University Eichstätt-Ingolstadt — **Ingolstadt, DE**, 10.2017 - 03.2021
- Grade: 2.1 with Finance Major
- Bachelor-Thesis: "CFP and CSP: An investigation on the impact of event-based ESG scoring downgrades on stock returns" (Grade 1.3)

Abitur (German Prerequisite for University Admission) at Gymnasium Roth — **Roth, DE**, class of 2017
- Grade: 2.1

RESEARCH EXPERIENCE

Doctoral Researcher at the Chair of Climate Finance — **Augsburg, DE**, since 08.2023
- Empirical research at the nexus of financial markets, public policy and sustainability
- Deployment of causal-inference toolkits and multi-factor models
- Building of end-to-end pipelines for large-scale data engineering and modelling

WORK EXPERIENCE

Commerzbank AG - Asset Management — **Frankfurt, DE**, since 04.2025
- Supporting carve-out and integration of multiple acquired asset management firms into a newly established standalone asset management entity
- Coordinating strategic and operational transition, including regulatory alignment, governance setup, and internal restructuring

Commerzbank AG - Green Infrastructure Finance Americas — **New York, US**, 01.2025 - 03.2025
- Collaborated in structuring and financing of renewable energy projects, including wind and solar farms and battery storage systems

Commerzbank AG - Deputy Global Lead Sustainable Finance — **Frankfurt, DE**, 01.2023 - 12.2024
- Supported board mandate to establish strategic ESG setup and translate it into banking model with global responsibility in corporate and institutional segment
- Held regular board and executive reporting, external representation, and implementation of ESG regulatory requirements (EBA, JST, etc.)
- Developed and integrated an ESG credit risk model for corporate clients
- Designed and implemented SBTi portfolio steering framework

INTERNSHIPS

Commerzbank AG - Bond Sales Asia — **Singapore, SG**, 09.2022 - 10.2022
- Sold plain vanilla products across all fixed income asset classes to clients in Asia
- Executed primary and secondary market trades and initiated private placements

Commerzbank AG - Lending, Risk and Resource Steering *Working Student* **Frankfurt, DE**
07.2022 - 12.2022

- Assessed portfolio CO_2 intensity and initiated steering strategies toward net-zero targets
- Conducted climate risk analysis, together with long-term portfolio impact projections, and definition of exclusion criteria

Commerzbank AG - Corporate Clients Relationship Management *Working Student* **Nuremberg, DE**
10.2019 - 12.2022

- Managed loan assignments, balance sheet analyses, risk hedging, and client acquisition tasks, including developing pitch decks and client materials

Bayern LB - Trade Finance **Nuremberg, DE**
08.2019

- Gained insight into trade finance operations and risk mitigation in international trade

UniCredit S.p.A. - Corporate Investment Bank Financials Credit Research **Munich, DE**
02.2019 - 04.2019

- Conducted research on Sub-Sovereigns and Agencies and Covered Bonds, focusing on valuation, risk analysis, data extraction, and visualizations

Commerzbank AG - Corporate Clients Relationship Management **Nuremberg, DE**
08.2018 - 09.2018

- Conducted research on corporate clients and industries, and assisted relationship managers with pitch decks, client materials, and outreach

ADDITIONAL INFORMATION

Languages	German (C2), English (C1), Spanish (B2), Latin certificate
Software	R and Python (statistical analysis), MS Office (esp., Excel, PowerPoint), financial market data platforms (e.g., Bloomberg, Refinitiv, Moody's, S&P, Fitch)
Memberships	BCG business@school, Finance Network Ingolstadt

Title

Plug and Play Policy Tool for Green Financial Market Development? Insights from Japan's Green Bond Subsidy Program

Abstract

Policymakers worldwide face significant challenges in raising money for climate action while ensuring economic stability. Subsidies emerge as one approach to mobilize green capital—but empirical evidence on whether this policy tool stimulates green bond issuance is lacking. Examining Japan's Financial Support Programme for Green Bond Issuance, our results show a substantial increase in the number of green bonds issued, market volume, and issuer diversity following its implementation, suggesting the effectiveness of the program. However, the average green bond size decreases post-subsidy, raising concerns about the program's efficiency. Moreover, when we extend the analysis to environmental issuer-level outcomes, we detect only modest, statistically insignificant shifts in the short run. This indicates that, although the subsidy effectively jump-starts issuance activity, its real-economy benefits may require longer horizons or complementary measures to materialize. Nonetheless, our findings hold significant implications for policymakers worldwide seeking pragmatic solutions to elevate green finance.

Attributes

green bonds, climate finance, public subsidies, synthetic control method

1 Introduction

Policymakers worldwide recognize the urgent need to bridge the climate finance gap (Butler 2024). For instance, the G20 implemented the Sustainable Finance Working Group with the main goal "to scale up private and public sustainable finance and in so doing, accelerate the implementation of the Paris Agreement" (Sustainable Finance Working Group 2022). Similarly, the European Union has pledged to attract at least EUR 1 trillion in sustainable investments (European Commission 2021), contributing to a green future. However, despite more than a decade of growth in climate finance flows, if investment continues at its current pace, global climate finance action will fall short by approximately EUR 24.6 trillion by 2030 (Benayad et al. 2023). This shortfall makes it highly unlikely that the goals of the Paris Agreement—requiring nearly EUR 185 trillion in total investment by 2050—will be achieved (Albuixech and Lazarova 2024). The situation in Asia illustrates the severity of the situation: the region needs around USD 1.1 trillion annually for climate-resilient infrastructure, but current investment levels remain at USD 333 billion (Basu and Lim 2024). Japan, one of Asia's largest economies, faces the prospect of significant economic consequences caused by climate change, with projections indicating a 3.72% decline in GDP by 2050 under current trends—a burden that could be cut in half with stronger climate policies (Fondazione CMCC 2021). Therefore, without a rapid and coordinated acceleration of global and regional climate finance, the world risks locking in irreversible climate damage and economic losses.

Against this backdrop, green bonds are a financial instrument with the potential to promote investment aimed at facilitating the transformation toward a more sustainable economy, as they signal credible environmental commitment and are associated with improved environmental outcomes (Flammer 2021). Green bonds derive their credibility from the broader institutional context, depending on transparent practices and the involvement of key stakeholders such as regulators, issuers, and investors. Compared to conventional bonds, they are associated with lower financing costs (Zhou and Kythreotis 2024) but require a dedicated framework aligned with recognized standards—such as those set by the International Capital Market Association, the Climate Bonds Initiative, and regional bodies like ASEAN and the EU—resulting in higher transaction costs. These challenges limit their broader uptake and effectiveness in mobilizing climate finance (OECD 2017). In addition, current policy frameworks provide insufficient support, indicating governments need to implement more direct financial incentives—such as cash rewards, subsidies, or tax breaks—to enhance corporate engagement in green finance (Liu et al. 2022). In this context, Japan stands out as

the only G7 country offering a direct subsidy for green bond issuance, covering 40% to 80% of external review and consultation fees per bond (MOE Japan 2024).

Building on Japan's unique policy approach, this study empirically investigates whether the subsidy facilitates the development of a stronger green bond market. Estimating the causal effect of such a policy, however, poses significant challenges due to endogeneity concerns. Green bond issuance trends are influenced by a multitude of factors—such as economic conditions (Tolliver et al. 2020), environmental policies (Lee et al. 2023), and investor preferences (Flammer 2021)—that may coincide with the introduction of the subsidy. To address this challenge, we apply the synthetic control method (SCM), which constructs a weighted combination of countries without a comparable subsidy to serve as a credible counterfactual (Abadie 2021). This synthetic Japan represents what Japan's green bond market would likely have looked like in the absence of the policy. To construct it, we use green bond data from LSEG—covering over 15,000 bonds issued across 101 countries between 2007 and 2024—and macroeconomic indicators from the World Bank. By matching Japan's pre-intervention trajectory on these key observed characteristics, the SCM mitigates endogeneity bias and enables us to estimate the policy's effect on issuance dynamics.

Our findings show increased bond count, market volume, and issuer diversity, highlighting the subsidy's role in shaping Japan's green bond market. However, we also observe a decrease in the average issuance size post-subsidy introduction. We expand our analysis to issuer-level outcomes, finding limited direct impacts. Notably, green bond announcements do not significantly affect firm value, as indicated by the absence of stock market reactions. Moreover, we observe no short-term improvements in issuers' CO_2 emissions or emission intensity, which may indicate that the subsidy supports longer-term investments rather than immediate, marginal improvements. Nonetheless, our results, robust across multiple tests, indicate significant effects of the subsidy program on green bond issuance dynamics, emphasizing the importance of government policies and market dynamics acting indispensably to channel capital toward green finance (Diaz-Rainey et al. 2023).

Our analysis contributes to three interrelated literatures. First, we advance the rapidly growing work on green bond issuance dynamics. Earlier studies highlight macroeconomic drivers (Tolliver et al. 2020), policy signals (Lee et al. 2023), and the importance of certification (Flammer 2020, Flammer 2021), but the role of direct cost-relief instruments remains underexplored. By showing that Japan's subsidy leads to a significant jump in bond count, market volume, and issuer diversity—while shrinking average deal size—we provide the first quasi-experimental evidence that a targeted policy can reshape both intensive and

extensive margins of issuance. This suggests that lowering issuance costs through direct financial support effectively alters managerial cost-benefit considerations, encouraging broader market participation without requiring structural reforms. Second, we contribute to ongoing debates about the financial and real-economy effects of green bonds. Despite the sharp rise in issuance, we find no abnormal stock price reactions and no short-term emission reductions following subsidy-induced issuance. These null effects align with mixed evidence in the literature (Wu 2022, Khiari et al. 2024, Zhou and Kythreotis 2024) and indicate that growing green capital flows do not automatically translate into measurable firm-level outcomes. Our findings suggest that while issuance subsidies can successfully build market depth, complementary policy measures may be necessary to convert these flows into firm valuation gains and rapid decarbonization. Third, our findings contribute to the broader climate finance literature by showing how targeted public support can enhance market-based mechanisms. Since market forces alone are unlikely to mobilize the scale of investment required for the low-carbon transition (Campiglio et al. 2018), recent work has emphasized the need for blended public–private approaches (Bai and Wang 2024; Shi and Yang 2025). Our results demonstrate that a well-designed, plug-and-play subsidy—easily implementable and integrated into existing infrastructure—can catalyze private capital without the need for deeper regulatory reform. In this way, Japan's program provides a scalable and transferable policy blueprint for advanced economies seeking to use market-based levers to accelerate the green transition.

The remainder of the paper is organized as follows. Section 2 reviews the theoretical background and related literature on government subsidies and green finance. Section 3 describes the data and variable construction. Section 4 outlines the synthetic control design and presents the main results together with robustness checks. Section 5 introduces the event study and difference-in-differences (DiD) approaches for firm-level analysis. Section 6 discusses the findings, and Section 8 concludes.

2 Theoretical Framework and Related Literature

This section begins by detailing the structure and objectives of Japan's green bond subsidy program, highlighting its role within the country's broader sustainable finance strategy. We then examine the theoretical and empirical rationale for scaling green finance, drawing on recent literature to contextualize the expected effects of targeted public interventions on market development and environmental outcomes.

2.1 Government Subsidy Program

Launched in April 2018 by the Ministry of the Environment (MOEJ), the Financial Support Programme for Green Bond Issuance (Ministry of the Environment Government of Japan 2024) provides subsidies to entities—including companies, municipalities, and other organizations—aiming to finance new or existing environmentally beneficial projects. The program subsidizes external review and consultation costs—such as pre-issuance assessments, post-issuance reviews, and support for establishing a green bond framework (Ministry of the Environment Government of Japan 2024)—up to a cap of JPY 50 million (approximately USD 330,000) per issuance (Azhgaliyeva and Kapsalyamova 2023). The scheme requires that issuers obtain external validation of their alignment with recognized green bond standards, such as the ICMA Green Bond Principles, ASEAN Green Bond Standards, or Japan's own Green Bond Guidelines (Climate Bonds Initiative 2024). Registered service providers, including second-party opinion firms and consulting companies, must be pre-approved by the MOEJ to prevent greenwashing and ensure credibility (MOE Japan 2024). This emphasis on certification is key as environmental improvements occur only when green bonds are certified (Flammer 2020).

By incentivizing adherence to high environmental and procedural standards, the subsidy serves both as a market catalyst and a quality assurance mechanism (MOE Japan 2024). This is reflected in the high prevalence of external reviews in Japan's green bond market, with approximately 90% of issues carrying a second-party opinion or rating (OECD 2020). Crucially, the subsidy is not a standalone measure but part of a broader strategy to align financial markets with Japan's decarbonization goals, which aim to mobilize roughly JPY 150 trillion (about USD 1.05 trillion) in green investment over the coming decade (Cabinet Secretariat et al. 2023). At the same time, its plug-and-play design—providing direct cash rewards without requiring major political reforms, new taxonomies, or complex institutional changes—makes it easily adoptable by other countries. This simplicity lowers entry barriers, enables a low-friction transition into green finance for a wide range of issuers, and strengthens the program's relevance as a scalable model for accelerating green bond issuance in diverse regulatory contexts.

2.2 The Role of Green Finance and Public Policy

Green finance has emerged as a powerful tool in promoting decarbonization and sustainability, particularly in countries undergoing rapid economic or industrial development. In East Asia, even marginal increases in green finance have been shown to improve sustainable development

outcomes, especially within the industrial sector (Shi and Yang 2025). OECD-wide studies confirm that green finance promotes green economic growth, attracts foreign investment, enhances capital accumulation, improves resource efficiency, and mitigates environmental degradation (Han and Gao 2024). Similar patterns are observed in China, where pilot zones for green finance reform and innovation have been shown to reduce industrial energy consumption, foster green technology innovation, and yield long-term benefits for energy savings (Zhang et al. 2023). Among the available financial instruments, green bonds stand out: their expansion is strongly correlated with rising ESG investment, with a 1% increase in issuance associated with a 0.33% rise in ESG capital flows (Bai and Wang 2024). Yet despite their promise, green bonds remain less attractive than conventional bonds for many issuers, owing to higher costs and regulatory constraints. As a result, recent literature highlights the potential of public policy—particularly subsidies and tax incentives—as a means to accelerate green finance (Bai and Wang 2024; Shi and Yang 2025), given that market forces alone appear insufficient to mobilize the required scale of investment for the low-carbon transition (Campiglio et al. 2018). Still, it remains unclear whether such policy interventions can generate a meaningful shift in market behavior and deliver tangible environmental benefits. This study addresses that by asking: Can a dedicated subsidy program significantly accelerate green bond market growth—and does this acceleration translate into measurable sustainability outcomes? Emerging evidence from China offers encouraging signals, suggesting that climate finance policies can prompt strong responses from government-owned, financial, and green industry firms (Saravade et al. 2023), leading to increased green innovation and expanded urban green space (Lee et al. 2023). However, systematic evaluations of such policies—especially outside of China—remain scarce.

3 Data

This section describes the dataset and outcome variables used to evaluate the effectiveness of the Japanese green bond subsidy. We examine both bond market development indicators and issuer-level outcomes.

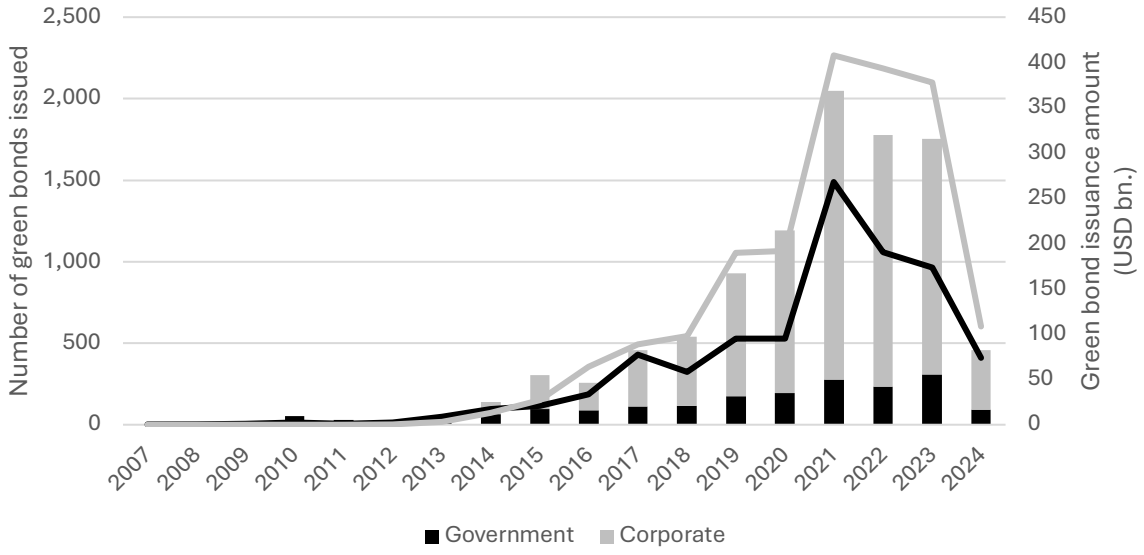
3.1 Sample Description

This study draws on green bond data from LSEG (formerly Refinitiv), which integrates data from the Climate Bonds Initiative into a single comprehensive database. LSEG uses a document-based classification approach, relying on issuer labels, frameworks, independent opinions, and the alignment of proceeds with ESG goals, making its labeling a strong signal

regarding the greenness of a bond. We aggregate issuer-level data from the LSEG Green Bond Guide to create a monthly country-level panel dataset. To ensure consistency and comparability, we standardize the issuer and bond type variables by consolidating certain categories. More precisely, issuer types related to government entities are grouped under a single classification: government. This leads to a dichotomous issuer type variable: government and corporate. For bond types, only specific classifications are considered green bonds, namely CBI Aligned Green Bond, Self-Labeled Green Bond, and CBI Certified Green Bond.

The green bond dataset comprises 15,619 bonds issued across 101 countries[1] between July 2007 and March 2024, of which 10,007 are explicitly classified as green bonds, representing a total issuance volume of USD 3,085.24 billion. Japan accounts for 6% of global green bonds but only 3% of total issuance volume (USD 96.26 billion). Compared to other G7 countries, Japan's market is less financial sector driven (27% vs. 73%) and more weighted toward government (13% vs. 4%), industrial (17% vs. 7%), and real estate issuers (25% vs. 4%). On a country level, China leads with 1,556 issued bonds totaling USD 369.14 billion, followed by Sweden, the US, Germany, France, and Japan. Compared to global averages, Japanese green bonds are smaller (USD 154.26 million vs. USD 308.31 million), have longer maturities (8.96 vs. 7.93 years), and offer lower coupon rates (0.82% vs. 3.34%). These differences underline Japan's stability-focused and domestically oriented market (East Asia Forum 2024) and form the basis for understanding how Japan's green bond market responds to subsidy policies.

Figure 1: Green bond issuance over time



The figure reports the annual count of green bonds issued and their total issuance volume in USD billion, covering all green bonds issued from July 2007 to March 2024.

3.2 Outcome Measures

For the SCM we use four country-level outcome variables—*BondCount*, *MarketVolume*, *UniqueIssuers*, and *IssuanceAmount*—constructed from the green bond dataset to analyze the subsidy effects on country-level. Our primary measure is cumulative green bond issuance (*BondCount*), defined as the total number of green bonds issued in a given country from 2007 to 2024. Using the LSEG database, where each bond is uniquely identified by its ISIN, we count the number of distinct bonds issued per country on a monthly basis and aggregate them over time. We use a cumulative measure for several reasons: Cumulative issuance reflects the total financial commitment toward sustainable financing, providing a clear and consistent view of the market's size and growth over time. This approach helps smooth out short-term volatility, capturing long-term trends and shifts, similar to the $CARs$ in event studies. Additionally, it enables a better assessment of how the green bond market responds to policy changes, investor interest, and economic conditions.

The market volume (*MarketVolume*) is measured as the cumulative nominal issuance amount of green bonds. We compute it by summing the USD-denominated issuance values, provided by LSEG, for all green bonds issued in each country on a monthly basis, following the same aggregation logic as for *BondCount*. This provides a straightforward measure of the total financial commitment toward sustainable financing over our time-period from 2007 to 2024.

For the remaining two variables—*UniqueIssuers* and *IssuanceAmount*—we switch from monthly to event-year aggregation, where each event-year covers a 12-month period relative to the policy start in April 2018 ($t = 0$). Using annual data minimizes seasonal fluctuations and short-term noise, providing a clearer view of sustained growth that aligns with the planning horizons of policymakers and businesses.

The unique issuers (*UniqueIssuers*) metric captures the number of distinct companies or entities issuing green bonds within each event-year, thereby providing an indicator of market participation and issuer diversity. To construct this measure, we identify the unique issuer names recorded in the dataset for each country and event-year.

The issuance amount (*IssuanceAmount*) reflects the relative issuance size of green bonds within each country and event-year. The *IssuanceAmount* metric is calculated at the event-year level by using the aggregate values of *BondCount* and *MarketVolume*. Specifically, we divide the total market volume by the total number of bonds issued in a given event-year for each country.

To examine the real-economy effects of green bond issuance at the issuer level, we draw on two variables from the LSEG database: CO_2 emissions (ENERDP023) and emission intensity. The former measures the total greenhouse gas output of an issuer, while the latter—defined as the ratio of CO_2 emissions to total assets (WC02999)—provides a standardized metric of emissions relative to the scale of an entity's operations, thereby complementing the analysis of absolute emissions. These variables are critical for assessing whether green bond issuance translates into measurable environmental improvements and enhanced sustainability practices at the firm level.

4 Aggregate Green Bond Market Dynamics

This section assesses the aggregate impact of Japan's green bond subsidy on market development. We first describe the methodological framework and present the main market-level results. Next, we examine sectoral dynamics and participation across industries using a panel DiD approach, complement the SCM with a country-level panel DiD, and conclude with robustness checks, including placebo and sensitivity tests.

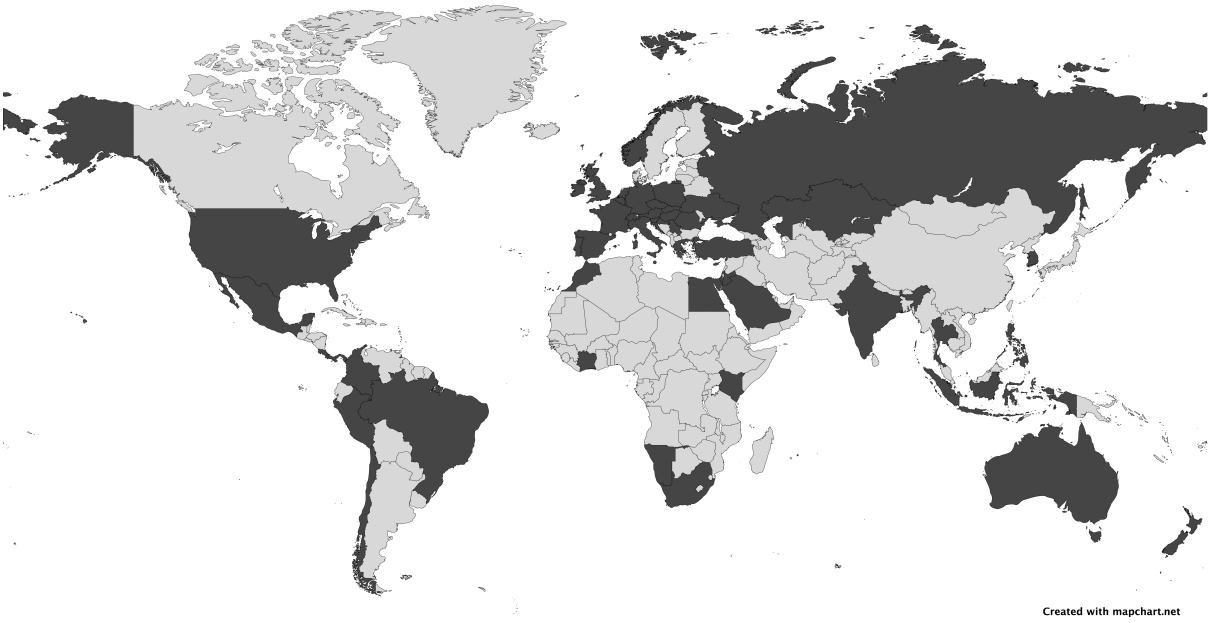
4.1 Synthetic Controls Method

The estimations in the following rely on the SCM—a standard approach in policy evaluation (Abadie and Gardeazabal 2003, Abadie et al. 2010)—with recent applications in finance (Opatrny 2021, Pfeil and Feld 2023, Tang et al. 2023, Meng et al 2024). The SCM constructs a synthetic control using a data-driven approach, enabling comparison against a treated unit to isolate the effect of an intervention (Abadie and Gardeazabal 2003, Abadie et al. 2010). While critics note that unobserved confounders and heterogeneous treatment effects may bias results, matching on pre-intervention outcomes can mitigate these concerns, provided sufficient pre-treatment data is available. This ensures that any observed post-intervention difference between the treated and synthetic unit is attributable to the intervention itself rather than to pre-existing conditions (Abadie et al. 2010). For a comprehensive methodological overview of the SCM, we refer to the works of Abadie (Abadie and Gardeazabal 2003, Abadie et al. 2010, Abadie et al. 2015, Hainmueller et al. 2011).

In our setting, the analysis includes a total of 101 units, comprising one treated unit, Japan, and 100 potential control units that constitute the donor pool. To accurately construct a counterfactual scenario without an intervention, we restrict the donor pool to countries with at least one green bond issuance, but without subsidy schemes. Hong Kong, Singapore, and Malaysia are excluded due to their subsidy policies. China and the US, despite having subsidy

programs, are included as their policies significantly differ from those under investigation.[2] This ensures that the various countries share similar economic conditions, but none of the control countries have implemented subsidies similar to Japan. To qualify as a donor country, a minimum of one annual data point for each predictor variable within the estimation period is required, which reduces the pool of potential donor countries, primarily excluding small economies.

Figure 2: Donor pool countries



The map depicts the donor pool used in the synthetic control analysis, consisting of countries with green bond issuance but without comparable subsidy schemes. Countries are excluded if they lack sufficient data for the predictor variables over the estimation period or if they implemented overlapping green bond support policies. (Countries with data: Australia, Austria, Belgium, Brazil, Chile, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Côte d'Ivoire, Egypt, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Jordan, Kazakhstan, Kenya, South Africa, South Korea, Luxembourg, Malaysia, Malta, Mauritius, Mexico, Morocco, Namibia, Netherlands, New Zealand, Norway, Panama, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Serbia, Seychelles, Singapore, Slovakia, Slovenia, Spain, Switzerland, Thailand, Turkey, Ukraine, United Kingdom, United States. / Countries without data: Andorra, Argentina, Benin, Bermuda, Bolivia, Burkina Faso, Canada, Cayman Islands, Channel Islands, China, Denmark, Dominican Republic, Ecuador, Estonia, Fiji, Finland, Georgia, Guinea-Bissau, Guatemala, Honduras, Hong Kong, Iceland, Isle of Man, Latvia, Laos, Liechtenstein, Lithuania, Macau, Mali, Marshall Islands, Niger, Nigeria, Pakistan, Paraguay, Senegal, Sudan, Sweden, Togo, United Arab Emirates, Uruguay, Uzbekistan, Venezuela, Vietnam, Virgin Islands).

Predictor variables are key observed characteristics used in the SCM for constructing a synthetic counterpart for the treated unit. These variables are selected based on their relevance to the outcome of interest, guiding the creation of a weighted combination of untreated units that closely mirrors the pre-intervention trends and attributes of the treated unit. In our case, we select predictor variables related to the determinants of the green bond market, drawing on empirical research on its drivers (Tolliver et al. 2020), the effects of green bond policies (Lee et al. 2023), and established studies applying SCM to country-level outcomes (Abadie and

Gardeazabal 2003, Abadie et al. 2015). This results in the inclusion of 14 country-level economic indicators from the World Bank's open database, capturing key factors that influence green bond markets (see Table 1). Furthermore, we use the first Japanese green bond issuance—October 2014—as a special predictor for each of the outcome variables, marking the inception of Japan's green bond market and its synthetic counterpart. This variable captures the timing of market maturity, an important factor in understanding the effectiveness of subsidy interventions, as the stage of market development at which the subsidy is introduced can significantly influence outcomes. By matching the predictor variables, the SCM estimates the counterfactual outcome of the treated unit in the absence of the intervention, thereby enabling a clear assessment of treatment effects.

Table 1: SCM predictor variables

Variable	Description	References
PPP	Gross domestic product based on purchasing power parity	Abadie et al. 2015, Eichengreen and Luengnaruemitchai 2004, Tolliver et al. 2020
TRD	Trade-to-GDP ratio	Abadie et al. 2015, Rajan and Zingales 2004, Tolliver et al. 2020
STV	Stocks traded, total value	Claessens et al. 2007, Tolliver et al. 2020
ROL	Rule of Law	Eichengreen and Luengnarumitchai 2004, LaPorta et al. 1998, Tolliver et al. 2020
RQE	Regulatory Quality	Mauro 1995, Tolliver et al. 2020
POP	Population density	Abadie and Gardeazabal 2003, Becker et al. 1999, Lee et al. 2023
SET	School enrollment, tertiary	Abadie and Gardeazabal 2003, Lee et al. 2023
SVA	Services, Value Added	Abadie and Gardeazabal 2003, Abadie et al. 2015, Lee et al. 2023, Saint-Paul 1992
GOV	Government Expenditure	Devarajan et al. 1996, Lee et al. 2023
FDI	Foreign Direct Investment	Lee et al. 2023, Li and Liu 2005, Mello 1997, Zhang 2001
GDP	GDP per Capita Growth	Abadie and Gardeazabal 2003, Chen 1991, Lee et al. 2023
DCP	Domestic Credit to Private Sector	Abadie et al. 2015
INF	Inflation rate	Abadie et al. 2015, Fama and Gibbons 1982
GCF	Gross Capital Formation	Abadie and Gardeazabal 2003

The table presents the predictor variables used in the SCM analysis. Each variable is accompanied by a brief description and the relevant literature that supports its inclusion. The selected predictors are sourced from well-established (empirical) studies, ensuring their theoretical and practical relevance. A more detailed description of all variables is provided in the Appendix.

Our sample comprises a balanced panel spanning the total period $T = T_0 \cup T_1$, where T_0 denotes the pre-intervention period and T_1 the post-intervention period. The intervention—Japan's introduction of the green bond subsidy in April 2018—occurs at $t = 0$. The treated unit is affected from $t \geq 0$ onward, while for $t < 0$, outcomes reflect the untreated trajectory Y_{1t}^{N}. The pre-intervention period starts with the first green bond issuance (EIB, July 2007) and ends six months before the intervention $(t - 6)$ to avoid anticipation effects (Abadie 2021). Embedded within this pre-intervention period, the optimization window spans five years

leading up to the six-month cutoff point ($t-66$ to $t-6$, i.e. October 2012 to October 2017), which is used to calibrate the weights of the control units. This window ensures that the synthetic control closely mimics the pre-treatment trends of the treated unit.

The SCM constructs a weighted average of control units to approximate the counterfactual path of the treated unit. Let $\boldsymbol{X_1}$ be a $k \times 1$ vector of pre-intervention characteristics of the treated unit, and $\boldsymbol{X_0}$ be a $k \times J$ matrix for the control units. The weights $\boldsymbol{W} = (w_2, \ldots, w_{J+1})'$ are chosen to minimize the weighted distance between $\boldsymbol{X_1}$ and $\boldsymbol{X_0 W}$. The relative importance of each predictor is captured in a diagonal matrix $\boldsymbol{V}$, which assigns non-negative weights $v_1, \ldots, v_k$ to the predictors. Formally, the optimization problem is:

$$\boldsymbol{W}^* = arg\min_{\boldsymbol{W} \in \mathcal{W}} (\boldsymbol{X_1} - \boldsymbol{X_0 W})' \boldsymbol{V} (\boldsymbol{X_1} - \boldsymbol{X_0 W})$$

Where $\mathcal{W} = \{\boldsymbol{W} \in \mathbb{R}^J : w_j \geq 0,\ \sum_j w_j = 1\}$ is a set of non-negative weights that sum to one.

The outcome, denoted as Y_{jt}, represents the value of the variable of interest (i.e., *BondCount*, *MarketVolume*, *UniqueIssuers*, and *IssuanceAmount*). The estimated counterfactual for the treated unit in the post-intervention period is given by:

$$\widehat{Y_{1t}^N} = \sum_{j=2}^{J+1} w_j^* Y_{jt}$$

and the estimated treatment effect is:

$$\widehat{\tau_{1t}} = Y_{1t} - \widehat{Y_{1t}^N}$$

The predictor variables $\boldsymbol{X_1}$ and $\boldsymbol{X_0}$, used to compute the optimal weights $\boldsymbol{W}^*$, are selected based on pre-intervention characteristics that predict post-intervention outcomes and are assumed to remain unaffected by the intervention. This approach provides a robust, data-driven framework for estimating the causal effect of the green bond subsidy by constructing a credible counterfactual trajectory for the treated unit.

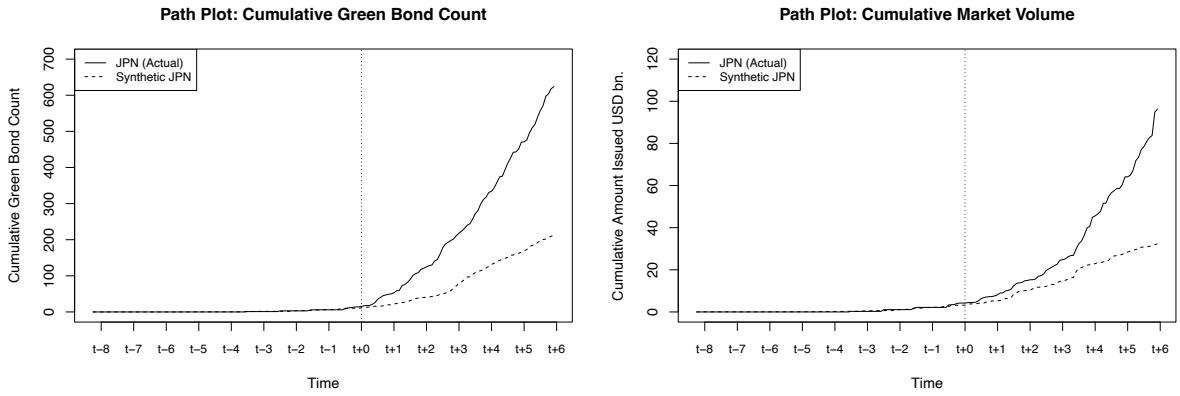
4.2 Market Effects of the Subsidy

Japan's green bond subsidy significantly accelerates market development by driving substantial increases in bond issuance, fostering market growth, and broadening issuer participation, while simultaneously reducing the average issuance size. We start by analyzing the subsidy's effect on the number of green bonds issued (*BondCount*). Prior to the subsidy, Japan issued 14 green bonds in total. Right after the subsidy is introduced the actual (solid line) and synthetic (dotted line) paths of green bond counts diverge significantly (see Figure 3). In the first post-subsidy year, the green bond market grows by 257%. This subsidy-driven surge

expands Japan's green bond market, measured by bond count, to 44 times its original size by the end of $t + 5$, compared to 19 times in Japan's synthetic green bond market. On average, the market grows at a monthly rate of about 6% post-subsidy, while synthetic Japan grows by 4%. As a result, the subsidy not only accelerates growth but also elevates Japan to the sixth-largest global issuer—after China, Sweden, United States, Germany, and France—in terms of green bond count, well above the anticipated thirteenth-place ranking without the intervention.

With respect to market volume (*MarketVolume*), actual and synthetic Japan exhibit a comparable divergence (see Figure 3). At the time of subsidy introduction, the market volume amounts to USD 4.21 billion. Since then, the market expands over 21 times, reaching USD 96.26 billion compared to synthetic Japan with only USD 32.32 billion. The average yearly growth rate for Japan post-subsidy is 70%, compared to 51% in the synthetic scenario, with market volume nearly doubling in the first year post-subsidy.

Figure 3: Trends in green bond issuance: Japan vs. synthetic Japan path plots

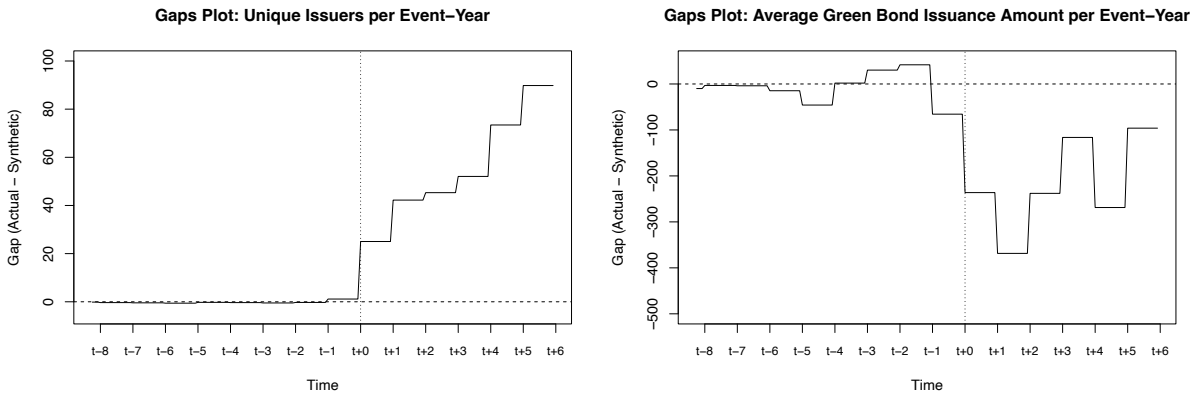


Path plot of the cumulative green bond count (*BondCount)* and the cumulative green bond market volume *(MarketVolume)* for Japan (solid line) and its synthetic counterpart (dashed line). The dashed vertical line marks the introduction of the subsidy in 04.2018.

Next, we focus on the number of unique issuers (*UniqueIssuers*) to examine whether the subsidy attracts more participants to the green bond market. Unique issuers see a distinct post-subsidy divergence (see Figure 4). The year before the subsidy, there are only seven unique issuers per event-year, which increases to 124 unique issuers five years after the policy intervention. In comparison, synthetic Japan reaches only 34 unique issuers by the same time. Immediately following the subsidy introduction, the number of unique issuers increases by 371%, maintaining a steady growth trajectory with an average annual growth rate of 89%. Between April 2022 ($t + 4$) and April 2023 ($t + 5$) growth slows to 7%, while synthetic Japan fails to sustain this rate, experiencing a 33% decline during the same period.

Finally, we examine whether the average issuance amount (*IssuanceAmount*) is affected by the subsidy. Indeed, issuance amounts decrease, with the average issue amount per event-year dropping over 62%, from USD 255.97 million to USD 95.42 million in the first year post-subsidy (see Figure 4). In contrast, synthetic Japan sees a modest increase of 3%, rising from USD 321.63 million to USD 331.73 million in the same period. Following the initial decline, Japan's issue size rebounds, reaching USD 208.74 million five years after the intervention but staying below the USD 304.84 million observed for the synthetic counterfactual. Furthermore, eight of the nine unique issuers before the subsidy continue issuing bonds post-subsidy, with corporate issuers reducing the size of their average bond issuance by 15% (USD 435 million to USD 371 million) and government issuers increasing theirs (USD 180 million to USD 381 million). Notably, the number of issuers issuing multiple bonds within a month rises significantly from one pre-subsidy to 62 post-subsidy, averaging 2.36 issuances per month.

Figure 4: Trends in green bond issuance: Japan vs. synthetic Japan gaps plots



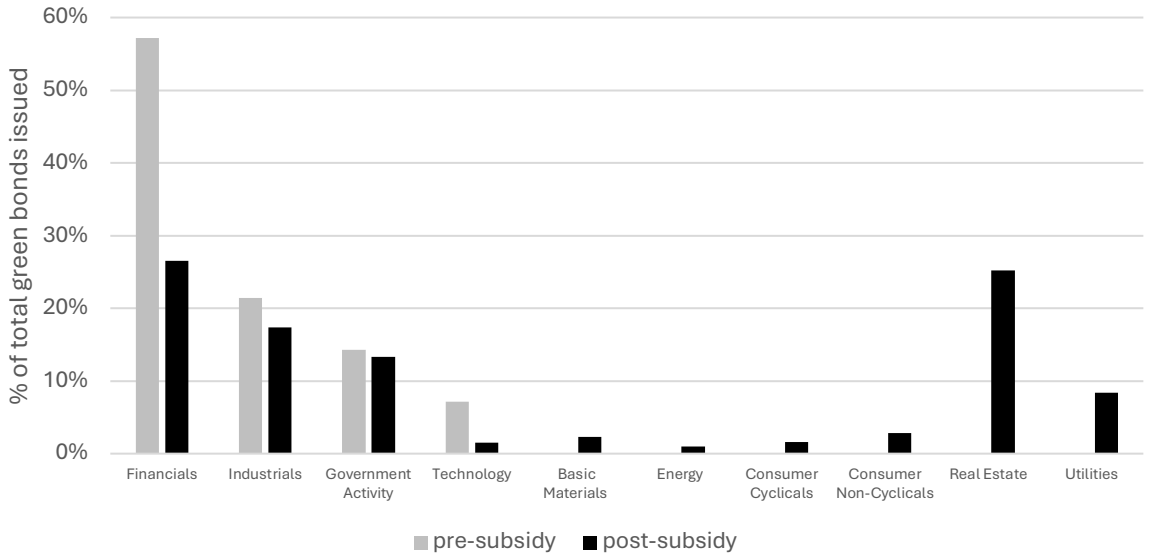
Gaps plot of the difference in unique issuers (*UniqueIssuers*) and average green bond issuance amount in USD million (*IssuanceAmount*) per event-year between Japan and its synthetic counterpart, with the synthetic control serving as the baseline. The dashed vertical line marks the introduction of the subsidy in 04.2018.

4.3 Sector-Level Analysis

As the number of unique issuers increases substantially after the subsidy is introduced, we examine sector dynamics and variation in the bonds use of proceeds. For the former analysis, we split the sample into pre- and post-subsidy periods and examine each sector's share of the total green bond count. Before the subsidy, firms in the financial industry dominate Japan's green bond market with a 57% share. Post-subsidy, this share drops to 27%, reflecting increased participation from other industries. Notably, the real estate sector grows from 0% pre-subsidy to 25% post-subsidy (see Figure 5). Examining the use of proceeds reveals a significant increase in categories like Energy Efficiency, Clean Transport, Climate Change

Adaptation, and Green Construction. Post-subsidy, Energy Efficiency projects account for 40%, with Green Construction jointly comprising nearly half the allocation. The findings align with Japan's Strategic Energy Plan (2018) (International Energy Agency 2019) and revisions to the Energy Efficiency Act (International Energy Agency 2017), emphasizing energy-efficient designs and climate adaptation, prompting real estate companies to leverage green finance. The rise in Clean Transport reflects Japan's Green Growth Strategy (Ministry of Economy, Trade and Industry 2022), aiming to reduce transport emissions below 2013 levels (United Nations Framework Convention on Climate Change 2021).

Figure 5: Sector distribution before and after subsidy introduction



The figure reports the percentage share of total green bonds issued across the TRBC 2-digit sectors during the pre- and post-subsidy period in Japan.

To further test whether Japan's green bond subsidy leads to broader sectoral participation, we construct a panel of country-sector-year observations from our global green bond issuance dataset. For each observation, we define a binary outcome variable $Sector\ Participation_{c,s,t}$ equal to one if a sector s in country c issues at least one green bond in year t. We then estimate the following DiD model:

$$Sector\ Participation_{c,s,t} = \alpha + \beta_1 \times Treatment_{c,t} + \gamma_s + \delta_t + \lambda_c + \varepsilon_{i,t}$$

where $Treatment_{c,t}$ is a binary interaction term, which is one for the post-subsidy period in Japan and zero otherwise. γ_s, δ_t, and λ_c are sector, year, and country fixed effects and $\varepsilon_{i,t}$ is the error term. The coefficient β_1 captures the differential change in sector-level green bond activity in Japan after the subsidy.

To complement this, we aggregate the data to country-year level and estimate a second DiD model with the number of active sectors ($Sector\ Diversity_{c,s}$) as the outcome:

$$Sector\ Diversity_{c,s} = \alpha + \beta_1 \times Treatment_{c,t} + \delta_t + \lambda_c + \varepsilon_{i,t}$$

This allows us to capture both the probability of individual sector participation and overall diversification of the green bond market.

As shown in Table 2, the subsidy leads to a statistically significant increase in the likelihood that a given sector issues at least one green bond in a given year—rising by approximately 44 percentage points. Complementing this, the parallel country-year analysis reveals that Japan recorded, on average, about 5.7 more active sectors per year following the subsidy's introduction. This reflects a substantial broadening of sectoral participation in the green bond market. These results remain robust when restricting the control group to OECD countries and when accounting for sector-specific trends, suggesting the observed expansion is attributable to the subsidy rather than underlying sectoral dynamics.

Table 2: Sectoral participation and diversity following subsidy introduction

	Sector Participation	**Sector Diversity**
Treatment	0.439***	5.702***
	(0.015)	(0.195)
Sector fixed effects	Yes	No
Time fixed effects	Yes	Yes
Country fixed effects	Yes	Yes
R-squared	0.265	0.638
Observations	19,422	1,494

The table reports the estimates from the difference-in-differences regressions evaluating the effect of Japan's green bond subsidy on sector dynamics. The treatment indicator equals one for Japan in the post-subsidy period (April 2018 onwards) and zero otherwise. Column (1) uses a country–sector–year panel; Column (2) collapses the data to country–year. All specifications include country and year fixed effects; the sector-level model additionally includes sector fixed effects. Standard errors, reported in parentheses, are clustered at the country level. *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

4.4 Extended Difference-in-Differences Approach

DiD can serve as a complementary analysis to the SCM and provide a useful benchmark for assessing robustness. This perspective is reinforced by Abadie, who shows that DiD can be seen as a special case of the broader framework underlying the SCM (Abadie 2021). When both methods yield consistent results, confidence in the estimated treatment effect is strengthened. We use the same setting as in the SCM and estimate the empirical model via a two-way fixed effects specification with country and month fixed effects:

$$Y_{i,t} = \alpha_i + \delta_t + \beta_1 \times Treatment_{i,t} + \beta_2 \times Controls_{i,t} + \varepsilon_{i,t}$$

$Y_{i,t}$ is the outcome variable—i.e. *BondCount*, *MarketVolume*, *UniqueIssuers* or *IssuanceAmount*—for country i at time t. $Treatment_{i,t}$ is a binary interaction term, which is

one for the post-subsidy period in Japan and zero otherwise. Therefore β_1 captures the average treatment effect on Japan post-subsidy. In extended specifications, we also include a set of time-varying controls ($Controls_{i,t}$) identical to the predictor variables used in the SCM setup. $\varepsilon_{i,t}$ is the error term and robust standard errors are clustered at the country level.

The DiD analysis reinforces the SCM findings, indicating the subsidy's significant impact on market development. Consistent with the sharp divergence in bond counts observed in Figure 3, DiD estimates in Table 3 show a significant post-subsidy increase of green bonds per month. The rise in market volume seen in the SCM is echoed in the DiD results, though the effect becomes insignificant with controls, indicating sensitivity to macro trends. The increase in unique issuers is strongly supported by the DiD estimates, underscoring the subsidy's role in expanding market participation. Finally, the DiD also confirms the SCM-detected drop in average issuance size, pointing to broader but smaller-scale activity. Robustness tests that restrict the control countries to OECD members yield consistent results. Overall, the DiD results mirror the SCM trajectory across almost all indicators, lending additional credibility to the causal interpretation.

Table 3: Green bond market outcomes following subsidy introduction

Panel A: *BondCount* and *MarketVolume*

	BondCount		**MarketVolume**	
Treatment	6.476***	4.933***	19.630***	4.108
	(27.037)	(13.746)	(3.563)	(1.407)
PPP		0.130		4.956
		(0.769)		(1.292)
TRD		−0.002		0.106
		(−0.366)		(1.411)
STV		0.307***		1.464
		(2.946)		(1.449)
ROL		−0.337		−9.622***
		(−1.038)		(−2.708)
RQE		−0.018		6.543**
		(−0.050)		(2.114)
POP		−0.002		−0.012
		(−0.802)		(−0.480)
SET		−0.006		−0.093
		(−1.079)		(−1.473)
SVA		−0.001		0.093
		(−0.082)		(0.635)
GOV		0.005		0.130*
		(0.627)		(1.697)
FDI		−0.001		0.002
		(−1.266)		(0.311)
GDP		−0.006		−0.007
		(−0.530)		(−0.054)
DCP		0.006		0.053
		(1.614)		(1.385)
INF		−0.001		0.065

		(−0.147)		(0.633)
GCF		0.028*		0.136
		(1.690)		(1.212)
Country fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	17,100	8,652	17,100	8,652
R-squared	0.291	0.370	0.371	0.632

Panel B: *UniqueIssuers* and *IssuanceAmount*

	UniqueIssuers		**IssuanceAmount**	
Treatment	62.528***	50.261***	−157.310***	−246.844***
	(37.790)	(24.660)	(−4.649)	(−5.827)
PPP		2.106		36.667
		(1.414)		(1.666)
TRD		0.035		2.301***
		(1.320)		(2.805)
STV		1.623*		−17.301**
		(1.726)		(−2.169)
ROL		−5.015***		−240.291**
		(−2.795)		(−2.568)
RQE		2.265		199.330***
		(1.372)		(3.397)
POP		−0.012		−0.817
		(−1.006)		(−1.435)
SET		−0.058		−1.688
		(−1.661)		(−1.141)
SVA		−0.040		−3.063
		(−0.354)		(−0.812)
GOV		0.078*		0.838
		(1.830)		(0.309)
FDI		−0.003		0.438
		(−0.484)		(1.554)
GDP		−0.003		−3.230
		(−0.032)		(−0.841)
DCP		0.050*		−1.484
		(1.854)		(−0.928)
INF		0.014		−0.839
		(0.220)		(−0.319)
GCF		0.205**		5.851**
		(2.387)		(2.285)
Country fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Observations	16,800	8,448	17,100	8,652
R-squared	0.529	0.697	0.174	0.256

The table reports the estimates from the difference-in-differences regressions evaluating the effect of Japan's green bond subsidy on issuance dynamics. The treatment variable is an indicator equal to one for Japan in the post-subsidy period (April 2018 onwards). All regressions include country and time fixed effects. Control specifications include the full set of macroeconomic and institutional variables used in the SCM. Standard errors are clustered at the country level and t-statistics are reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

In sum, the introduction of Japan's green bond subsidy significantly strengthens the country's green bond market, particularly by increasing the number of bonds issued and attracting a broader set of issuers. The SCM analysis confirms sustained growth in bond count and issuer participation, as well as a significant rise in market volume. While DiD estimates for market volume are sensitive to the inclusion of controls, the overall evidence suggests that

the subsidy plays a role in deepening the market. This development not only supports sustainable project funding and aligns with Japan's environmental goals, but a more developed green bond market and broadened issuer participation enables the economy to better withstand financial shocks and distributes risks across sectors (OECD 2024, BlackRock 2022). Furthermore, by elevating Japan to the sixth-largest global issuer in green bonds, the subsidy strengthens its global standing in sustainable finance.

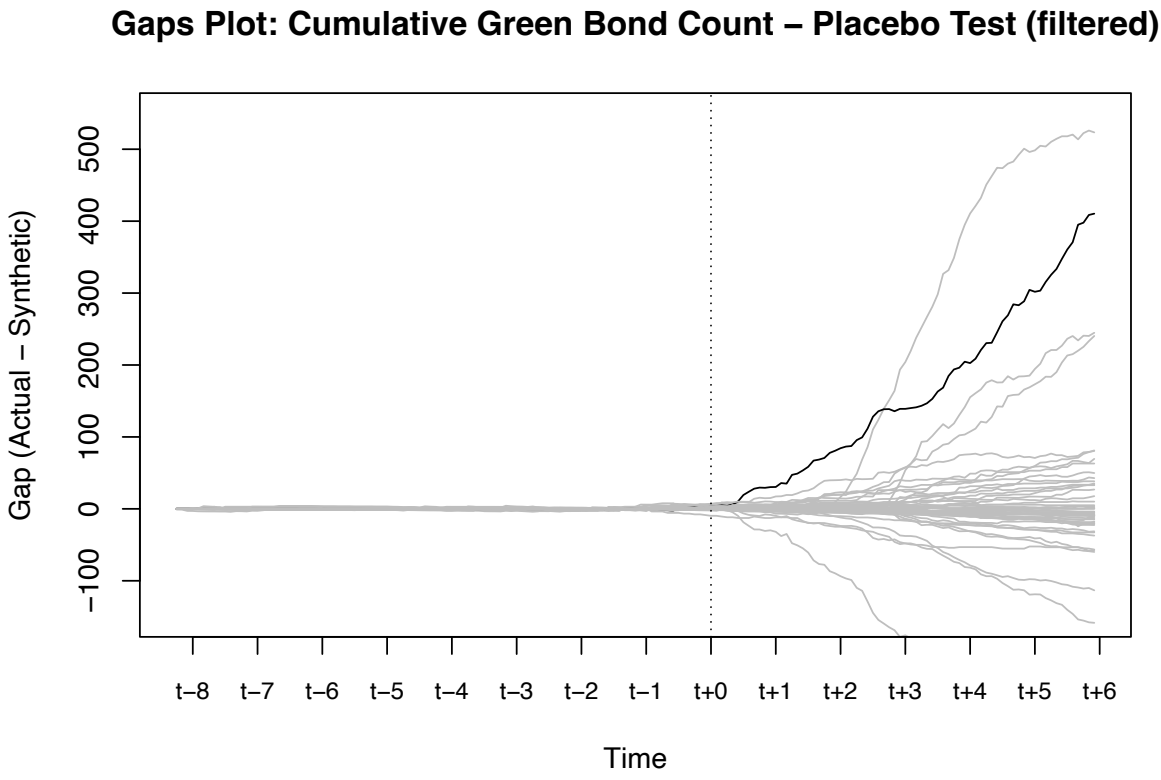
4.5 SCM Robustness

To evaluate the consistency of the treatment effect and the stability of the synthetic control model, we assess the significance of the treatment effect by conducting placebo tests (Abadie et al. 2010). Using the SCM, we construct counterfactual scenarios where control group units are hypothetically exposed to the intervention, while the treated unit is shifted back to the donor pool. If the resulting placebo effects are comparable to the observed effect, this indicates that the treatment has no significant impact. Conversely, consistently smaller placebo effects provide evidence of a significant treatment effect. The reliability of placebo tests depends on the accuracy of the synthetic control unit. To ensure this, we exclude control units with a pre-treatment Mean Squared Prediction Error (pre-MSPE) exceeding a country-specific factor of the treated unit's pre-MSPE, as they violate the parallel trends assumption (Abadie et al. 2010). The MSPE measures the average squared differences between actual and synthetic outcomes, serving as a metric for model accuracy. By filtering out units with a high pre-MSPE, we enhance the robustness of our comparisons between treatment and placebo effects. To further evaluate the accuracy of the synthetic control, we compute the Root Mean Squared Prediction Error (RMSPE), which is the square root of the MSPE. A low RMSPE indicates a reliable synthetic control and is calculated as follows:

$$RMSPE = \left(\frac{1}{T_0} \sum_{t=1}^{T_0} \left(Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \right)^2 \right)^{\frac{1}{2}}$$

Figure 6 displays the results of the placebo tests for the variable green bond count (*BondCount*). Among the countries tested, only Germany shows a larger difference in outcome (see Figure 6), making it the only country exceeding Japan in this regard. The probability of observing a gap of this size under a random permutation of the intervention is less than 5%, indicating statistical significance (Abadie et al. 2010). The lack of similar effects in placebo countries indicates limited confounding factors.

Figure 6: Trends in green bond count (*BondCount*): Placebo test



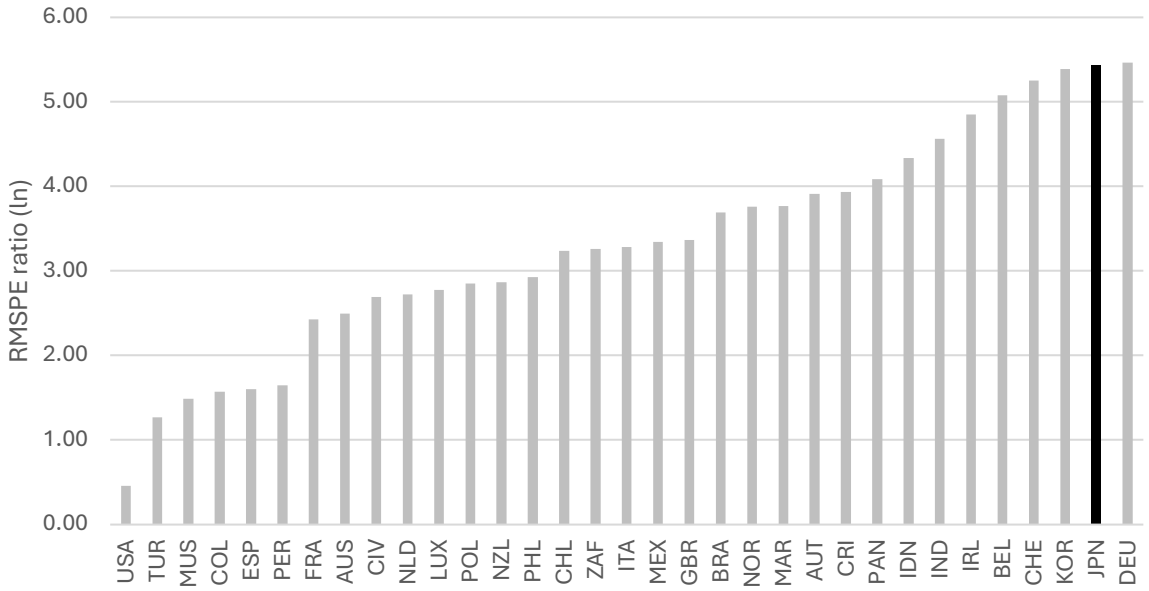
Gaps plots for the placebo test of the cumulative green bond count (*BondCount*). Treatment is falsely assigned to control units from the donor pool. Grey lines show gaps plots for placebo-treated units, the black line shows Japan's gaps plot. Countries with a pre-subsidy MSPE 20 times higher than Japan are discarded. The dashed vertical line marks the introduction of the subsidy in 04.2018.

To compare the treatment and control groups, we compute the RMSPE ratio, which is influenced by two key factors: the alignment of pre-treatment characteristics and the post-treatment gap between the treated unit and its synthetic counterpart. The RSMPE ratio is defined as the post-treatment RMSPE divided by the pre-treatment RMSPE:

$$RMSPE\text{-}Ratio = \frac{post\text{-}RMSPE}{pre\text{-}RMSPE}$$

A higher RMSPE ratio for the treated unit compared to the control group suggests a significant treatment effect (Abadie et al. 2010, Abadie et al. 2015). To keep the comparison meaningful, we exclude countries that didn't issue green bonds before the intervention, avoiding inflated ratios driven by near-zero baselines. Within this trimmed donor pool, Japan shows the second-highest RMSPE ratio (see Figure 7), pointing to a substantial, policy-induced shift in green bond issuance behavior, rather than poor model fit or low baseline activity.

Figure 7: RMSPE ratio (ln) of the green bond count *(BondCount)*



This figure reports the natural logarithm (ln) of the RMSPE ratio of the cumulative green bond count (*BondCount*), which is the ratio of post-intervention RMSPE to pre-intervention RMSPE. Placebo tests form the basis for the calculation of the pre- and post-RMSPE. Countries with zero green bond issuance in the pre-treatment period are excluded from the analysis. Japan, represented by the black bar, demonstrates a high post-intervention RMSPE, along with a notably low pre-treatment value.

Furthermore, we conduct sensitivity tests to assess the resilience of our primary findings to variations in the predictor weights, denoted as V^*. These weights are derived from the optimization process used in the SCM to approximate the treated unit's characteristics. To address concerns about overfitting and robustness, we iteratively delete each predictor variable to observe its influence on the results. In this process, we repeatedly re-estimate the baseline model to generate a synthetic unit, systematically excluding one of the predictor variables in each iteration. While this approach may entail a reduction in goodness of fit, it serves as a crucial sensitivity analysis, enabling us to evaluate the influence of individual predictors on our results (Abadie et al. 2015). The results remain robust and consistent throughout this procedure (see OA Figure 1).

To ensure that our estimated treatment effect is not confounded by contemporaneous Japanese climate and energy policies, we restrict the sample to exclude bond issuances most directly shaped by such initiatives. Specifically, Japan's 2018 Strategic Energy Plan (International Energy Agency 2019) and successive amendments to the Energy Efficiency Act (International Energy Agency 2017) channel funding toward building-related energy efficiency and climate adaptation, while the Green Growth Strategy (Ministry of Economy, Trade and Industry 2022) prioritizes low-carbon transport. These policy shifts are clearly reflected in the post-subsidy data: energy-efficiency projects alone account for around 40% of total proceeds,

and—together with green construction—make up nearly half the market, while clean transport sees a marked increase. To account for these dynamics, we exclude (i) all real estate issuers and (ii) any bond whose use of proceeds is classified as energy efficiency, green construction, or clean transport. Re-estimating the synthetic control model on this restricted sample produces treatment effects that remain robust. This confirms that our findings are not artefacts of overlapping policy measures.

To further strengthen the robustness of our findings, we conduct additional tests addressing potential confounding factors. To address concerns about the choice of countries serving as potential controls, we limit the donor pool to OECD countries, ensuring comparability and avoiding over-reliance on small economies. Furthermore, we exclude the US and China given their green finance policy interventions. To rule out that the subsidy's effects are driven by government-issued bonds, we exclude them from our analysis. These measures collectively enhance the robustness of our analysis, isolating the specific effects of the green bond subsidy. These additional tests consistently support the robustness of the subsidy's estimated effects on Japan's green bond market, indicating that the observed trends are unlikely to be driven by specific predictors, alternative donor pool selections, government-issued bonds, or concurrent policies, thereby reinforcing the validity of our findings.

5 Disaggregate Firm-Level Dynamics

This section shifts the focus from aggregate market outcomes to firm-level dynamics, assessing whether green bond issuance affects stock market reactions and environmental performance. We begin with an event study that evaluates investor responses to green bond announcements and continue with firm-level DiD models to examine how green bond issuance influences firm environmental performance.

5.1 Event Study

To complement our SCM findings, we examine how financial markets respond to green bond announcements. While conventional bond issuance typically causes no significant market reaction (Eckbo et al. 2007), green bonds may generate mixed responses: their higher costs could prompt a negative reaction, but their sustainability signal, generally viewed favorably, might lead to a positive response (Flammer 2013, Klassen and McLaughlin 1996, Krueger 2015). We hypothesize that as Japan's subsidy offsets the additional costs, the positive sustainability signal dominates.

To test this hypothesis, we conduct an event study following the specification in Flammer (2021). Daily stock price data is sourced from LSEG, while the five-factor data is obtained from the Fama-French database for Japan. Event dates are identified based on the announcement date disclosed by LSEG. Stock returns are calculated using the total return index, and excess returns are determined by subtracting the risk-free rate from the individual stock returns. Initially, we identify 404 announcement dates across 177 companies. We retain only the first issuance per company, which carries the most information (Flammer 2021). This reduces the sample to 177 announcement dates, which further narrows to 138 after accounting for stock data availability. Using a 200-trading day estimation window ending 20 trading days before each event date, the abnormal returns are calculated based on the Fama-French five-factor model:

$$AR_{i,t} = R_{i,t} - [R_{f,t} + \widehat{\alpha_i} + \widehat{\beta_{1,i}}(R_{m,t} - R_{f,t}) + \widehat{\beta_{2,i}}SMB_t + \widehat{\beta_{3,i}}HML_t + \widehat{\beta_{4,i}}RMW_t + \widehat{\beta_{5,i}}CMA_{i,t}]$$

where $(R_{m,t} - R_{f,t})$ is the excess market return at time t, $R_{f,t}$ is the risk-free rate, and the terms SMB_t, HML_t, RMW_t, and $CMA_{i,t}$ represent the size, value, profitability, and investment factors, respectively. Abnormal returns are aggregated into cumulative abnormal returns ($CARs$) over specified event windows, as follows:

$$CAR_{i,t} = \sum_{t=\tau_1}^{\tau_2} AR_i$$

The primary event window spans [–5, 10], with additional intervals—[–20, –11], [–10, –6], [11, 20], [21, 60]—analyzed to capture pre- and post-event effects. To ensure robustness, we also examine alternative event windows, testing whether our findings remain consistent across varying time frames. The $CARs$ are statistically evaluated using t-tests to assess whether their mean significantly deviates from zero.

We find that $CARs$ in the event window [–5, 10] are small and statistically insignificant (see Table 4). These results hold across other event windows, subsamples split in pre- and post-subsidy introduction, early and late adoption, and under alternative models, including the Fama-French Three-Factor Model and the market model (see OA Table 2).

Table 4: Event study results to the green bond announcement

	FF5M			
Event time	CAR	Std. err.	T-statistic	P-value
[–20, –11]	0.0026	0.0408	0.7393	0.46
[–10, –6]	0.0034	0.0340	1.1661	0.25
[–5, 10]	0.0011	0.0446	0.2948	0.77
[11, 20]	0.0011	0.0148	0.8625	0.39
[21, 60]	0.0041	0.0269	1.7782	0.08 *

This table reports the stock market reaction to the announcement of a green bond issuance. We report the average cumulative abnormal return (CAR) for different event windows with the announcement of the green bond issuance designated as the event. The sample consists of $N = 138$ Japanese first-time green bond issuances. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

5.2 Firm-level Difference-in-Differences Analysis

Green bonds are intended to finance projects with environmental benefits, which raises the question of whether they improve the emissions of issuing firms. A key challenge in identifying such effects is that issuers may differ from non-issuers in unobservable ways, such as their underlying commitment to sustainability. To address this, we follow Flammer (2021) and implement a matching-based DiD approach that pairs green bond issuers with similar non-issuers based on several firm-level characteristics, aiming to reduce selection bias. Treated firms, defined as the 177 Japanese-listed companies issuing green bonds, are matched to control firms based on several criteria to ensure comparability. These include being from the same country and two-digit TRBC economic sector, as well as proximity in firm-level characteristics (obtained from LSEG): total assets (WC02999), return on assets (WC08326), market to book value (MTBV), leverage (WC08221), and environment rating (ENSCORE). Matching is performed using the Mahalanobis distance, considering both the levels of these variables in the year preceding the green bond issuance ($t-1$) and their pre-trends ($t-2$ to $t-1$) (see OA Table 1). Data for the matching and outcome variables is sourced from LSEG, covering the timeline from 2010 to 2024, with the earliest issue year of a green bond from a listed Japanese company being 2019. The matching process reduces the sample size to 77 treated firms due to limitations in data availability for the required variables.

The DiD is specified as follows:

$$Y_{i,t} = \alpha_i + \alpha_s \times \alpha_t + \beta_1 \times Green\ bond_{i,t} + \beta_2 \times Controls_{i,t} + \varepsilon_{i,t}$$

where $Y_{i,t}$ is the outcome—CO_2 emissions, or emission intensity—for firm i in year t. Firm fixed effects α_i and sector-year fixed effects $\alpha_s \times \alpha_t$ account for unobserved heterogeneity. $Green\ bond_{i,t}$ is the treatment indicator equal to one from the year of the firm's green bond issuance onward. $Controls_{i,t}$ include total assets, return on assets, market to book

value, and leverage. Standard errors are clustered at the sector level. The coefficient β_1 captures the average treatment effect of green bond issuance relative to matched controls.

Our findings reveal no significant changes in CO_2 emissions or emission intensity (see Table 5), suggesting that green bond issuance has limited immediate impact on these metrics.

Table 5: Environmental performance following green bond issuance

	Environmental performance			
	CO_2 emissions		Emission intensity	
Green bond	1753.156	1645.438	79.917	62.345
	(1836.021)	(1749.965)	(82.561)	(67.107)
Total assets (log)		2761.522		222.962
		(2493.641)		(262.366)
Return on assets		−30.257		−55.005
		(58.185)		(35.855)
Market to book value		5.487		−7.353
		(28.599)		(10.391)
Leverage		74.924		1.080
		(94.191)		(10.187)
Firm fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes
Observations	1,460	1,456	1,460	1,456
R-squared	0.901	0.904	0.933	0.938

The table reports the estimates of the difference-in-differences regression. Green bond is the treatment indicator equal to one from the year of the firm's green bond issuance onward. CO_2 emissions, and control variables are obtained from LSEG. CO_2 emissions is reported in tons. Emission intensity is calculated as the ratio of CO_2 emissions to total assets and expressed in tons of CO_2 per billion JPY. The sample includes all firm-year observations of the treated and matched control firms from 2010-2024. Standard errors (reported in parentheses) are clustered at the two-digit TRBC economic sector level. *, **, and *** denotes significance at the 10%, 5%, and 1% level, respectively.

We complement our analysis with the group-time average treatment effect (ATT) estimator proposed by Callaway and Sant'Anna (Callaway and Sant'Anna 2021), which accounts for staggered treatment adoption and heterogeneous effects—well suited to our context of firms adopting green bond issuance at varying times. To implement this approach, we define treated firms as those 177 Japanese-listed companies that issue green bonds during the sample period (2010–2024). We assign each treated firm to a cohort based on the year of its first green bond issuance. Firms serve as controls until treated, or throughout the sample if they never issue a green bond. This setup enables dynamic comparisons across early adopters, late adopters, and never-treated firms. The outcome variables and covariates are defined in the same way as in our baseline DiD specification.

Formally, we estimate the following group-time ATT model:

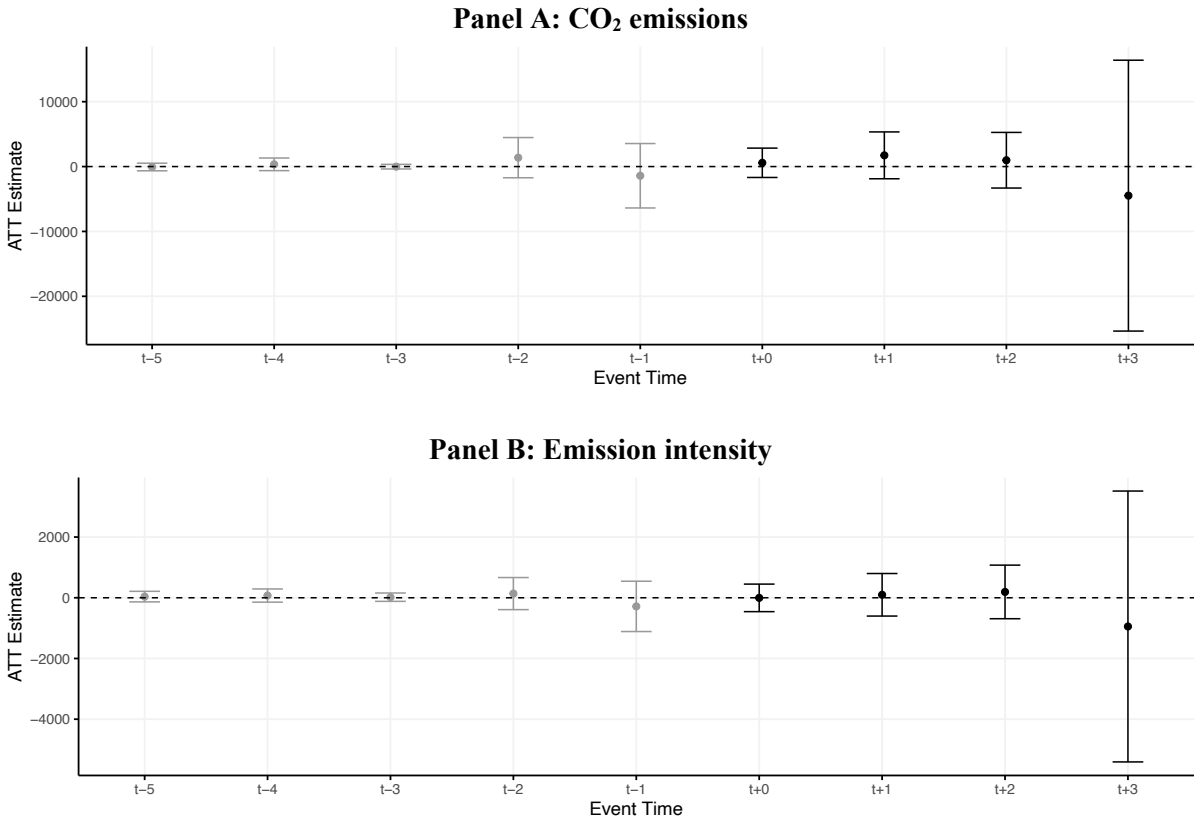
$$Y_{i,t} = \theta_{g,t} \times (G_i = g) + \beta_1 \times Controls_{i,t} + \varepsilon_{i,t}$$

$Y_{i,t}$ denotes the outcome for firm i in year t, $(G_i = g)$ indicates the year firm i first receives treatment (i.e., issues a green bond), $\theta_{g,t}$ captures the average treatment effect for the group treated in year g at time t, $Controls_{i,t}$ is a vector of control variables, and $\varepsilon_{i,t}$ is the

error term. Standard errors are clustered at the firm level. The results are aggregated across treatment cohorts using group-specific ATT estimators to provide an overall and dynamic average treatment effect.

Consistent with the estimates in Table 5, the dynamic treatment effects in Figure 8 provide no evidence of a significant post-treatment improvement in either CO_2 emissions (Panel A) or emission intensity (Panel B). The point estimates show a slightly declining trend in later periods, but large confidence intervals and the lack of statistical significance suggest that any environmental benefits from green bond issuance are, at best, modest and slow to materialize. These findings caution against expecting immediate environmental impact from issuance alone and underscore the importance of examining longer-term dynamics with larger samples.

Figure 8: Dynamic treatment effects of green bond issuance on environmental outcomes



The plots depict group-time average treatment effects estimated using the doubly robust estimator by Callaway and Sant'Anna, with firm-level covariates included. The pre-treatment period is shaded in grey, and the post-treatment period in black. Estimates are based on a staggered adoption design and restricted to five years before treatment. Confidence intervals represent 95% bounds based on robust standard errors. The large confidence intervals toward the end of the event window are due to small sample size.

6 Discussion

This study investigates the effect of Japan's Financial Support Programme for Green Bond Issuance on key issuance dynamics within the country's green bond market. Based on our results, we conclude that the subsidy program in Japan effectively increases green bond issuance, overall market volume, and diversifies the range of issuers. However, the subsidy also leads to a reduction in the average size of green bond issuances. This trend may indicate that firms are optimizing subsidies by issuing smaller bonds more frequently, as reflected in the notable rise in issuers releasing multiple bonds within the same month. At the same time, the influx of smaller issuers post-subsidy introduction—reflected in the decline of the average market capitalization[3] of listed issuers from USD 4.72 billion pre-subsidy to USD 1.06 billion post-subsidy—suggests that this fragmentation is partly driven by increased participation from smaller firms, rather than solely strategic behavior of larger issuers. Supporting this, corporate issuers average bond-to-assets ratio[4] rises from 3.87% pre-subsidy to 5.66% post-subsidy, showing smaller issuers contribute relatively larger issuances. A complementary DiD analysis—mirroring our main specification on firm-level environmental outcomes but now treating leverage as the outcome variable and therefore omitting it from the control set and matching procedure—detects no significant change in firm leverage around green bond issuance. This suggests that many issuers relabel existing or planned debt rather than expand their balance sheets. Imposing a cap on subsidy claims per issuer, as previously implemented in Hong Kong, can prevent strategic issuance fragmentation that inflate administrative costs without boosting overall volume. However, Hong Kong later removed the cap (Hong Kong Monetary Authority 2024), recognizing that while it limits subsidy exploitation, it may also hinder market growth by making smaller green bonds less attractive for new or smaller issuers, given the fixed structuring costs that apply to every issuance.

Whether the subsidy incentivizes the issuance of new green financial instruments or primarily leads to the reclassification of existing ones remains an important aspect to consider. While we observe a significant increase in green bond issuance (*BondCount*), overall market volume (*MarketVolume*), and the number of unique issuers (*UniqueIssuers*) post-subsidy—indicators that suggest a strengthening green finance market—it remains unclear whether the subsidy specifically prompts firms to issue bonds solely because of the program. While comparing the use of proceeds for conventional bonds before and after the subsidy introduction could help identify whether existing green projects were reclassified as green bonds, such an analysis is unreliable and inconclusive, as conventional bonds are typically issued for general

purposes and do not disclose detailed use of proceeds information—LSEG only labels 0.48% as use of proceeds bonds from 07.2007 onward. Further, such an analysis might not fully account for other overlapping policies, market conditions, regulatory changes, and company-level dynamics that could influence green bond issuance.

The statistically insignificant $CARs$ suggest that green bond announcements are not perceived as enhancing firm value, indicating the subsidy does not drive a shift from public to private capital. This aligns with mixed evidence showing that green bond announcements may generate positive market responses when seen as credible signals of environmental commitment—particularly from first-time or certified issuers (Flammer 2021)—but can also lead to negative or muted reactions due to concerns over greenwashing, firm fundamentals, issuance costs, or geographical differences (Khiari et al. 2024, Wu 2022). Furthermore, the muted market response may reflect the maturation of Japan's green bond market, where growth and diversification have likely diluted the signaling power of individual announcements, making them appear routine rather than impactful to investors. This pattern is consistent with theoretical perspectives emphasizing that ESG-related asset pricing effects depend on demand-side shocks and the credibility of climate-related information (Avramov et al. 2024, Barnett 2023). Taken together, green bond subsidies can lower barriers to entry and expand issuer participation, their impact on market perception and stock price reactions remain ambiguous.

While green bonds aim to support corporate sustainability, our results challenge the assumption that issuance alone translates into short-term environmental improvements. This aligns with recent evidence showing no clear link between green bond issuance and CO_2 reductions post-net-zero pledges (Zhou and Kythreotis 2024), while other studies point to more sector-specific effects, suggesting that the impact of green bonds may depend on contextual and sectoral factors (Kartal et al. 2025). Overall, the Callaway and Sant'Anna results offer a more differentiated picture of the environmental effects of green bond issuance, revealing emerging downward trends in CO_2 emissions and emission intensity after issuance. These patterns point to the possibility of delayed environmental improvements, rather than immediate impacts. Taken together, these findings indicate that while green bonds might not yield short-term environmental gains across the board, they may still support gradual improvements. Accordingly, our findings should prompt further research to evaluate the long-term environmental impacts of green bonds.

Overall, the subsidy appears to have effectively lowered financing barriers and broadened market participation, functioning primarily as a market-building instrument. This interpretation is consistent with the view that green capital mobilization alone is unlikely to

drive emission reductions without complementary forces such as investor conviction, regulation, or broader structural change (Angelis et al. 2022).

7 Conclusion

In sum, our findings reveal critical implications for governmental policy design and effectiveness in climate finance. The development of green debt capital markets plays a pivotal role in scaling sustainable finance. By fostering liquidity, transparency, and accountability, robust green bond markets drive capital allocation toward impactful sustainability initiatives, narrowing the global financing gap for climate change mitigation (Saltane 2022). Japan's green bond subsidy, despite constituting just 0.01%[5] of the country's total yearly government expenditure (Ministry of Finance Japan 2024), demonstrates a strategic and globally relevant policy tool to stimulating green finance. Its strength lies in institutional simplicity: operating within existing market frameworks, the subsidy avoids the complexity of taxonomies or regulatory overhauls. This plug-and-play design enhances transferability, particularly to advanced economies that control most global capital and emissions yet often face political or institutional limits to regulatory reform. The Japanese model thus offers a fiscally pragmatic and scalable approach to mobilizing private capital for climate action.

[1] To align with World Bank data, which is used for the SCM, Taiwan is consolidated with China, and Jersey is grouped under Great Britain.
[2] The US previously offered Qualified Energy Conservation Bond and Clean Renewable Energy Bond incentives, which ended in 2017. This program differed from Japan's subsidy model, as it targeted clean energy projects rather than addressing disadvantages and review costs for sustainable bonds. China's green finance policies exhibit substantial heterogeneity due to a pilot zone approach, making it not comparable to Japan. A robustness test including both countries in the donor pool showed consistent results.
[3] Market capitalization (WC08001) is sourced from LSEG.
[4] The bond-to-assets ratio is calculated as the value of each green bond issuance divided by the issuing firm's total assets (WC02999) in the respective year. This ratio provides a standardized measure of the relative size of each issuance compared to the firm's size.
[5] Average is based on every green bond claiming the subsidy.

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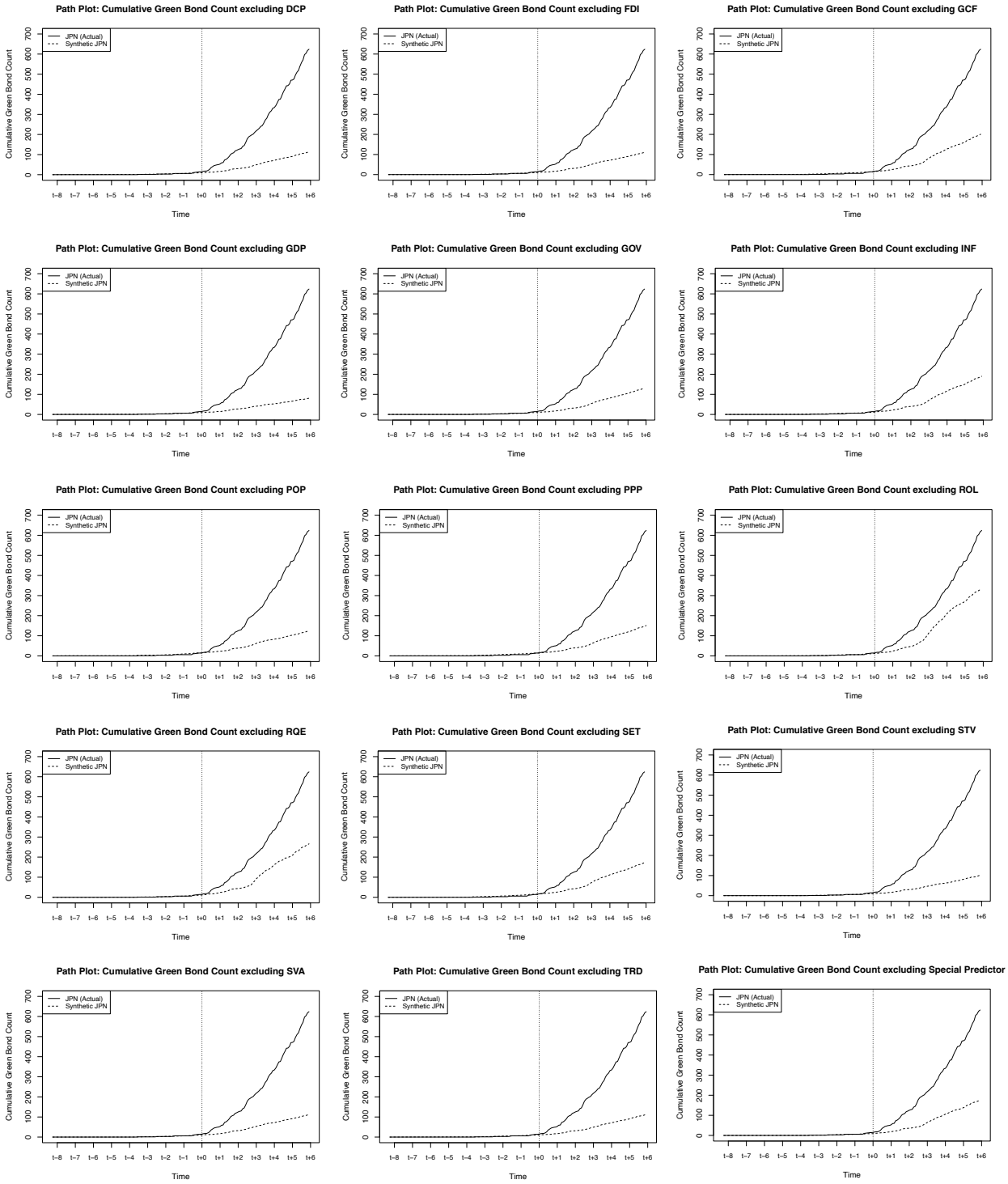
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Online Appendix (OA)

OA Figure 1: Trends in green bond count (*BondCount*): Sensitivity analysis



Path plots for the sensitivity analysis of the predictor variables of the cumulative green bond count (*BondCount*). Baseline model is repeatedly re-estimated to generate a synthetic unit, systematically excluding one of the predictor variables in each iteration. Solid line represents Japan, dashed line synthetic Japan. The dashed vertical line marks the introduction of the subsidy in 04.2018.

OA Table 1: Issuer characteristics before and after matching

		Mean	Std. dev.	P-value	
Panel A. Unmatched characteristics					
Total assets	Green bond	17,581,352,059.69	56,736,643,980.78	0.03	**
	Unmatched control	3,333,078,511.50	12,488,574,864.60		
Return on assets	Green bond	3.10	4.60	0.01	**
	Unmatched control	4.42	5.38		
Market to book value	Green bond	1.14	0.75	0.00	***
	Unmatched control	1.93	4.15		
Leverage	Green bond	46.62	20.32	0.00	***
	Unmatched control	28.22	22.89		
Environment rating	Green bond	67.36	21.75	0.00	***
	Unmatched control	48.77	27.80		
Δ Total assets	Green bond	235,741,941.08	1,786,973,085.51	0.71	
	Unmatched control	159,771,322.79	1,118,136,404.97		
Δ Return on assets	Green bond	−0.41	3.07	0.12	
	Unmatched control	0.15	4.03		
Δ Market to book value	Green bond	−0.08	0.31	0.47	
	Unmatched control	−0.02	5.04		
Δ Leverage	Green bond	0.60	6.75	0.35	
	Unmatched control	−0.13	5.87		
Δ Environment rating	Green bond	3.47	8.94	0.10	*
	Unmatched control	1.76	8.06		
Panel B. Matched characteristics					
Total assets	Green bond	17,581,352,059.69	56,736,643,980.78	0.55	
	Matched control	12,712,450,942.48	42,385,548,540.26		
Return on assets	Green bond	3.10	4.60	0.84	
	Matched control	3.26	5.23		
Market to book value	Green bond	1.14	0.75	0.32	
	Matched control	1.26	0.68		
Leverage	Green bond	46.62	20.32	0.26	
	Matched control	42.87	20.71		
Environment rating	Green bond	67.36	21.75	0.79	
	Matched control	66.45	21.25		
Δ Total assets	Green bond	235,741,941.08	1,786,973,085.51	0.83	
	Matched control	294,403,836.91	1,560,942,743.93		
Δ Return on assets	Green bond	−0.41	3.07	0.87	
	Matched control	−0.49	2.75		
Δ Market to book value	Green bond	−0.08	0.31	0.47	
	Matched control	−0.04	0.36		
Δ Leverage	Green bond	0.60	6.75	0.66	
	Matched control	0.15	5.99		
Δ Environment rating	Green bond	3.47	8.94	0.57	
	Matched control	2.74	6.77		

The table reports descriptive statistics of the treated and control firms, before and after matching. Treated firms are defined as the ones issuing green bonds. Variable levels are measured in the year preceding the green bond issuance ($t-1$), while the pre-trends, denoted by Δ, are measured as the change between $t-2$ and $t-1$. We report the mean, standard deviation and the p-value of the difference in means test. *, **, and *** denotes significance at the 10%, 5%, and 1% level, respectively.

OA Table 2: Event study results to the green bond announcement (extended)

FF5M					
Event time	CAR	Std. err.	T-statistic	P-value	
[–20, –11]	0.0026	0.0408	0.7393	0.46	
[–10, –10]	0.0042	0.0577	0.8652	0.39	
[–10, –6]	0.0034	0.0340	1.1661	0.25	
[–5, 5]	0.0001	0.0386	0.0327	0.97	
[–5, 10]	0.0011	0.0446	0.2948	0.77	
[–2, 2]	−0.0025	0.0271	−1.0965	0.27	
[–1, 1]	−0.0013	0.0215	−0.7018	0.48	
[–2, 0]	−0.0015	0.0243	−0.7362	0.46	
[–1, 0]	−0.0004	0.0193	−0.2622	0.79	
[0, 1]	−0.0012	0.0185	−0.7765	0.44	
[0, 2]	−0.0014	0.0209	−0.7762	0.44	
[0, 5]	0.0017	0.0294	0.6878	0.49	
[0, 10]	0.0027	0.0381	0.8428	0.40	
[11, 20]	0.0011	0.0148	0.8625	0.39	
[21, 60]	0.0041	0.0269	1.7782	0.08	*

FF3M					
Event time	CAR	Std. err.	T-statistic	P-value	
[–20, –11]	0.0023	0.0418	0.6539	0.51	
[–10, –10]	0.0037	0.0573	0.7517	0.45	
[–10, –6]	0.0042	0.0327	1.5235	0.13	
[–5, 5]	−0.0001	0.0391	−0.0191	0.98	
[–5, 10]	−0.0003	0.0451	−0.0700	0.94	
[–2, 2]	−0.0024	0.0271	−1.0623	0.29	
[–1, 1]	−0.0016	0.0206	−0.9338	0.35	
[–2, 0]	−0.0016	0.0240	−0.7683	0.44	
[–1, 0]	−0.0009	0.0182	−0.5944	0.55	
[0, 1]	−0.0012	0.0181	−0.7567	0.45	
[0, 2]	−0.0013	0.0207	−0.7511	0.45	
[0, 5]	0.0012	0.0292	0.4836	0.63	
[0, 10]	0.0010	0.0373	0.3138	0.75	
[11, 20]	0.0015	0.0143	1.1890	0.24	
[21, 60]	0.0039	0.0240	1.8936	0.06	*

MM					
Event time	CAR	Std. err.	T-statistic	P-value	
[–20, –11]	0.0025	0.0431	0.6795	0.50	
[–10, –10]	0.0067	0.0622	1.2717	0.21	
[–10, –6]	0.0060	0.0345	2.0446	0.04	**
[–5, 5]	0.0011	0.0436	0.2891	0.77	
[–5, 10]	0.0010	0.0493	0.2387	0.81	
[–2, 2]	−0.0023	0.0307	−0.8822	0.38	
[–1, 1]	−0.0024	0.0230	−1.2034	0.23	
[–2, 0]	−0.0013	0.0258	−0.6089	0.54	
[–1, 0]	−0.0013	0.0195	−0.7544	0.45	
[0, 1]	−0.0019	0.0196	−1.1533	0.25	
[0, 2]	−0.0018	0.0228	−0.9204	0.36	
[0, 5]	0.0011	0.0326	0.3910	0.70	
[0, 10]	0.0010	0.0398	0.2994	0.77	
[11, 20]	0.0006	0.0144	0.5163	0.61	
[21, 60]	0.0036	0.0258	1.6184	0.11	

This table reports the stock market reaction to the announcement of a green bond issuance. We report the average cumulative abnormal return (CAR) for different event windows with the announcement of the green bond issuance designated as the event. The results are presented for three models used to estimate expected returns: the Fama-French five-factor model, the Fama-French three-factor model, and the market model. The sample consists of $N = 138$ Japanese first-time green bond issuances. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Predictor Variables—Definitions and Rationale

The following provides detailed information on the predictor variables used in the SCM analysis. The selection of variables is grounded in prior studies (Tolliver et al. 2020, Lee et al. 2023, Abadie and Gardeazabal 2003, Abadie et al. 2015), ensuring both theoretical justification and empirical robustness.

Gross domestic product based on purchasing power parity (PPP) (Tolliver et al. 2020, Abadie et al. 2015) is used as a predictor variable due to its significance in reflecting economic size. PPP provides the value of gross domestic product in international dollars adjusted by a purchasing power parity conversion factor, which standardizes price levels across countries (World Bank). Smaller economies with lower PPP may struggle to develop robust bond markets, limiting appeal to foreign issuers and increasing price volatility (Eichengreen and Luengnaruemitchai 2004). In contrast, larger economies with higher PPP typically offer more stable investment environments and better governance, crucial for the development and attractiveness of green bond markets.

The Trade-to-GDP ratio (TRD) (Tolliver et al. 2020, Abadie et al. 2015), which is the sum of exports and imports of goods and services measured as a share of the gross domestic product (World Bank), serves as an indicator of a country's degree of openness to international trade and its exposure to global competitive forces. An increased TRD suggests a greater integration into global markets, potentially influencing the behavior of entrenched interest groups, such as banks (Rajan and Zingales 2004). Countries with higher TRDs are often more prepared to adopt global standards and attract international capital leading to more developed bond markets.

Stocks traded, total value (STV) (Tolliver et al. 2020), is defined as the aggregate value of shares traded, encompassing both domestic and foreign shares, multiplied by their corresponding market prices (World Bank). This measure provides insight into the overall activity and liquidity within a country's stock market. Well-developed domestic financial systems, as measured by bank deposits and stock market size, lead to larger domestic bond markets (Claessens et al. 2007). This suggests that a robust financial infrastructure promotes the growth of local bond markets.

Rule of Law (ROL) (Tolliver et al. 2020) expresses societal adherence to legal norms, property rights enforcement, and judicial effectiveness (World Bank). Strong ROL fosters bond market development by enhancing investor confidence, while corruption diminishes this trust (Eichengreen and Luengnarumitchai 2004). Additionally legal traditions, especially common

law systems, protect investor rights and stimulate financial market growth (LaPorta et al. 1998). One can argue that countries with reliable law enforcement attract more investment and exhibit larger bond markets.

Regulatory Quality (RQE) (Tolliver et al. 2020) refers to perceptions of the government's ability to formulate and implement effective policies and regulations that facilitate private sector development (World Bank). This impacts economic factors such as investments in human and physical capital, economic incentives availability, and efficient resource allocation. Regulatory quality significantly influences economic growth by affecting investment levels (Mauro 1995). By creating a stable and predictable framework for investments, high regulatory quality can encourage issuances, attract investors, and foster innovation in sustainable finance.

Two variables mentioned in the study of green bond market drivers (Tolliver et al. 2020) are excluded from this study for the following reasons. First, Trade Freedom (TF) by the Heritage Foundation is excluded because it overlaps with other included variables, potentially leading to redundancy and confounding effects. Additionally, TF is an index calculated by a third party, introducing external biases and inconsistencies. Second, the Paris Agreement NDCs are excluded as it is a proprietary calculation by the author, lacking public availability and verifiability, which could undermine the reproducibility and transparency of the study.

Population density (POP) (Lee et al. 2023, Abadie and Gardeazabal 2003), population divided by land area (World Bank), may serve as a measure for the economic activity and market size of a region. Higher population density often correlates with increased economic activity (Becker et al. 1999) and can impact the demand for financial instruments, including bonds.

Higher education levels are associated with better financial literacy and innovation, which can influence the development of financial markets. Tertiary education enrollment rates (SET) (Lee et al. 2023, Abadie and Gardeazabal 2003), measured by the gross enrollment ratio (World Bank) indicates the availability of skilled labor and the potential for economic growth, both of which can affect the bond market.

Services, Value Added (SVA) (Lee et al. 2023, Abadie et al. 2015, Abadie and Gardeazabal 2003), measures the net output of service sectors as a percentage of GDP (World Bank). The services sector's contribution to GDP indicates the structure of an economy. Economies with a significant service sector possess more developed financial markets (Saint-Paul 1992), which in turn foster the development of more specialized and efficient technologies and thus greater potential for the issuance and trading of bonds, including green bonds.

Government Expenditure (GOV) (Lee et al. 2023), denotes government expenditure on fiscal policy and public investments, including wages, subsidies, grants, and other costs (World Bank). A higher proportion of public expenditure allocated to current expenses contributes positively to economic growth (Devarajan et al. 1996). Therefore, government spending can lead to greater economic stability and development, which can create a favorable environment for bond markets.

Foreign Direct Investment (FDI) (Lee et al. 2023), the net inflow of foreign capital into a country (World Bank), signals investor confidence in the economy. Beyond its direct contribution to growth, FDI indirectly boosts economic development through synergies with human capital, infrastructure, and technology (Mello 1997, Zhang 2001, Li and Liu 2005). This overall economic enhancement can positively impact the attractiveness of the bond market.

GDP per Capita Growth (GDP) (Lee et al. 2023, Abadie and Gardeazabal 2003), reflects the annual percentage change in average economic output per person, adjusted for inflation and population changes (World Bank). Higher economic growth is positively correlated with expected future investment opportunities (Chen 1991), potentially leading to greater demand for bonds, and also enhancing the ability to service debt.

Domestic Credit to Private Sector (DCP) (Abadie et al. 2015), represents the proportion of a country's GDP that is allocated as financial resources to the private sector through various means such as loans and securities purchases (World Bank), impacting the bond market by potentially influencing interest rates and liquidity conditions, thereby shaping investment opportunities and market dynamics. It is referred to as a standard economic growth predictor.

Inflation rates (INF) (Abadie et al. 2015) affect the real return on investments and the stability of the financial environment, as the expected real return on interest rates is negatively related to the expected inflation component (Fama and Gibbons 1982). Lower and stable inflation is generally favorable for bond markets as it preserves the value of returns.

Gross Capital Formation (GCF) (Abadie and Gardeazabal 2003) is the total investment in fixed assets and inventory changes within an economy (World Bank). Higher capital formation indicates robust economic activity and the potential for growth, which can positively impact the bond market, including the issuance and investment in green bonds. It is referred to as a standard economic growth predictor.