Do green bonds lead to more sustainable projects?

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Abstract
This study contributes to the understanding of green bond issuance by exploring the motivations of issuers and the potential environmental outcomes. It reveals that issuers are driven by a combination of environmental concerns and financial incentives. The empirical approach employed in this study is a two-way random effects linear regression model, commonly used in panel data analysis to address unobserved heterogeneity at both the unit and time levels. While green bonds have the potential to enhance issuers' environmental performance and encourage sustainable strategies, the study highlights limitations in establishing a causal relationship between green bond issuance and environmental outcomes due to methodological challenges and data limitations. The study finds that an increase in green bond issuance leads to a reduction in CO_2 emissions. Moreover, findings indicate that an increase in environmental taxes is associated with a higher allocation of GDP to sustainable projects or environmental protection. Lastly, the findings also shed light on the complex relationships between green bond issuance, CO_2 emissions, power consumption, and fossil fuel subsidies, emphasizing the need for comprehensive approaches to reduce reliance on fossil fuels and promote sustainable alternatives.

Keywords: green bonds, sustainability, environment, CO_2 emissions

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1 Introduction

In an era characterized by escalating environmental challenges and a growing urgency to battle against climate change, the search for innovative financial instruments that promote sustainable development has intensified. One such instrument that has gained considerable attention in recent years is the green bond. This financial instrument offers a unique pathway to bridge the gap between capital markets and sustainable development. With their ability to unite investors, corporations, and governments in the pursuit of environmentally conscious investments, green bonds hold the key to unlocking a more sustainable and greener tomorrow.

This master thesis delves into green bonds and their impact on driving tangible sustainability outcomes. This study aims to analyze the potential of green bonds by closely investigating the link between their increased issuance and the advancement of sustainable projects. Through an analysis of empirical evidence, I aim to unravel the relationship between green bonds and sustainable project development.

Ultimately, this study not only seeks to enhance the understanding of the transformative power of green bonds but also aims to inspire deeper discussions among investors, policymakers, and sustainability advocates. By exploring the possible relationship between the growth of green bonds and the progress of sustainable projects, this study aims to contribute to a better understanding of how these financial instruments can be utilized to achieve a greener and more sustainable future.

1.1 What are green bonds?

Green bonds refer to debt instruments issued by governments, municipalities, or corporations to raise capital specifically for projects with environmental benefits. These bonds are labeled "green" because their proceeds are dedicated to financing or refinancing environmentally friendly initiatives such as renewable energy projects, energy efficiency improvements, sustainable infrastructure development, climate change adaptation, and other environmentally sustainable activities (Bloomberg, 2023).

The green bond market has experienced remarkable growth since its inception in 2007, as evidenced by the significant increase in issuance volumes (Climate Bonds Initiative, 2023). The first green bond, an AAA-rated instrument, was jointly issued by the European Investment Bank and the World Bank. The initial purpose of the green bond was to enable investors to support climate solutions without sacrificing returns or taking higher risks (The World Bank, 2019). The issuance of the first green bond marked the beginning of an expanding market, with each following year setting new all-time highs for issuance levels. Subsequently, in 2013, a French electricity-generating company issued the first corporate green bond, raising funds for an advanced climate-friendly project with cutting-edge technology. In 2015 the first significant milestone was reached when the green bond market reached a cumulative issuance of $100 billion. Just five years later, in 2020, the cumulative issuance soared to $1 trillion. Even though the green bond market is rapidly growing, the issued value of green bonds is still low compared to the total value of all bond classes since it is slightly above 1% (Chasan, 2019).

1.2 Research question

As the urgency to address climate change and promote sustainable development intensifies, green bonds have emerged as a powerful financial tool, channeling investment towards projects with positive environmental impacts. According to Bhutta et. al (2022), green bonds significantly promote sustainable development by mobilizing private capital for environmentally beneficial projects. Empirical evidence from their paper suggests that green bonds have positively impacted environmental outcomes, including the promotion of renewable energy, energy efficiency, and sustainable infrastructure.

Other papers, such as a study conducted by Maltais & Nykvist (2020), show that green bonds are frequently positioned as instruments of considerable impact. Nevertheless, their analysis concludes that green bonds do not significantly shift capital from unstainable to sustainable investments. Consequently, the utilization of green bonds does not appear to facilitate access to new capital for green investments or render them financially viable in cases where that would otherwise be impossible.

Additional research also exhibits a more skeptical view. Dill's (2023) empirical study demonstrates a reduction of 14% in emissions during 1990-2019 as a result of green bond issuance (Dill, 2023). However, her study raises the question as to whether these sustainable projects would only have been executed with financing via green bonds or would the sustainable projects have been financed either way. Consequently, the question arises regarding the extent to which green bonds genuinely contribute to the increase of sustainable projects, or whether they merely serve as a means to secure financial resources for such initiatives. In light of the introduction above, this thesis researches the following question:

"Does a causal relationship exist between the issuance of green bonds and the development of sustainability projects?"

Before delving into the empirical analysis, it is imperative to comprehend the fundamental mechanisms underpinning green bonds. Consequently, this thesis will adopt a two-section structure. Firstly, this study will qualitatively examine the motivations described in the literature for the introduction of green bonds and determine their intended objectives. Subquestion one will represent the part. Secondly, a quantitative analysis of the collected data will be undertaken to ascertain whether green bonds fulfill their intended functions. The second subquestion is based on that part.

Subquestion 1: *"What are the key motivations and drivers for issuers to issue green bonds?"*

Subquestion 2: *"Does the issuance of green bonds influence other sustainability measures such as CO2 emissions, electric power consumption, and fossil fuel subsidies?"*

1.3 Data

Three primary data sources were utilized for this research. The first source is Eikon, a financial database, which provided information on green bonds. The dataset from Eikon includes details such as the countries of issuance, the year of issuance, and the amounts of green bonds issued. The dataset covers the period from 2007 to 2021, and it is structured as balanced panel data categorized by country and year.

To assess the level of sustainable projects within each country, data from the International Monetary Fund (IMF) was used. Specifically, the percentage of GDP allocated to environmental protection was examined. This indicator serves as a proxy for the extent of sustainable development initiatives undertaken by each country. Consistency was ensured by exclusively including green bonds issued by governments and municipalities in the dataset. This selection reflects the understanding that governmental entities bear the primary responsibility for financing environmental protection efforts. By focusing solely on green bonds issued by these entities, the study maintains alignment between the financing instruments and the stakeholders responsible for environmental protection expenditures.

Lastly, data from The World Bank was also incorporated in the analysis. This dataset covers all remaining variables and spans until 2021, providing comprehensive information for the study.

1.4 Methodology

This analysis aims to provide empirical evidence regarding the impact of green bond issuance on the financing of environmentally friendly initiatives. The Hausman test was performed, and the results suggested using random effects. By incorporating both time and unit random effects, this study accounts for time-invariant unobserved heterogeneity at both the country and time levels, enhancing the accuracy and validity of the results.

The utilization of a two-way random effects linear regression model holds several implications for policymakers, investors, and financial institutions. The empirical analysis accounts for both observed and unobserved heterogeneity, providing more reliable and robust evidence regarding the relationship between green bond issuance and sustainable project financing. The results of this analysis can guide policymakers in formulating effective strategies to promote green finance and encourage sustainable investments.

Furthermore, investors and financial institutions can leverage the findings to make informed decisions regarding the allocation of resources and the integration of green bonds into their investment portfolios. The empirical evidence derived from the two-way random effects model can inform investment strategies that align with environmental goals, fostering a more sustainable and responsible financial ecosystem.

1.5 Environmental and economic relevance

The pursuit of sustainable development, particularly in relation to environmental concerns, is relevant to both academics and practitioners aiming to achieve the Sustainable Development Goals (SDGs) under the United Nations Development Program (UNDP). Addressing environmental issues is crucial for attaining sustainable development, with CO_2 emissions being a primary contributor to environmental damage (Sarkodie and Strezov, 2018). The Paris Agreement emphasizes the incorporation of Environmental, Social, and Governance (ESG) strategies into long-term business planning to uphold global temperature targets (UNFCCC, 2015). The energy sector alone demands an annual investment of around US$3.5 trillion between 2020 and 2050 to effectively combat climate change on a global scale (Naeem et al., 2021). Furthermore, the attainment of the objectives set forth in the Paris climate change agreement requires a total investment of approximately US$110 trillion (Ferrer et al., 2021).

The findings of this study will contribute to the existing literature on green finance and sustainable development. This analysis plays a critical role in assessing the effectiveness of green bonds as a financial instrument for promoting sustainable development and addressing environmental challenges. The implications of this research extend to various stakeholders, including policymakers, investors, and financial institutions. Policymakers can benefit from the insights gained through data analysis in designing effective policies and regulations that foster the growth of green bond markets and encourage sustainable investments. Moreover, investors and financial institutions can utilize these findings to make informed decisions regarding the allocation of resources and the integration of sustainability considerations into their investment strategies. It also contributes to the literature on sustainable finance and green bonds more broadly. Furthermore, it contributes to research on government debt policy and the political economy of the green transition.

1.6 Preview of the results

The findings of this study present contrasting evidence regarding the relationship between green bond issuance and the allocation of GDP to sustainable projects. The results indicate a lack of a significant causal link between green bonds and sustainable project financing.

Regarding the impact of green bonds on CO_2 emissions, the findings strongly support the hypothesis proposed, which suggests that an increase in green bond issuance leads to a reduction in CO_2 emissions. Moreover, the results are also consistent when excluding random effects, which demonstrates that the effect is not driven by country-specific factors and remains stable over time. These findings demonstrate the effectiveness of green bond issuance in facilitating the desired environmental outcomes across various countries and time periods.

In examining the impact of green bonds on electric power consumption, no significant relationship is found. This suggests that other factors beyond green bonds play a more prominent role in influencing power consumption, such as technological advancements, energy efficiency measures, or changes in consumer behavior.

The investigation into the impact of green bonds on total fossil fuel subsidies reveals a negative effect, but it is not statistically significant. Similarly, the analysis does not yield firm conclusions regarding a significant relationship between green bond issuance and fossil fuel subsidies.

The next part of this thesis includes the theoretical framework that explores the economic aspects of how green bond issuance impacts sustainable project financing. The focus then shifts to the dataset used, and the key variables analyzed in the study. After that, an explanation of the methodology employed is presented. The subsequent section interprets the main findings derived from the analysis. These findings form the basis for drawing conclusions about the relationship between green bond issuance and sustainable project financing. Finally, the thesis concludes with a discussion of the obtained results, including a reflection on the study's limitations, and recommendations for future research directions.

2 Theoretical Framework

2.1 Climate change and green bonds

The issue of climate change has emerged as a pressing and existential challenge for populations worldwide (Xuefeng et al., 2021). The escalation of greenhouse gas emissions is contributing significantly to global warming, posing severe threats to the ecosystem and life on our planet. These challenges are of great concern, requiring immediate action to mitigate the rate of carbon emissions and prevent potential environmental catastrophes. It is essential to mobilize substantial financial resources to address these issues effectively and establish a low-carbon economy. The energy sector alone requires an estimated annual investment of approximately US$3.5 trillion from 2020 to 2050 to support a comprehensive global climate change response (Naeem et al., 2021). Moreover, achieving the targets outlined in the Paris climate change agreement by 2050 necessitates a total investment of approximately US$110 trillion (Ferrer et al., 2021). Consequently, the challenges posed by climate change, greenhouse gas emissions, and global warming have captured the attention of individual and institutional investors, driving the search for financial innovations that promote a greener global economy and foster sustainable development. In response to these pressing environmental concerns and the growing demand for sustainable investment solutions, green bonds have emerged as a prominent financial instrument that aims to align capital flows with environmentally conscious projects.

The body of literature concerning green bonds is still in its early stages of development. The existing research primarily focuses on the asset pricing characteristics of green bonds, with significant debate revolving around the extent to which these bonds enable issuers to secure funds at lower interest rates compared to other financing options, often referred to as the "greenium" effect (Hachenberg & Schiereck, 2018). However, only a limited number of studies have examined the impact of green bonds on environmental indicators.

2.2 Motivation to issue green bonds

Understanding the motivations behind green bond issuance is crucial to grasp the underlying factors that drive issuers to adopt this financial instrument. While some issuers may be primarily motivated by environmental concerns and a desire to support sustainability initiatives, others may be driven by financial incentives, such as accessing a broader investor base, diversifying their funding sources, or capitalizing on market demand for green investments. Exploring these motivations can shed light on the different perspectives and objectives of issuers.

According to survey-based research, governments claim to issue green bonds to battle climate change (Climate Bonds Initiative, 2021). This is often confirmed in papers, describing green bonds as a valuable instrument to combat climate change (Ferrer et al., 2021) and as a tool to attract more investments toward sustainable projects (Torvanger et al., 2021). Moreover, Doronzo et al. (2021) assert that green bonds operate as highly efficient financial instruments for guiding the transition toward a more environmentally sustainable economy.

In a case study conducted by Witkowsky (2022) on the Swedish government's issuance of green bonds, it was found that the primary motivation behind the issuance was not solely to finance green investments. Instead, the study revealed several other key reasons for issuing green bonds. These included the promotion of the green bond market, communicating the government's existing environmental investment initiatives, assisting investors in building more sustainable portfolios and reinforcing the Swedish government's position as a bond issuer.

The evaluation of governments' claims regarding the issuance of green bonds as a means to address climate change is important and raises some concerns. One possible concern is the potential overlap between projects financed by green bonds and those that corporations would have undertaken, regardless of green bond issuance. This raises doubts about the extent to which green bonds genuinely enable additional environmental impact beyond existing commitments. Nonetheless, studies have shown alternative ways in which green bonds can contribute positively to environmental outcomes. Flammer (2021) and Maltais & Nykvist (2020) find that green bonds can enhance the environmental performance of issuers and intensify the pressure on organizations to pursue greener strategies. These findings indicate that although the assumptions underlying the initial assertions should be carefully examined, green bonds can still have a positive impact on sustainable outcomes.

Additional investigations exploring the underlying motivations behind the issuance of green bonds have demonstrated that issuance serves as a communication tool to showcase environmental strategies (Deschryver & de Mariz, 2020). Findings from Deschryver & de Mariz (2020) further indicate that issuers face peer pressure from competitors to issue green bonds and seek to encourage the engagement of environmentally conscious young professionals. Furthermore, Flammer (2021) has revealed that green bonds contribute positively to the development of relationships with investors and attract a greater number of long-term investors. Both studies by Deschryver & de Mariz (2020) and Flammer (2021) highlight the scarcity of substantial evidence regarding the role of issuers in driving the green transition. Issuers utilize green bonds to effectively communicate their sustainability agendas and enhance their rapport with investors, rather than solely aiming to support sustainable initiatives.

Transparency and accountability are crucial aspects of green bond issuance to maintain investor confidence and ensure the integrity of the instrument. Issuers typically provide disclosure frameworks or guidelines that outline how the proceeds from green bonds will be allocated and the environmental criteria that financed projects must meet. This framework helps ensure transparency and clarity in the use of proceeds. Various mechanisms, such as external reviews, or certifications, may be employed to verify the environmental impact of the projects and make sure they meet the stated goals. Independent reviews or second-party opinions can be sought to assess the alignment of the issuer's green bond framework with recognized standards or industry best practices. These reviews provide an external perspective on the issuer's environmental claims and can enhance transparency and credibility. In some cases, issuers may engage third-party verifiers to assess and confirm the environmental impact of the projects funded through green bonds. This verification process adds an extra layer of credibility to the issuer's claims and enhances transparency. Understanding these mechanisms can help evaluate current practices' effectiveness and identify improvement areas.

2.3 Synergizing carbon pricing and green bonds: sharing the climate burden

In recent years, academics such as Flaherty et al. (2017) and Heine et al. (2019) have developed economic models that highlight the potential synergies between carbon pricing initiatives and the utilization of green bonds. They argue that a carbon pricing initiative fosters a transition towards a low-carbon economy by imposing costs on the current generation, thus incentivizing emission reductions. On the other hand, projects financed through green bonds contribute to emissions reduction in the short term, but the responsibility to repay the debt incurred is shifted to future generations. Consequently, the combination of both mechanisms allows for a more reasonable distribution of the financial burden associated with addressing climate change across generations. Furthermore, the combination of carbon pricing and green bonds mitigates the political challenges associated with relying solely on tax charges or solely on green bond financing to support the fight against global warming. By diversifying the instruments, the political resistance to carbon pricing or the potential risks associated with heavy reliance on green bonds as a financing mechanism can be reduced (Heine et al., 2019).

In contrast to carbon pricing initiatives, green bonds are not government-imposed policies but rather voluntary issuances that serve as a signaling mechanism to the market and present an additional financing option for projects. From the issuers' perspective, the issuance of green bonds can potentially enhance access to institutional investors with sustainability-focused investment policies, thus expanding and diversifying their investor base (Hussain & Dill, 2022). On the investor side, the acquisition of green bonds may be incentivized by factors such as portfolio diversification, lower risk exposure, and long-term economic sustainability, as highlighted by Maltais and Nykvist (2020).

According to Sachs (2014), climate change is relevant to future generations, but measures to improve the environment are matters for the current generation. To achieve this, Sachs puts forth the proposal of financing environmental enhancements through public debt. This policy approach seeks to avoid a tradeoff between the present generation's welfare and that of future generations, instead framing it as a tradeoff between climate change and the burden of taxation that future generations may encounter. Sachs (2014) addresses the issue of future generations and their potential dissatisfaction with increased taxation. However, he argues that despite this concern, intervening in climate change is necessary and ultimately beneficial for future generations. Sachs states that the outcomes of climate change mitigation efforts outweigh the potential burdens of higher taxes, suggesting that future generations are better off with proactive measures to address climate change rather than inaction.

Flaherty et al. (2017) extend the research conducted by Sachs (2014) by proposing the implementation of green bonds to actualize Sachs' proposal. The intergenerational tax-and-transfer policy transformation suggested by Flaherty et al. offers a favorable approach for both generations, leading to an overall improvement in welfare. The findings of Flaherty et al. affirm the innovation of Sachs' model, contributing valuable insights that can guide the development of new frameworks within the field of climate change.

Furthermore, Flammer (2018) showed in her article that green bonds cause contributes to improvements in environmental footprints and increase green innovation. Her study reveals that companies experience a reduction in their carbon emissions after issuing certified green bonds. However, Flammer also acknowledges the concerns of greenwashing – i.e., behaviour or activities that make people believe that a company is doing more to protect the environment than it is (Cambridge, 2023). Companies can cultivate a public image of environmental responsibility by issuing green bonds without necessarily adhering to these standards. This is one of the motivations to issue green bonds as a company. According to Flammer, greenwashing is a result of the absence of public governance in the context of green bonds.

2.4 Yields and development of the green bond market

According to a research paper by Baker et al. (2018), green bonds are priced higher compared to plain vanilla bonds. The results from the papers' ordinary least square (OLS) regressions show that the yields at the time of issuance for green bonds are approximately 6 basis points lower than the yields offered by otherwise equivalent bonds. This indicates that investors are willing to accept slightly lower returns for green bonds compared to non-green bonds. Baker emphasizes the urgent demand for climate change solutions, identifying green bonds as a primary solution to address this pressing issue. The findings by Baker et al. (2018) are confirmed by Zerbib (2019), who observed a negative premium of approximately 2 basis points for green bonds in comparison to conventional bonds. Despite the lower yields, investors continue to demonstrate an interest in investing in green bonds, indicating a positive outlook for future growth and development of the green bond market.

However, several empirical studies utilizing surveys and interviews with investors have consistently revealed that investors exhibit a reluctance to acquire green bonds at premium prices compared to similar non-green bonds (Chiang, 2017; Sangiorgi & Schopohl, 2021). Additionally, Maltais and Nykvist (2020) arrived at a similar outcome, leading them to deduce that green bonds do not facilitate the mobilization of new capital for green investments. These findings led Witkowsky (2022) to conclude that corporations and other stakeholders do not issue green bonds with the intent of reducing financing costs, and as a result, the issuance of green bonds is unlikely to make a significant contribution towards financing or refinancing additional green investments.

2.5 Green bonds and environmental outcomes

According to Bhutta et. al (2022), green bonds significantly promote sustainable development by mobilizing private capital for environmentally beneficial projects. Empirical evidence from their paper suggests that green bonds have positively impacted environmental outcomes, including the promotion of renewable energy, energy efficiency, and sustainable infrastructure.

Multiple studies have looked at the emissions of issuers after the issuance of green bonds. Fatica and Panzica (2021) find that companies' emissions reductions were more pronounced following green bond issuances after the implementation of the 2015 Paris Agreement. Meo and Karim (2021) adopt a bivariate approach, utilizing data from 2008 to 2019, and focus on the ten most prominent economies in terms of green finance utilization. Their analysis reveals a general negative correlation between green bond issuance and CO_2 emissions.

Tolliver et al. (2019) provide a critical perspective on the attribution of additional environmental benefits to green bonds, highlighting that while these bonds contribute to financing green projects, they are occasionally misconstrued as the sole determinant of such projects' environmental advantages. The authors assert that green bonds primarily function as refinancing mechanisms rather than being the sole factor influencing the decision-making process for project financing. Tolliver et al. argue against the notion that green bonds are the driving force behind the existence of green projects, emphasizing that the prominence attributed to green bonds is inflated. Consequently, the environmental impact associated with green bonds may not necessarily entail additional benefits, as the projects financed through green bonds could often be supported using alternative financing mechanisms.

This viewpoint is shared by Dupre et al. (2018), who suggest that the prevailing sentiment among green bond investors and advocates indicates that investing in green bonds can lead to an increased flow of funds toward green projects, thereby stimulating additional investments. The underlying theory suggests that as more investors allocate their financial resources to green bonds, issuers are compelled to issue a greater volume of these bonds to meet the rising demand. Consequently, issuers may encounter a shortage of suitable green projects to which the bond proceeds can be allocated, necessitating a need to enhance their green investment plans. In such a scenario, investors have valid grounds to assert that they are expanding the financial resources available for green projects, thereby contributing to increased investments in those projects. However, similar to the observations made by Tolliver et al., Dupre et al. critically acknowledge that bonds primarily serve as refinancing instruments. As a result, in many instances, the issuance of green bonds alone does not act as the determining factor for investment decisions. Nonetheless, it can be argued that the potential for "easier" refinancing through green bonds may be taken into consideration when making investment decisions.

In a paper about green bonds, fossil fuel subsidies, and electric power consumption, the researchers find that gradually phasing out fossil fuel subsidies creates conditions for a stable low-carbon transition (Monasterolo & Raberto, 2019). The study suggests that the subsidy share is more important than the specific financing mechanism, such as environmental taxes or green bond issuance) for the accumulation of renewable energy capacity. Although the issuance of green sovereign bonds increases public debt, the study argues that this debt is sustainable in the long term, since this debt supports sustainable investments.

According to the study conducted by Taghizadeh-Hesary et al. (2021), a significant proportion of investments in the energy sector, approximately 60%, was allocated to fossil fuels in the year 2018. In contrast, renewable energy sources received only 19% of the total investments during the same period. During the period of 2020-2021, investment in renewable power, energy efficiency, and other environmentally friendly projects experienced a substantial decline attributed to the COVID-19 pandemic and the global economic recession. These circumstances led to a significant reduction in fossil fuel prices, posing a challenge to the development of renewable energy initiatives. The diminished cost of fossil fuels rendered sources such as solar, wind, and other renewable energy options less competitive as providers of electricity. Consequently, investors exhibited a decreased interest in clean fuels, thereby posing a potential threat to the attainment of targets outlined in the Paris Agreement on climate change and various Sustainable Development Goals (SDGs).

Taghizadeh-Hesary et al. (2022) conducted another study focusing on green bonds in Nigeria, a country heavily reliant on fossil fuels but attempting to change its course. The issuance of green bonds in Nigeria primarily originates from public entities, representing an estimated 99% of the green bonds listed on the Nigerian Stock Exchange. These green bonds are utilized to support the development of energy-efficient projects and are commonly issued by commercial banks and governmental bodies. Empirical observations from Nigeria indicate that a sum of over 30 million nairas, derived from a green bond issued by the Federal Government, was allocated for the purpose of planting 6,000 trees in Oyo state. However, after a span of three years, only a mere hundred trees are visible. This circumstance raises an unresolved inquiry: To what extent has the increased green bond issuance translated into the realization of environmentally sustainable and efficient energy outcomes, particularly within developing nations?

2.6 De-greening vs. creating new opportunities

Green bond issuers operate without inherent restrictions on their investment practices and are not compelled to adopt an overall greener investment approach. Consequently, there are no inherent obligations compelling issuers of green bonds to investments towards environmentally friendly projects or substantially deviate from their customary investment plans. Issuers of green bonds often engage in investment activities that include both green and brown projects. As a result, when an issuer of green bonds directs the proceeds towards its existing green investments, the funds initially intended for environmentally friendly initiatives become virtually reallocated to support brown projects exclusively. This phenomenon effectively results in the "de-greening" of the issuer's standard bonds, as the funds originating from green bond issuance are effectively channeled towards non-environmentally friendly endeavors.

This situation has Nicol et al. (2019) to conclude that "most of the existing green bonds and their associated projects would likely have been undertaken regardless of whether the bonds issued to finance them were labeled as green or not." If green bonds are to effectively stimulate additional investments in the low-carbon transition, they must extend beyond their existing informational benefits and contribute to the reduction of capital costs for the underlying projects. The authors suggest that an increase in investments in the green bond market could be generated by a decrease in the prices of green bonds compared to vanilla bonds, such as a decreased coupon. Another mechanism to stimulate financing in green bonds is advocating for enhanced transparency and accountability within financial institutions and corporations regarding monitoring their environmentally sustainable investments and establishing standardized criteria for these assets.

According to Hill (2023), it is anticipated that green bonds, by providing financial support to environmentally sustainable projects, will play a significant role in climate mitigation efforts and contribute to the reduction of greenhouse gas emissions. The underlying objective of green bonds is to channel funds toward projects that adhere to rigorous environmental criteria. The findings reveal that the issuance of green bonds is associated with an average emissions reduction of 14% during the period spanning from 1990 to 2019. This decrease can be attributed to the fact that these projects would not have been undertaken in the absence of green bonds, highlighting the distinctive impact of these bonds in fostering environmentally beneficial initiatives. However, it remains a subject of discussion whether these projects would have remained unrealized in the absence of green bonds, as it is plausible that they could have secured financing through conventional bonds. This raises the question of whether green bonds truly introduce new opportunities for environmental initiatives or simply provide an alternative avenue for financing that may have been attainable through conventional means.

2.7 Hypotheses

Based on the above-discussed literature, the following hypotheses are formed. Hypothesis 1 relates to the research question, and hypotheses 2, 3, and 4 relate to subquestion 2.

Hypothesis 1: An increase in green bond issuance leads to a growth in environmental sustainability projects measured as the percentage of GDP assigned to environmental protection.

Hypothesis 2: An increase in green bond issuance leads to a reduction in CO_2 emitted per capita.

Hypothesis 3: An increase in green bond issuance leads to a reduction in electric power consumption per capita.

Hypothesis 4: An increase in green bond issuance leads to a reduction in fossil fuel subsidies by the government.

3 Methodology

3.1 Econometric tools

3.1.1 The Hausman test

The appropriateness of the two-way fixed effects method for testing the hypotheses was assessed by conducting the Hausman test (Hausman, 1978). The Hausman statistical test determines the appropriate choice between fixed effects and random effects models. The test revolves around the notion of unobserved individual-level effects in panel data analysis. Fixed effects models assume that these unobserved effects are correlated with the independent variables, while random effects models treat them as uncorrelated. The Hausman test aims to determine whether the correlation exists, and which model is more appropriate for the analysis. The test begins by estimating the coefficients using both the fixed effects and random effects models. It then calculates the difference between the two sets of coefficients, known as the "Hausman statistic." This statistic follows a chi-squared distribution and is used to test the null hypothesis that the coefficients from the fixed effects model are consistent and efficient, while the random effects model may suffer from endogeneity issues.

The decision regarding accepting or rejecting the null hypothesis in the Hausman test hinges on the p-value associated with the Hausman statistic. The predetermined significance level, commonly set at 0.05, serves as a threshold for determining statistical significance. In this case, if the p-value is below 0.05, the null hypothesis is rejected in favor of the alternative hypothesis, indicating that the fixed effects model is favored due to its desirable properties of consistency and efficiency. Conversely, if the p-value exceeds the significance level, it suggests that the random effects model is more appropriate, as there is no significant correlation between the unobserved effects and the independent variables.

The obtained p-value for the chi-squared statistic in the Hausman test is 0.209. This p-value is greater than the significance level of 0.05, indicating that the null hypothesis cannot be rejected. Therefore, this p-value suggests that the random effects model is more suitable for the analysis, as there is no significant correlation between the unobserved effects and the independent variables.

In summary, the evaluation of the p-value associated with the Hausman statistic guides the decision to whether reject the null hypothesis, or not. In this case, the p-value of 0.209 indicates that the random effects model is more appropriate, as there is no significant correlation between the unobserved effects and the independent variables.

Table 1

Hausman test

	Coef.
Chi-square test value	31.539
P-value	.209

3.1.2 Linear regression with two-way random effects

The main empirical approach for this study was a two-way random effects linear regression model. Two-way random effects is a statistical technique commonly used in panel data analysis to control for unobserved heterogeneity that may vary randomly across units at both the unit and time levels (Wooldridge, 2021). The primary objective of employing two-way random effects is to account for unobserved factors that are specific to each country or year and that may affect the dependent variable but vary randomly across units. This model is suitable for examining panel data, where observations are collected over multiple periods and across various units, such as countries. The unit random effects capture time-invariant heterogeneity specific to each country, which is not captured by other observed variables (Imai & Kim, 2020). These random effects control for country-specific factors that may influence the allocation of resources to sustainable projects, thereby isolating the causal effect of green bond issuance. Similarly, the time random effects account for time-specific factors that may affect the dependent variable, ensuring the estimation captures only the effect of green bonds over time. By incorporating random effects, you are effectively controlling for these time-invariant country-specific characteristics that vary randomly across units and could potentially confound the relationship between green bond issuance and sustainable projects. In this research, the unit refers to the countries, while the time refers to the different years for which data is available. By including both unit and time random effects in the regression model, the specific impact of green bond issuance on the allocation of resources to environmental protection can be isolated. This approach helps to mitigate the potential biases that may arise from omitted variables or unobserved factors at the country and time levels, allowing you to obtain more reliable and robust estimates of the relationship of interest.

Including country random effects allows for the examination of the unique characteristics and factors specific to each country that may influence the relationship between green bond issuance and environmental protection expenditure. It helps account for country-specific variations in policies, regulations, economic conditions, and environmental priorities that may affect the allocation of funds toward green projects. If only country random effects are included, and time random effects are excluded, the model may not capture time-specific trends or fluctuations that impact the relationship over different time periods.

If the results for including only country random effects are very similar to the results including both time and country random effects, it suggests that the country-specific factors play a dominant role in influencing the relationship between variables. This means that the variation in the relationship across different time periods is relatively small compared to the variation across different countries. In this case, including time random effects may not provide significant additional insights or explanatory power to the model. The similarity in results indicates that the relationship between variables is primarily driven by country-specific characteristics that affect the relationship consistently over time. It suggests that country-specific factors have a stronger influence on the relationship than time-related factors.

On the other hand, if the results for including only country random effects are not similar at all to the results including both time and country random effects, it suggests that the inclusion of time random effects is important for capturing additional variation and understanding the relationship between the variables. When country random effects alone yield significantly different results compared to including both country and time random effects, it indicates that there are time-specific factors influencing the relationship between the variables. Time random effects help account for temporal trends, changes in policies, market conditions, or other time-varying factors that may impact the relationship.

Including time random effects captures the temporal variations and trends in the relationship between green bond issuance and expenditure. It considers the changing global context, evolving sustainability goals, and potential shifts in market dynamics that may impact the allocation of funds over time. However, by excluding country random effects, the model does not capture the heterogeneity across different countries and may overlook country-specific characteristics that influence the relationship.

If the results for including only time random effects are very similar to the results including both time and country random effects, it suggests that the time-specific factors play a dominant role in influencing the relationship between variables. This means that the variation in the relationship across different countries is relatively small compared to the variation over different time periods. In this case, including country random effects may not provide significant additional insights or explanatory power to the model. The similarity in results indicates that the relationship between variables is primarily driven by time-related factors that affect all countries in a similar manner.

If the results for including only year random effects are not similar to the results for including both random effects, it suggests that the inclusion of both time and country random effects is important for capturing the relationship between the variables. It indicates that there are country-specific factors and time-specific trends at play, which collectively influence the relationship. Therefore, including both time and country random effects helps capture the variation in the relationship across different countries and over time, considering the interplay between country-specific characteristics and the dynamic changes occurring in different time periods.

3.1.3 Time lag regression

In addition to conducting linear regressions to analyze the relationships under investigation, a time lag regression will be employed to examine the influence of variables, such as green bond issuance, on the subsequent year's expenditure on environmental protection. The time lag regression will be based on percentage changes observed in the variables, taking into account the values from the previous year.

The inclusion of a time lag regression enables an examination of the temporal dynamics between green bond issuance and the subsequent year's change in GDP expenditure on environmental protection (t+1). This approach allows for an assessment of whether there is a delayed effect or time-dependent relationship between the variables. By considering the percentage changes and incorporating the lagged component, the analysis can capture the potential influence of the previous year's green bond issuance on the subsequent year's environmental expenditure.

3.2 Models

3.2.1 Hypothesis 1

The first hypothesis states that an increase in green bond issuance leads to a growth in environmental sustainability projects measured as the percentage of GDP assigned to environmental protection. By using linear regression including two-way random effects the hypothesis is tested. Model 1 is displayed below.

$$EP\_GDP = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * CO2\ emissions + \beta_{14} * CO2\ emissions\ change + \beta_{15} * CO2\ per\ capita + \beta_{16} * poverty + \beta_{17} * GNI + \beta_{18} * GNI\ per\ capita + \beta_{19} * incomeshare\ lowest\ 20 + \beta_{20} * water\ productivity + \beta_{21} * energy\ use + \beta_{22} * electric\ power + \beta_{23} * agriculture + \beta_{24} * industry + \beta_{25} * technology\ export + \beta_{26} * debt + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (1)$$

The second and third models of hypothesis 1 are constructed similarly to the abovementioned model. However, the second model includes only country random effects, while the third model incorporates only year random effects. By excluding year random effects from the second model, the influence of time-specific factors on the relationship between variables can be observed. This exclusion shows whether the observed relationship remains consistent across various periods or exhibits temporal variability. Consequently, it aids in identifying potential time-specific trends or fluctuations that may impact the relationship under investigation. This approach enhances the understanding of the dynamics and temporal nuances associated with the relationship between the variables of interest within the context of the analysis without the influence of random effects.

Similarly, excluding country random effects in the third model allow for an examination of the extent to which the observed relationship between variables is influenced by country-specific factors. This approach enables an assessment of whether the relationship holds across different countries or if it is mainly driven by specific countries. Through this analysis, it becomes possible to identify the share of the relationship's variation that can be attributed to country-specific characteristics. Comparable results are expected from these two models. This similarity in results would indicate that the observed relationships between the variables are relatively stable and consistent across different countries and time periods. Since both models are very similar to the one displayed above, both are placed in the Appendix.

Hence, in light of the first hypothesis that posits a significant positive relationship between green bond issuance and the expansion of environmental sustainability projects (H0), it is expected that the estimated parameter for β_1 will show a positive sign. This positive parameter estimate would indicate a significant positive relationship between the increase in green bond issuance and the expansion of environmentally sustainable projects, as measured by the percentage of GDP allocated to environmental protection. If the calculated p-value exceeds the predetermined significance level of 0.05, the statistical analysis does not provide sufficient evidence to reject the null hypothesis. This does not mean H0 is true, it rather indicates a lack of statistical significance in supporting the alternative hypothesis (H1).

In order to investigate the causal link between an increase in green bond issuance and the subsequent growth in environmentally sustainable projects, a fourth model is developed. This model incorporates a time-lag regression and is formulated based on the percentage changes observed in the variables representing environmental protection and green bonds. The inclusion of a time lag regression allows for an examination of whether there exists a time-based relationship between green bond issuance and the subsequent year's change in GDP expenditure on environmental protection (t+1). By introducing this lagged variable, it is possible to assess the potential impact of green bond issuance on future environmental spending. This model specifically aims to determine whether an increase in green bond issuance is followed by a corresponding change in the allocation of GDP towards environmental protection in the subsequent year. The model is displayed below.

$$EP\_GDP\ change = \beta_0 + \beta_1 * L.green\ bonds\ change + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * CO2\ emissions + \beta_{14} * CO2\ emissions\ change + \beta_{15} * CO2\ per\ capita + \beta_{16} * poverty + \beta_{17} * GNI + \beta_{18} * GNI\ per\ capita + \beta_{19} * incomeshare\ lowest\ 20 + \beta_{20} * water\ productivity + \beta_{21} * energy\ use + \beta_{22} * electric\ power + \beta_{23} * agriculture + \beta_{24} * industry + \beta_{25} * technology\ export + \beta_{26} * debt + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (4)$$

In line with expectations, it is anticipated that the estimated parameter β_1 in this model will exhibit a positive sign. This positive parameter estimate would signify a statistically significant positive relationship between the increase in green bond issuance and the subsequent year's growth in the percentage of gross domestic product (GDP) allocated to environmental protection. However, a potential explanation for the insignificant result could be that governments and organizations issuing green bonds often have specific environmental goals and targets they strive to accomplish. By allocating the funds raised through green bond issuance towards increased expenditure on environmental protection in the same year, they can demonstrate their dedication to sustainability and align their actions with their stated objectives. This immediate impact serves as a confirmation of the credibility and effectiveness of green bonds as a financing instrument for supporting environmental projects.

3.2.2 Hypothesis 2

The second hypothesis investigates the relationship between green bond issuance and CO_2 emissions. Similar to the first hypothesis, four different models are constructed. The first dependent variable in this model is CO_2 emissions per capita including two-way random effects. Model 9 is displayed below.

$$CO2\ emissions\ per\ capita = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} *$$

$explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * electric\ power + \beta_{20} * agriculture + \beta_{21} * industry + \beta_{22} * technology\ export + \beta_{23} * debt + \beta_{24} * EP\_GDP + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it}$ (5)

The next two models are similarly constructed to the first model, just as for the first hypothesis. The second model includes only country random effects, while the third model incorporates only year random effects contains. Since both models are very similar to the one displayed above, both are placed in the Appendix (regressions 10 and 11). Hence, in light of the second hypothesis that posits a significant negative relationship between green bond issuance and CO_2 emissions per capita (H0), it is expected that the estimated parameter for β_1 will show a negative sign. Alternatively, if the calculated p-value exceeds the significance level of 0.05, the statistical analysis does not provide sufficient evidence to reject the null hypothesis. This does not indicate a negative relationship between green bond issuance and CO_2 emissions per capita (H0), it rather indicates a lack of statistical significance in supporting the alternative hypothesis that no relationship exists between green bond issuance and CO_2 emissions per capita (H1).

When comparing the outcomes of the alternative models with different random effects, it is expected that certain differences will be visible. This expectation is supported by a prior study examining green bond issuance in Nigeria, as discussed in the previous chapter (Taghizadeh-Hesary et al, 2022). The study revealed a marginal decline in CO_2 emissions after the issuance of green bonds. Therefore, when exclusively incorporating time random effects in the analysis, contrasting outcomes are expected in contrast to the inclusion of both random effects. Additionally, the inclusion of country random effects may provide insights into the specific countries that significantly contribute to the observed relationship. It helps to identify whether certain countries have a stronger or weaker association between green bond issuance and CO2 emissions, highlighting the role of country-specific policies, regulations, or environmental factors.

To investigate the causal link between an increase in green bond issuance and the subsequent decrease in CO_2 emissions per capita, a time-lag model is developed. It is formulated based on the percentage changes observed in the variables representing CO_2 emissions per capita and green bonds. The inclusion of a time lag regression allows for an examination of whether there exists a time-based relationship between green bond issuance and the subsequent year's change in CO_2 emissions per capita (t+1). The model is displayed below.

$$CO2\ emissions\ change = \beta_0 + \beta_1 * L.green\ bonds\ change + \beta_2 * population + \beta_3 * population\ growth + \beta_4 * GDP + \beta_5 * GDP\ growth + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * electric\ power + \beta_{20} * agriculture + \beta_{21} * industry + \beta_{22} * technology\ export + \beta_{23} * debt + \beta_{24} * EP\_GDP + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (8)$$

In line with the second hypothesis, a negative sign for the estimated parameter β_1 is expected. This negative parameter estimate would signify a statistically significant negative relationship between the increase in green bond issuance and the subsequent year's decrease in CO_2 emissions per capita.

3.2.3 Hypothesis 3

The third hypothesis investigates the relationship between green bond issuance and electric power consumption. By using linear regression, including two-way random effects, the hypothesis is tested. The model is displayed below.

$$Electric\ power = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * CO2\ emissions + \beta_{20} * CO2\ emissions\ change + \beta_{21} * CO2\ per\ capita + \beta_{22} * agriculture + \beta_{23} * industry + \beta_{24} * technology\ export + \beta_{25} * debt + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (9)$$

Just as for the first and second hypotheses, two additional models are constructed similarly to the abovementioned model. However, the second model includes only country random effects, while the third model incorporates only year random effects. Comparable results are expected from these two models. This similarity in results would indicate that the observed relationships between the variables are relatively stable and consistent across different countries and time periods. Since both models are very similar to the one displayed above, both are placed in the Appendix.

Considering the third hypothesis, which suggests a significant negative association between green bond issuance and electric power consumption (H0), it is anticipated that the estimated parameter, β_1, will exhibit a negative sign. If the resulting p-value exceeds the predetermined significance level of 0.05, the statistical analysis does not provide substantial evidence to reject the null hypothesis. Not-rejecting the null hypothesis does not imply a negative relationship between green bond issuance and electric power consumption (H0), but rather indicates a lack of statistical significance in supporting the alternative hypothesis that no relationship exists between green bond issuance and electric power consumption (H1).

To explore the causal relationship between green bond issuance and subsequent changes in electric power consumption, a fourth model is constructed. This model incorporates a time-lag regression, using percentage changes in the variables representing environmental protection and green bonds. It investigates whether an increase in green bond issuance is followed by a corresponding change in electric power consumption in the subsequent year. The model is presented below.

$$Electric\ power\ change = \beta_0 + \beta_1 * L.green\ bonds\ change + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * CO2\ emissions + \beta_{20} * CO2\ emissions\ change + \beta_{21} * CO2\ per\ capita + \beta_{22} * agriculture + \beta_{23} * industry + \beta_{24} * technology\ export + \beta_{25} * debt + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (12)$$

Also in this model, it is expected that the estimated parameter β_1 will show a negative sign. This negative parameter estimate would indicate a statistically significant negative relationship between the increase in green bond issuance and the electric power consumption in the following year. If the results show no significant negative sign this could be due to the fact that the impact of green bond-funded projects on power consumption may take time to materialize and become observable.

3.2.4 Hypothesis 4

The fourth hypothesis investigates the relationship between green bond issuance and fossil fuel subsidies. The model used to analyze this relationship is displayed below.

$$Total\ fossil\ fuel\ subsidies = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * poverty + \beta_{11} * GNI + \beta_{12} * GNI\ per\ capita + \beta_{13} * incomeshare\ lowest + \beta_{14} * water\ productivity + \beta_{15} * energy\ use + \beta_{16} * CO2\ emissions + \beta_{17} * CO2\ emissions\ change + \beta_{18} * CO2\ per\ capita + \beta_{19} * agriculture + \beta_{20} * industry + \beta_{21} * technology\ export + \beta_{22} * electric\ power + \beta_{23} * debt + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (13)$$

Similar to the previously discussed hypotheses, two additional models are constructed similarly to the abovementioned model. However, the second model includes only country random effects, while the third model incorporates only year random effects. Since both models are very similar to the one displayed above, both are placed in the Appendix.

Considering the third hypothesis, which suggests a significant negative association between green bond issuance and total fossil fuel subsidies (H0), it is anticipated that the estimated parameter, β_1, will exhibit a negative sign. If the resulting p-value exceeds the predetermined significance level of 0.05, the statistical analysis does not provide substantial evidence to reject the null hypothesis. Not-rejecting the null hypothesis does not imply a negative relationship between green bond issuance and total fossil fuel subsidies consumption (H0), but rather indicates a lack of statistical significance in supporting the alternative hypothesis that no relationship exists between green bond issuance and electric power consumption (H1). As discussed in the theoretical framework this could be due to governments prioritizing economic growth, energy securing, and maintaining affordable energy prices which can result in continued subsidies for fossil fuels.

To explore the causal relationship between green bond issuance and subsequent changes in total fossil fuel subsidies a fourth model is constructed. This model incorporates a time-lag regression, using percentage changes in the variables. It investigates whether an increase in green bond issuance is followed by a corresponding change in fossil fuel subsidies in the subsequent year. The model is presented below.

$$Total\ fossil\ fuel\ subsidies\ change = \beta_0 + \beta_1 * L.green\ bonds\ change + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * poverty + \beta_{11} * GNI + \beta_{12} * GNI\ per\ capita + \beta_{13} * incomeshare\ lowest + \beta_{14} * water\ productivity + \beta_{15} * energy\ use + \beta_{16} * CO2\ emissions + \beta_{17} * CO2\ emissions\ change + \beta_{18} * CO2\ per\ capita + \beta_{19} *$$

$$agriculture + \beta_{20} * industry + \beta_{21} * technology\ export + \beta_{22} * electric\ power + \beta_{23} * debt + \mu_n * D_{country} + \theta_n * D_{year} + \alpha_i + u_{it} \quad (16)$$

Also in this model, it is expected that the estimated parameter β_1 will show a negative sign. This negative parameter estimate would indicate a statistically significant negative relationship between the increase in green bond issuance and the electric power consumption in the following year.

4 Data

The aim of this master's thesis is to investigate the relationship between the issuance of green bonds and the development of sustainable projects. The following section provides an overview of the data utilized in this study. It includes a description of the data sources, variables, and descriptive statistics.

4.1 Datasets

For the purpose of this research, three primary data sources were employed. Firstly, information regarding green bonds was sourced from Eikon, a financial database. The dataset includes data about the countries of issuance, the year of issuance, and the respective amounts of green bonds issued. As the first green bond issuance dates back to 2007, the dataset is initiated from that year onwards. It spans until 2021. The dataset consists of balanced panel data, structured by country and year. To ensure consistency, the dataset exclusively comprises green bonds issued by governments and municipalities. This selection is justified by the understanding that the primary financial responsibility for environmental protection lies with governmental entities. By only focusing on green bonds issued by these entities, the study maintains consistency in aligning the financing instruments with the corresponding stakeholders responsible for environmental protection expenditures.

To measure the level of sustainable projects within each country, data from the International Monetary Fund was utilized. Specifically, the percentage of GDP allocated to environmental protection was examined. This indicator provides insights into the commitment of each country towards sustainable development and serves as a proxy for the scale and magnitude of sustainable projects undertaken.

Lastly, data from The World Bank is extracted. This dataset contains data about all the remaining variables and contains data till 2021 as well. The datasets are combined into a single dataset, constituting panel data organized by year and country.

4.2 Variables

4.2.1 Dependent variables

EP_GDP This variable focuses specifically on the allocation of a country's GDP toward environmental protection. This indicator serves as a valuable tool for assessing a country's commitment to sustainable development and acts as a proxy for evaluating the scope and significance of undertaken sustainable projects. The variable represents the financial investment made by each government in environmental protection measures, expressed as a percentage of the country's GDP.

EP_GDP_change This variable is similar to the aforementioned variable, but it measures the percentage change in comparison to the previous year. This variable assesses the year-on-year fluctuations in the allocation of GDP towards environmental protection, offering a dynamic perspective on the progress in a country's financial investment in sustainable initiatives.

CO2_capita The next variable under consideration is CO_2 emissions per capita. Carbon dioxide emissions are a by-product of the combustion of fossil fuels and the production of cement. They encompass the release of carbon dioxide during the consumption of solid, liquid, and gas fuels, as well as from gas flaring. Given their environmental implications, the effects of carbon dioxide are of significant interest. CO_2 constitutes the largest proportion of greenhouse gases, which contribute to global warming and climate change, according to data from the World Bank (2021). The variable is measured in metric tons per capita.

CO2_change The annual percentage growth rate of CO_2 is calculated using CO_2 emissions in kilotons and is measured relative to the previous year.

Electricpower Electric power consumption serves as an indicator of the production and consumption of electricity within an economy, reflecting both its size and level of development. While some nations engage in the exportation of electric power, the majority of production is allocated for domestic consumption. The challenge of expanding electricity supply to meet the increasing demands of urbanized and industrialized economies while avoiding economic, and environmental consequences represents a significant hurdle for developing countries. While energy use has experienced substantial growth in low- and middle-income economies, high-income economies still exhibit nearly five times higher energy consumption per capita. Governments across various nations are increasingly recognizing the urgent necessity to optimize the utilization of global energy resources. Enhancing energy efficiency often emerges as the most economically viable and readily accessible approach to improving energy security and mitigating greenhouse gas emissions. The variable is measured in kilowatt-hours (kWh) per capita.

Electricpower_change This variable is similar to the aforementioned variable, but it measures the percentage change in comparison to the previous year. This variable assesses the year-on-year fluctuations in electric power consumption.

Totalfossilfuelsubsidies This variable is the sum of two other variables: explicit fossil fuel subsidies and implicit fossil fuel subsidies. Both variables will further on be explained. Total fossil fuel subsidies include underpricing due to supply costs being greater than prices paid by users and costs for the difference between supply costs and socially optimal prices, taking into account the negative externalities associated with fossil fuel utilization and the foregone revenues from consumption taxes. It is measured as a percentage of GDP.

Totalfossilfuelsubsidies _change This variable is similar to the aforementioned variable, but it measures the percentage change in comparison to the previous year. This variable assesses the year-on-year fluctuations in electric power consumption and provides insight into a country's financial investment in fossil fuels.

Preliminary analysis of the green bond data reveals interesting patterns. A significant increase in the issuance of green bonds has been observed globally in recent years, indicating a growing recognition of their potential in promoting sustainability. Furthermore, the examination of the percentage of GDP allocated to environmental protection provides valuable insights into the commitment of countries toward sustainable projects. By comparing this data with the trends in green bond issuance, it becomes possible to assess the extent to which increased green bond activity is associated with higher levels of sustainable project development. In addition to investigating the relationship between green bond issuance and sustainable projects, this study will explore various other relationships of interest. The other dependent variables are CO_2 emissions per capita, electric power consumption, and total fossil fuel subsidies. These variables have been selected to provide a comprehensive understanding of the broader environmental and energy-related dimensions that may be influenced by the issuance of green bonds.

4.2.2 Explanatory variables

Greenbonds The variable Greenbonds represents the cumulative value of green bonds issued during the period spanning from 2007 to 2021, measured in billions of U.S. dollars. These green bonds are exclusively issued by governmental entities or municipalities, reflecting their role as primary issuers responsible for financing environmentally sustainable projects.

Greenbonds_change This variable is similar to the aforementioned variable, but it measures the percentage change in comparison to the previous year. This variable assesses the year-on-year fluctuations in green bond issuance.

Agriculture The variable Agriculture represents the contribution of the agriculture, forestry, and fishing sectors to the overall gross domestic product (GDP) of a country. It measures the net output of these sectors, accounting for the total value of their outputs and subtracting the value of intermediate inputs. This indicator provides insights into the economic significance of these sectors and their contribution to the overall economic activity within a given country.

Environmental_taxes An environmental tax refers to a tax on specific physical units that have been linked to negative effects on the environment. Examples are a gallon of petrol, a passenger flight, or a ton of waste destined for landfill. The variable is expressed as a percentage of a country's Gross Domestic Product (GDP).

Explicitfossilfuelsubsidies Explicit subsidies reflect underpricing due to supply costs being greater than prices paid by users. The sum of the implicit fossil fuel subsidies and explicit fossil fuel subsidies are the total fossil fuel subsidies.

GDP The variable GDP represents the total value of goods and services produced within an economy, taking into account both the gross value added by resident producers and any product taxes. It reflects the overall economic activity and output. The data is in billions of US dollars and provides insights into the monetary value of the economy's productive activities, including both domestic production and international trade.

Implicitfossilfuelsubsidies Implicit subsidies are the difference between supply costs and socially optimal prices, taking into account the negative externalities associated with fossil fuel utilization and the foregone revenues from consumption taxes. Implicit subsidies do not include any explicit subsidies. The sum of the implicit fossil fuel subsidies and explicit fossil fuel subsidies are the total fossil fuel subsidies.

Industry This variable represents the added value in the industry sector. This sector consists of various components, including mining, construction, and electricity. It is expressed as a percentage of GDP.

Inflation The inflation rate, measured through the consumer price index (CPI), denotes the annual percentage fluctuation in the cost incurred by the average consumer to obtain a predetermined basket of goods and services.

Population Total population is based on the definition of population, which counts all residents regardless of legal status or citizenship. It is measured in millions of people.

Technology_export This variable refers to the exports of products with a high level of research and development (R&D) intensity, including sectors such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. This variable quantifies the proportion of total manufactured exports accounted for by high-technology products and is measured as a percentage. It provides insights into the relative significance of technologically advanced sectors in a country's export composition.

4.2.3 Control variables

Debt Total debt refers to the amount of payments made on long-term debt, including both principal repayments and interest, as well as interest payments on short-term debt, and any repayments made to the International Monetary Fund (IMF). The total debt service is expressed as a percentage of the Gross National Income (GNI). This indicator provides insights into the financial obligations and burdens associated with servicing a country's debt, reflecting the proportion of national income allocated towards debt repayment.

Energyusage Energy use refers to use of primary energy before transformation to other end-use fuels. It is measured in kilogram of oil per capita.

Foreigndirectinvestment This variable represents the net inflows of investment in an enterprise operating within an economy other than that of the investor. Foreign direct investment can have implications for economic development and growth. It is expressed in billions of U.S. dollars.

GDP_capita GDP per capita is GDP divided by midyear population. It is measured in thousands of U.S. dollars.

GDP_change The annual percentage growth rate of GDP is calculated using constant local currency and is measured relative to a base year. The aggregates are computed using constant 2015 prices and are expressed in US dollars. This indicator provides insights into the rate of change in the value of goods and services produced within an economy, adjusted for inflation and currency fluctuations. It serves as a valuable measure of economic growth and allows for meaningful comparisons across different time periods and countries.

GNI Gross National Income (GNI) represents the total value added by all resident producers. It also includes net receipts of primary income from abroad. It is expressed in U.S. dollars, which are converted using the purchasing power parity (PPP) conversion factor. The PPP conversion factor serves as a spatial price deflator and currency converter, mitigating the influence of variations in price levels among countries.

GNI_capita This variable provides the per capita values for GNI. It is expressed in U.S. dollars converted by purchasing power parity (PPP) conversion factor.

Incomeshare_lowest This variable refers to the subgroup representing the 20% of the population with the lowest income or consumption levels.

Population_change Annual population growth rate for year *t* is the exponential rate of growth of midyear population from year *t-1* to t, expressed as a percentage. The definition for the population is the same definition as used in the variable "Population".

Poverty The poverty rate, determined based on national poverty lines, signifies the proportion of the population that does not meet the standard considered essential by a country to fulfil basic needs. It serves as an indicator of the extent to which individuals within a given population experience a lack of economic resources required to meet essential living requirements.

Waterproductivity Water productivity represents the ratio of GDP measured in constant prices to the annual total water withdrawal. The availability of freshwater varies across countries, with some having abundant supplies while others face scarcity. Sustainable management of water

4.3 Descriptive statistics

The following section presents the descriptive statistics for the key variables in the dataset.

Table 2

Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Greenbonds billion($)	720	.685	3.068	0	43.169
EP_GDP(%)	720	.919	1.817	0	16.300
GDP billion($)	720	1406.736	3013.814	0.847	23315.081
Inflation(%)	720	3.691	5.124	-4.478	59.220
Environmentaltaxes(%)	720	2.116	1.292	0	5.14

Totalfossilfuelsubsidies(%)	720	7.184	7.427	0	58.487
co2percapita	720	7.337	4.512	1.124	23.155
Electricpower(kWh)	720	7479.618	6827.378	538.787	54799.175

The table above shows some interesting points. The summary statistics for the sample utilized in this thesis are presented below, highlighting the key observations. Notably, the standard deviation of green bonds in billions exceeds the mean by several multiples, indicating substantial variations in the issuance volume of green bonds across countries. Additionally, the maximum inflation value reaches 58%. Finally, the standard deviation of GDP is twice the magnitude of the mean, reflecting the inclusion of both wealthier and poorer nations within the dataset.

Table 3

Pairwise correlation table

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Greenbonds billion($)	1.000							
(2) EP_GDP(%)	0.064	1.000						
(3) GDP billion($)	0.237	-0.080	1.000					
(4) Inflation(%)	-0.080	-0.288	-0.085	1.000				
(5) Envorionmentaltaxes%	-0.052	0.374	-0.145	-0.237	1.000			
(6) Totalfossilsubsidies(%)	0.061	-0.058	0.071	-0.071	-0.141	1.000		
(7) co2percapita	-0.138	0.204	-0.049	-0.219	0.436	-0.177	1.000	
(8) Electricpower(kWh)	-0.161	0.063	-0.072	0.094	0.051	-0.562	0.313	1.000

Table 3 displays the pairwise correlations of the key variables in this thesis. Correlations are low, except for the correlation between electric power consumption and total fossil fuel subsidies. Interestingly, fossil fuel subsidies and green bonds are negatively correlated. This shows that subsidies for fossil fuels and green bonds are substitutes from the perspective of a government. Also, these correlations show premature evidence of a positive relationship between the percentage of GDP spent on green bond leads and environmental subsidies. Also a negative relationship between green bonds and CO_2 emissions per capita. The quantitative analysis presented further in this thesis will complement these premature findings.

5 Results

5.1 Results of quantitative research

This chapter provides an overview of the results obtained from the regression models and their implications for the hypotheses under investigation. The results are presented and discussed in relation to the research questions, providing insights into the relationships between key variables.

5.1.1 Hypothesis 1

Hypothesis 1 refers to the research question. The results are displayed below in Table 4. The first column includes both time and country random effects. The second column includes only country random effects, while the third column includes only year random effects. The last column incorporates a time-lag regression and is based on the percentage changes observed in the variables representing environmental protection and green bonds. Country and year random effects have been omitted from the table for the sake of brevity.

Table 4

Results Hypothesis 1

	(1) EP_gdp%	(2) EP_gdp%	(3) EP_gdp%	(4) L.EP_gdpchange
Green bonds bln $	0.366 (1.162)	0.428 (1.159)	0.221 (1.169)	
Population	0.521 (0.341)	0.000781 (0.101)	0.592 (0.337)	-39.85 (40.75)
Population growth (annual %)	-2.099 (6.738)	-3.545 (6.623)	-4.294 (6.559)	-279.5 (589.1)
GDPcurrentUS	-0.00163 (0.00555)	-0.000500 (0.00461)	-0.00468 (0.00539)	0.304 (0.292)
GDP growth (annual %)	-0.884 (1.317)	-1.258 (1.311)	-1.656 (1.007)	-191.3* (81.93)
Inflation	-0.945 (0.710)	-1.167 (0.705)	-1.235 (0.697)	64.12 (62.58)
Foreigndirectinvestment	-0.0110 (0.0629)	-0.00998 (0.0626)	-0.0508 (0.0623)	-0.317 (2.831)
GDP per capita	0.429 (0.765)	1.152 (0.641)	0.665 (0.715)	3.673 (52.95)

Environmental taxes	0.200**	0.234**	0.266***	0.748
	(0.0751)	(0.0734)	(0.0726)	(4.143)
Explicit fossil fuel subsidies	0.0303	0.0172	-0.0921	-0.652
	(0.0751)	(0.0737)	(0.0640)	(3.695)
Implicit fossil fuel subsidies	-0.165	-0.124	-0.163	-0.811
	(0.159)	(0.153)	(0.157)	(6.070)
Total fossil fuel subsidies	0.237	0.196	0.210	-6.829
	(0.155)	(0.150)	(0.155)	(5.876)
co2 emissions in kt	0.0337	0.0289	0.0573*	-0.462
	(0.0313)	(0.0306)	(0.0279)	(1.532)
co2 change changer	-0.0261	-0.0309	-0.0104	-0.167
	(0.0234)	(0.0234)	(0.0227)	(1.202)
co2 per capita	-0.123***	-0.102**	-0.103***	1.074
	(0.0345)	(0.0337)	(0.0298)	(1.989)
Poverty headcount ratio	0.0120	0.00685	0.0532	2.744
	(0.0973)	(0.0965)	(0.0971)	(4.684)
GNI	0.0690**	0.0642**	0.0660**	-1.087
	(0.0242)	(0.0240)	(0.0243)	(1.517)
GNI per capita	-0.0634*	-0.0577	-0.0768**	7.457
	(0.0302)	(0.0298)	(0.0294)	(10.16)
Incomeshare lowest 20%	-0.270	-0.184	-0.212	-13.06
	(0.201)	(0.197)	(0.198)	(9.778)
Forest area (sq. km)	-0.0650	-0.0597	0.0196	-0.00135
	(0.0655)	(0.0608)	(0.0495)	(2.565)
Water productivity	-0.0454	-0.0437	-0.0221	0.134
	(0.0265)	(0.0260)	(0.0250)	(1.420)
Energy use	-0.0888	-0.0914	-0.00430	4.575
	(0.0497)	(0.0494)	(0.0427)	(2.930)
Electric power consumption	-0.0517	-0.0399	0.0150	1.689
	(0.0539)	(0.0527)	(0.0425)	(3.052)
Agriculture	0.121*	0.100	0.0940	-0.329
	(0.0560)	(0.0528)	(0.0557)	(2.650)
Industry	-0.152*	-0.180**	-0.156*	-1.156
	(0.0644)	(0.0576)	(0.0607)	(3.315)
High-technology exports	-0.0146	-0.0135	-0.0116	-0.216
	(0.0200)	(0.0199)	(0.0198)	(1.123)
Total debt	-0.00504	-0.0597	-0.0239	9.372
	(0.127)	(0.124)	(0.128)	(7.177)
greenbondschange				0.00119
				(0.0365)
Constant	431.2***	326.6***	408.2***	-2948.8
	(56.82)	(52.80)	(54.54)	(4495.9)
Observations	717	717	717	220

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The findings of the first column show contradictory evidence of the hypothesized relationship between green bond issuance and the allocation of GDP to sustainable projects. The coefficient β_1 is positive, but contrary to expectations it is statistically insignificant. This result suggests that the statistical analysis does not provide sufficient evidence to reject the null hypothesis. These findings raise questions concerning the effectiveness of green bonds as a financing mechanism for sustainable projects.

Upon examining the first column, other several notable findings emerge. Firstly, the variable environmental taxes exhibit a positive and statistically significant coefficient. This suggests that an increase in environmental taxes is associated with a higher proportion of GDP being allocated to sustainable projects or environmental protection initiatives. This finding highlights the potential effectiveness of environmental taxation as a policy tool to incentivize environmentally responsible activities. It suggests that environmental taxes can play a crucial role in shaping economic behavior and promoting sustainable practices. By internalizing the environmental costs associated with certain activities, environmental taxes provide economic incentives for businesses and individuals to adopt greener alternatives and contribute to environmental protection efforts. This means that higher environmental taxes may lead to a shift in economic activities towards more sustainable and environmentally friendly practices.

Secondly, the variable CO_2 per capita shows a negative and significant coefficient. This implies that higher levels of CO_2 emissions per capita are associated with a lower allocation of GDP to sustainable projects or environmental protection. The negative coefficient suggests that regions with higher carbon footprints may prioritize other areas of expenditure, such as economic development or infrastructure, over environmental initiatives. It highlights a potential tension between economic growth and environmental sustainability, where environmental concerns may be given lower priority in resource allocation decisions.

Lastly, the variable agriculture, forestry, and fishing reveal a positive and significant coefficient. This indicates that a greater contribution of agriculture, forestry, and fishing to a nation's GDP corresponds to a higher allocation of GDP towards sustainable projects or environmental protection. This finding suggests that countries or regions with a substantial contribution of agriculture, forestry, and fishing to their GDP are more likely to prioritize environmental sustainability. This finding highlights the potential alignment between economic activities in these sectors and environmental conservation objectives. It indicates that countries heavily reliant on agriculture, forestry, and fishing recognize the importance of protecting natural resources, preserving biodiversity, and implementing sustainable practices within these industries.
Comparing the second and third columns to the first one, similar coefficients are visible. This suggests that the inclusion of either country or time random effects does not significantly impact the issuance of green

bonds on environmental protection. This indicates a robust relationship that is consistent across different countries and time periods. The similarity in results suggests that the variations in the relationship attributed to country-specific or time-specific factors are relatively small or negligible in this context. Therefore, the influence of country or time random effects appears to be minimal.

The last column incorporates a time-lag regression and is based on the percentage changes observed in the variables representing expenditure on environmental protection and green bonds. The variable green bonds change is insignificant. Besides that, all other variables, except for the annual change in GDP are insignificant. The insignificance of the variables could be explained by the time lag, which allows for cumulative effects to accumulate over time, potentially diluting the immediate impact and making it more challenging to detect a significant relationship. Additionally, the use of percentage changes may further amplify the noise in the data and obscure the underlying relationship. So, this suggests that H0 cannot be rejected based on these results.

5.1.2 Hypothesis 2

The second hypothesis examines the impact of green bonds on CO_2 emissions. The results are displayed in the table below. The first column includes both time and country random effects. The second column includes only country random effects, while the third column includes only year random effects. The last column incorporates a time-lag regression and is based on the percentage changes observed in the variables representing CO_2 emissions and green bonds.

Table 5

Results Hypothesis 2

	(1) co2 per capita	(2) co2 per capita	(3) co2 per capita	(4) L.co2capchange
Green bonds bln $	-2.896* (1.319)	-4.781** (1.634)	-3.091* (1.330)	
EP_GDP%	-0.162*** (0.0451)	-0.158** (0.0551)	-0.111** (0.0427)	0.0278 (0.128)
Populationtotal	1.387*** (0.385)	1.235** (0.474)	-0.0244 (0.0817)	0.563 (1.585)
Population growth (%)	-3.528 (7.703)	17.67 (9.224)	-4.973 (7.529)	-3.174 (23.85)
GDP	-0.00182 (0.00624)	-0.0129 (0.00745)	0.00488 (0.00474)	-0.000704 (0.0120)
GDP growth (annual %)	0.665 (1.482)	8.439*** (1.356)	0.182 (1.487)	-1.776 (3.410)

Inflation (annual %)	0.719 (0.812)	-0.549 (0.984)	0.573 (0.811)	-1.829 (2.588)
Foreigndirectinvestment	-0.0495 (0.0719)	-0.0837 (0.0878)	-0.0603 (0.0721)	0.476*** (0.117)
GDPpercapitacurrentUS	0.991 (0.874)	-0.0279 (1.007)	1.216 (0.649)	-3.918 (2.286)
Environmental taxes	0.192* (0.0858)	0.710*** (0.0985)	0.255** (0.0828)	0.0690 (0.167)
Explicit fossil fuel subsidies	-0.0111 (0.0855)	-0.237** (0.0898)	-0.0102 (0.0839)	0.151 (0.154)
Implicit fossil fuel subsidies	-0.156 (0.182)	-0.0616 (0.222)	0.00854 (0.176)	-0.0589 (0.253)
Total fossil fuel subsidies	0.401* (0.177)	0.388 (0.218)	0.235 (0.172)	0.0938 (0.241)
Poverty headcount ratio	0.159 (0.111)	0.134 (0.137)	0.129 (0.111)	0.130 (0.197)
GNI	0.0328 (0.0278)	0.0174 (0.0343)	0.0323 (0.0274)	0.0886 (0.0623)
GNI per capita	-0.00608 (0.0347)	-0.0850* (0.0416)	0.00549 (0.0341)	0.454 (0.436)
Income share lowest 20%	-0.197 (0.230)	0.494 (0.278)	-0.0152 (0.226)	0.202 (0.415)
Forest area (sq. km)	-0.119 (0.0748)	0.307*** (0.0677)	-0.130* (0.0649)	0.0612 (0.108)
Water productivity	-0.110*** (0.0298)	-0.0178 (0.0351)	-0.0878** (0.0293)	0.104 (0.0589)
Energy use per capita	-0.0542 (0.0569)	0.0425 (0.0602)	-0.0681 (0.0567)	-0.00863 (0.120)
Electric power consumption (kWh per capita)	0.0915 (0.0616)	0.259*** (0.0590)	0.123* (0.0596)	0.236 (0.127)
Agriculture, forestry, fishing	0.177** (0.0639)	0.125 (0.0785)	0.153** (0.0574)	-0.0637 (0.111)
Industry	-0.0721 (0.0732)	0.0516 (0.0851)	-0.0956 (0.0607)	0.123 (0.136)
High-technology exports	0.0499* (0.0228)	0.0379 (0.0279)	0.0510* (0.0228)	-0.00142 (0.0458)
Total debt	-0.147 (0.145)	-0.364* (0.179)	-0.232 (0.140)	0.0852 (0.297)
greenbondschange				-0.000598 (0.00149)
Constant	111.2 (67.33)	-35.93 (79.66)	277.3*** (54.57)	-111.4 (201.4)
Observations	718	718	718	221

Standard errors in parentheses
[*] $p < 0.05$, [**] $p < 0.01$, [***] $p < 0.001$

The hypothesis put forth in this study posited that an increase in green bond issuance would result in a reduction in CO_2 emissions. Upon analyzing the results presented in the table, it becomes apparent that the findings provide substantial evidence in support of the initial hypothesis. In the first column, which considers year and country random effects, β_1 is negative and significant. The results observed in the second and third columns are very comparable and significant as well, suggesting that the observed effect is not primarily driven by country-specific characteristics and remains consistent over time. The relationship holds true across different countries and remains stable over the specified time period.

It is interesting to notice that the variable total fossil fuel subsidies is also significant. The positive coefficient indicates that for every 1% increase in total fossil fuel subsidies as a percentage of GDP, there is an estimated increase of 0.401 tons of CO_2 emitted per capita, all else being equal. This suggests that the governments also indirectly impact the CO_2 emissions per capita. These findings raise questions about current subsidy policies' effectiveness and alignment with climate change mitigation goals. A study conducted by the International Energy Agency (IEA) has forecasted a forthcoming rise in fossil fuel subsidies for the year 2023 due to inflationary pressures and escalating demand for energy (IEA, 2022). This would thus lead to an increase in CO_2 emissions as well. The IEA research will be examined in a subsequent section about the analysis of total fossil fuel subsidies. However, when the random effects are excluded from the model, as in the second and third columns, the relationship becomes non-significant. This suggests that the observed relationship between green bond issuance and fossil fuel subsidies is primarily driven by time-specific factors and country-specific characteristics. In this case, the inclusion of the random effects help account for the variation in the relationship that is attributable to different time periods and countries.

The significance of certain variables varies when comparing the results between the second column (including only country random effects) and the third column (including time random effects). When comparings the tables, a significant relationship between changes in GDP and CO_2 emissions is observed when including only country random effects, but becomes nonsignificant when including only time random effects, suggesting that the relationship between these variables may be primarily driven by country-specific factors rather than time-specific factors. The variation in CO2 emissions across countries might explain a substantial portion of the relationship, while the time-based factors may not have a consistent influence.

Furthermore, the time-lag regression in the fourth column shows an insignificant relationship between percentage changes in green bonds and changes in CO_2 emissions. Moreover, every other variable is also insignificant except for foreign investments. The lack of significance in the variables could be attributed to the time lag, which may diminish the immediate impact and make it more difficult to observe a significant relationship. Furthermore, the use of percentage changes could introduce additional noise into the data and obscure the underlying association. Consequently, these findings indicate that there is insufficient evidence to reject the null hypothesis (H0). However, it is also important to note that the results do not provide significant support for the alternative hypothesis (H1).

5.1.3 Hypothesis 3

The third hypothesis examines the impact of green bonds on electric power consumption, measured in kWh per capita. The results are displayed in the table below. The first column includes both time and country random effects. The second column includes only country random effects, while the third column includes only year random effects. The last column incorporates a time-lag regression and is based on the percentage changes observed in the variables representing green bonds and electric power consumption.

Table 6

Results Hypothesis 3

	(1) Electric power consumption (kWh per capita)	(2) Electric power consumption (kWh per capita)	(3) Electric power consumption (kWh per capita)	(4) Electricpower change
Green bonds bln $	-1.389	-1.835	-0.962	
	(0.857)	(1.082)	(0.889)	
Forest area (sq. km)	0.0555	-0.0349	0.0390	-0.0139
	(0.0484)	(0.0459)	(0.0357)	(0.0132)
EP_GDP%	-0.0282	0.0129	0.00422	-0.0459**
	(0.0295)	(0.0366)	(0.0259)	(0.0158)
co2 per capita	0.0363	0.103***	0.0763**	-0.00745
	(0.0257)	(0.0276)	(0.0241)	(0.0101)
Populationtotal	-0.850***	-0.587	-0.0512	0.267
	(0.250)	(0.313)	(0.0340)	(0.207)
Population growth (%)	10.41*	0.319	5.057	-4.520
	(4.963)	(6.085)	(4.779)	(2.993)
GDP	0.0244***	0.0135**	0.00486	-0.00158
	(0.00399)	(0.00497)	(0.00251)	(0.00156)
GDP growth (annual %)	0.102	-0.893	-0.770	0.0304
	(0.974)	(0.935)	(0.999)	(0.418)
Inflation,(annual %)	-0.0404	0.0772	-0.763	-0.321
	(0.526)	(0.648)	(0.531)	(0.318)
Foreigndirectinvestment	0.0902	0.107	0.0576	0.00555
	(0.0464)	(0.0576)	(0.0474)	(0.0143)

GDPpercapita	-1.859***	-1.290	-0.805*	-0.0717
	(0.561)	(0.661)	(0.341)	(0.281)
Environmental taxes	-0.184***	-0.157*	-0.128*	0.00551
	(0.0554)	(0.0677)	(0.0519)	(0.0210)
Explicit fossil fuel subsidies	0.213***	-0.328***	0.118*	-0.0189
	(0.0549)	(0.0580)	(0.0547)	(0.0188)
Implicit fossil fuel subsidies	0.192	0.0138	0.134	-0.181***
	(0.117)	(0.146)	(0.116)	(0.0309)
Total fossil fuel subsidies	-0.0410	-0.233	0.0171	0.126***
	(0.115)	(0.144)	(0.114)	(0.0298)
co2 emissions in kt	-0.00502	0.0202	-0.0454*	0.000148
	(0.0232)	(0.0259)	(0.0218)	(0.00781)
co2 change prev year %	0.0109	0.0115	0.0145	0.0181**
	(0.0173)	(0.0210)	(0.0181)	(0.00614)
Poverty headcount ratio	0.0141	-0.00140	0.0360	0.0387
	(0.0719)	(0.0901)	(0.0717)	(0.0241)
GNI	-0.0488**	-0.113***	-0.0418*	-0.000353
	(0.0179)	(0.0222)	(0.0175)	(0.00771)
GNI per capita	0.0485*	-0.0459	0.0480*	0.0107
	(0.0223)	(0.0274)	(0.0221)	(0.0533)
Income share lowest 20%	0.0477	0.0316	0.139	-0.102*
	(0.149)	(0.184)	(0.146)	(0.0509)
Water productivity	0.00635	0.0307	0.00331	-0.0241**
	(0.0196)	(0.0231)	(0.0190)	(0.00742)
Energy use	0.0170	0.300***	0.0255	-0.0137
	(0.0368)	(0.0378)	(0.0370)	(0.0148)
Agriculture, forestry, fishing	0.0547	-0.0148	-0.0366	-0.0105
	(0.0415)	(0.0517)	(0.0331)	(0.0135)
Industry	-0.191***	-0.124*	-0.0753*	0.0276
	(0.0472)	(0.0564)	(0.0329)	(0.0169)
High-technology exports	0.0702***	0.0656***	0.0681***	-0.00101
	(0.0145)	(0.0182)	(0.0147)	(0.00569)
Total debt	0.0357	0.155	0.0129	0.0257
	(0.0941)	(0.118)	(0.0870)	(0.0364)
greenbondschange				-0.0000159
				(0.000185)
Constant	208.8***	125.9*	220.5***	17.24
	(43.08)	(52.51)	(32.39)	(27.38)
Observations	717	717	717	221

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The hypothesis that an increase in green bond issuance leads to a reduction in electric power consumption was not supported by the data, as the coefficient for green bond issuance, β_1, was negative but not statistically significant. The absence of insignificant coefficients is observed in the second and third columns as well. This means that there is not enough evidence to conclude that there is a significant relationship between green bond issuance and electric power consumption, so we cannot reject H0. The lack of a significant relationship between green bond issuance and power consumption may indicate that other factors beyond green bonds play a more prominent role in influencing electric power consumption. These factors could include technological advancements, energy efficiency measures, or changes in consumer behavior.

However, it is noteworthy that an increase in population was found to have a significant negative relationship with power consumption per capita. This suggests that population growth may lead to more efficient use of electricity or the adoption of energy-saving practices. It is possible that as the population increases, there is greater awareness and emphasis on energy conservation measures. Moreover, the variable population becomes non-significant when only one of the random effects is included. This suggests that both random effects are important for explaining the relationship. The inclusion of both year and country random effects captures the variation in the data due to time-specific factors and country-specific factors, which contributes to the significant relationship. However, when one of the random effects is excluded, the model may not adequately account for all the sources of variation, leading to a loss of significance in the relationship. This highlights the importance of considering both year and country random effects in order to obtain a comprehensive understanding of the relationship between the variables.

The table also shows a significant negative relationship between environmental taxes and electric power consumption. This finding suggests that an increase in environmental taxes is associated with a decrease in electric power consumption. It implies that higher taxes imposed on energy consumption provide economic incentives for individuals and businesses to reduce their electricity usage, promoting energy efficiency and conservation. These results support the effectiveness of environmental taxes as a policy tool for achieving sustainable energy goals and reducing the environmental impact of power consumption.

Moreover, the relationship between explicit fossil fuel subsidies and electric power consumption shows different patterns depending on the inclusion of random effects, it suggests that the influence of these factors may vary. The positive relationship observed when including both country and time random effects implies that higher explicit fossil fuel subsidies are associated with increased electric power consumption. This could be due to the subsidized nature of fossil fuels, which may lead to greater consumption and reliance on these energy sources. This relationship may be attributed to the lower cost of energy for consumers, which can incentivize greater energy usage and potentially lead to less efficient energy consumption patterns. However, when only country random effects are included, the relationship becomes negative, indicating that higher explicit fossil fuel subsidies are associated with lower electric power consumption. This contrasting finding suggests that country-specific factors play a significant role in determining the impact of subsidies on power consumption. It could be attributed to varying energy policies, efficiency measures, or renewable energy adoption across different countries. Interestingly, when only time random effects are included, the relationship returns to being positive, suggesting that the influence of time-specific factors may override the country-specific effects. This could be due to changes in energy consumption patterns over time, evolving energy policies, or other external factors influencing the relationship.

The variable industry value added, measured in the percentage of GDP, represents the contribution of the industrial sector to the overall GDP of a country. A significant positive coefficient suggests that countries with a larger industrial sector relative to their GDP tend to have higher power consumption per capita. This could be attributed to the energy-intensive nature of industrial activities and the power demands of manufacturing processes. Similarly, the variable high-technology export captures the extent to which a country exports high-technology products. A significant positive coefficient implies that countries with a higher export share of high-technology goods tend to have higher power consumption per capita. This could be attributed to the energy requirements of producing and exporting technologically advanced goods.

Moreover, the inclusion of a time-lag regression in the fourth column reveals a non-significant association between the percentage changes in green bonds and the corresponding changes in electric power consumption. The lack of statistical significance can potentially be attributed to the time lag, which may weaken the immediate impact and hinder the detection of a significant relationship. Furthermore, the utilization of percentage changes as a measure introduces additional variability into the data, potentially obscuring the underlying association. Thus, these findings suggest that there is insufficient empirical support to reject the null hypothesis (H0). It is important to note, however, that the results do not yield substantial evidence in favor of the alternative hypothesis (H1).

5.1.4 Hypothesis 4

The fourth hypothesis examines the impact of green bonds on total fossil fuel subsidies, as a percentage of total GDP. The first column includes both time and country random effects. The second column includes only country random effects, while the third column includes only year random effects. The last column incorporates a time-lag regression and is based on the percentage changes observed in the variables representing green bonds and electric power consumption. The results are displayed in the table below.

Table 7

Results hypothesis 4

	(1) Total fossil fuel subsidies as %gdp	(2) Total fossil fuel subsidies as %gdp	(3) Total fossil fuel subsidies as %gdp	(4) Total fossil fuel subsidies, change
Green bonds bln $	-0.179 (0.298)	-0.248 (0.297)	-0.128 (0.304)	
Electric power consumption (kWh per capita)	-0.00495 (0.0139)	-0.0175 (0.0108)	-0.00354 (0.0118)	5.411 (4.692)
Forest area (sq. km)	-0.0205 (0.0168)	-0.0119 (0.0126)	-0.00379 (0.00657)	-3.232 (4.013)
EP_GDP%	0.0157 (0.0102)	0.0136 (0.0100)	0.0162^{**} (0.00573)	-6.197 (4.806)
co2 per capita	0.0198^{*} (0.00892)	0.0141 (0.00764)	0.00354 (0.00629)	-4.445 (3.021)
Population	-0.613^{***} (0.0842)	-0.616^{***} (0.0825)	-0.0250^{***} (0.00494)	-35.11 (60.45)
Population growth (%)	7.705^{***} (1.703)	7.689^{***} (1.641)	2.232 (1.293)	354.1 (909.7)
GDP	0.00312^{*} (0.00142)	0.00381^{**} (0.00136)	0.000665 (0.000499)	-0.661 (0.471)
GDP growth (%)	-0.204 (0.338)	-0.248 (0.256)	-0.274 (0.335)	-171.5 (126.9)
Inflation, (annual %)	0.277 (0.182)	0.271 (0.177)	0.230 (0.170)	-204.7^{*} (96.52)
Foreigndirectinvestment	-0.000432 (0.0162)	-0.00493 (0.0158)	0.00590 (0.0153)	0.0819 (4.351)
GDPpercapita	-0.413^{*} (0.196)	-0.291 (0.182)	-0.0924 (0.0672)	155.9 (85.53)
Environmental taxes	-0.0110 (0.0194)	-0.0191 (0.0186)	-0.00182 (0.0131)	8.449 (6.371)
Explicit fossil fuel subsidies	0.0604^{**} (0.0191)	0.0825^{***} (0.0160)	0.0390^{*} (0.0173)	-5.915 (5.661)
Implicit fossil fuel subsidies	0.934^{***} (0.0167)	0.937^{***} (0.0153)	0.932^{***} (0.0147)	6.828 (5.214)
co2 emissions in kt	0.00156 (0.00805)	-0.00352 (0.00711)	0.0000306 (0.00570)	0.549 (2.377)
co2 change (%)	0.00405 (0.00602)	0.00279 (0.00576)	0.00469 (0.00636)	1.558 (1.863)
Poverty headcount ratio	0.0359 (0.0249)	0.0380 (0.0247)	0.00662 (0.0205)	-14.07 (7.323)
GNI	0.000534 (0.00627)	0.00278 (0.00620)	-0.00171 (0.00478)	1.220 (2.323)
GNI per capita	0.0113 (0.00777)	0.0176^{*} (0.00749)	0.000312 (0.00706)	-11.50 (16.18)

Income share lowest 20%	-0.0294 (0.0516)	-0.0320 (0.0503)	-0.0411 (0.0434)	-6.608 (15.46)
Water productivity	0.00720 (0.00681)	0.00731 (0.00635)	-0.00641 (0.00525)	-2.509 (2.255)
Energy use	0.0428*** (0.0127)	0.0204 (0.0108)	0.0310** (0.0111)	6.222 (4.466)
Agriculture, forestry, fishing	0.000855 (0.0144)	0.00578 (0.0142)	0.0122 (0.00704)	3.347 (4.109)
Industry	-0.0143 (0.0166)	-0.0249 (0.0155)	-0.00222 (0.00606)	3.049 (5.153)
High-technology exports	-0.00273 (0.00514)	-0.00102 (0.00505)	-0.00292 (0.00448)	-1.284 (1.718)
Total debt service	0.0379 (0.0326)	0.0348 (0.0325)	-0.0214 (0.0217)	-9.670 (10.99)
greenbondschange				-0.0255 (0.0561)
Constant	0.841 (15.24)	5.333 (14.46)	-6.445 (8.725)	-3779.4 (8325.3)
Observations	717	717	717	221

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The fourth hypothesis aims to investigate whether an increase in green bond issuance is associated with a decrease in fossil fuel subsidies. The findings demonstrate that β_1 has a negative coefficient. However, it is important to note that this negative effect is not statistically significant. Hence, given the existing evidence, conclusions regarding the presence of a significant relationship between green bond issuance and fossil fuel subsidies cannot be made, thereby preventing the rejection of the null hypothesis (H0).

Other results from this table show that the variable population demonstrates a significant negative effect on fossil fuel subsidies. This suggests that as the population increases, there is a tendency for a decrease in fossil fuel subsidies as a percentage of GDP. This finding implies that higher population levels may lead to greater economic efficiency or policy shifts that result in a reduced reliance on subsidies for fossil fuels. One possible implication of this finding is that countries with larger populations may have implemented measures or policies that promote energy efficiency, renewable energy sources, or alternative means of energy production. These initiatives could be driven by the need to meet the energy demands of a growing population while simultaneously addressing environmental concerns and reducing dependence on fossil fuels.

Moreover, the variable GDP exhibits a significant positive effect on total fossil fuel subsidies, implying that as the GDP rises, there is an increase in the proportion of GDP allocated to subsidizing fossil fuels. This effect is significant for the first and second columns. This relationship highlights the potential trade-off between economic growth and environmental sustainability. As GDP increases, there is typically a greater demand for energy to support industrial activities, transportation, and the growing needs of the population. This increased energy demand may lead to continued reliance on fossil fuels, which are often more readily available and cheaper in the short term compared to renewable energy alternatives. Furthermore, the positive relationship between GDP and fossil fuel subsidies suggests that governments may prioritize economic growth and energy security over environmental considerations. In some cases, subsidizing fossil fuels can be seen as a way to maintain affordable energy prices, support domestic industries, and stimulate economic development. However, this approach may hinder efforts to mitigate climate change, reduce greenhouse gas emissions, and transition to cleaner and more sustainable energy systems.

Furthermore, implicit fossil fuel subsidies show a positive and significant effect on total fossil fuel subsidies, as do explicit subsidies. This implies that both types of subsidies contribute to a higher percentage of GDP being allocated to support fossil fuel industries. The presence of significant positive coefficients for implicit and explicit subsidies underscores the importance of considering the impact of both forms of subsidies when examining the overall level of support provided to the fossil fuel sector.

Lastly, the time-lag regression in the fourth column shows an insignificant relationship between percentage changes in green bonds and changes in fossil fuel subsidies. The lack of significance could be attributed to the time lag, which may diminish the immediate impact and make it more difficult to observe a significant relationship. Furthermore, the use of percentage changes could introduce additional noise into the data and obscure the underlying association. Consequently, these findings indicate that there is insufficient evidence to reject the null hypothesis (H0). However, it is also important to note that the results do not provide significant support for the alternative hypothesis (H1).

6 Conclusion and Discussion

6.1 Conclusion subquestion 1

What are the key motivations and drivers for issuers to issue green bonds?

Understanding the motivations behind green bond issuance is essential for understanding the driving factors behind the implementation of green bonds. While some issuers are primarily motivated by environmental concerns and a commitment to sustainability, others are driven by financial incentives, such as accessing a broader investor base, diversifying funding sources, and capitalizing on the demand for green investments. Exploring these motivations provides insights into the varied perspectives and objectives of issuers.

Government claims and research indicate that green bonds are issued to combat climate change and attract investments toward sustainable projects. However, a case study on the Swedish government's issuance of green bonds revealed additional motivations, including promoting the green bond market, communicating existing environmental initiatives, assisting investors in building sustainable portfolios and reinforcing the government's bond issuer position. Evaluating governments' claims about green bond issuance as a response to climate change raises concerns about potential overlaps with existing commitments and the extent to which green bonds generate additional environmental impact. Nonetheless, studies suggest that green bonds can enhance issuers' environmental performance and encourage the pursuit of greener strategies.

6.2 Conclusion subquestion 2

Does the issuance of green bonds influence other environmental measures such as CO2 emissions, electric power consumption, and fossil fuel subsidies?

6.2.1 Conclusion hypothesis 2

The findings of this analysis strongly support the hypothesis proposed, which suggests that an increase in green bond issuance leads to a reduction in CO_2 emissions. Moreover, the significant and consistent results observed in the first three columns further reinforce the validity of this relationship, as they demonstrate that the effect is not driven by country-specific factors and remains stable over time. These findings demonstrate the effectiveness of green bond issuance in facilitating the desired environmental outcomes across various countries and time periods.

Fossil fuel subsidies, which involve providing financial support to the fossil fuel industry, may have unintended consequences for environmental sustainability, as indicated by the positive relationship with CO_2 emissions per capita. The positive coefficient suggests that a greater allocation of GDP towards fossil fuel subsidies is associated with increased reliance on fossil fuel consumption, leading to higher CO_2

emissions. Policy interventions aimed at reducing fossil fuel subsidies or reallocating these funds towards sustainable alternatives could potentially contribute to lowering CO_2 emissions and promoting environmental sustainability. The findings raise questions about current subsidy policies' effectiveness and alignment with climate change mitigation goals.

6.2.2 Conclusion hypothesis 3

The hypothesis that an increase in green bond issuance leads to a reduction in electric power consumption was not supported by the data, as the coefficient for green bond issuance was not statistically significant. This suggests that there is insufficient evidence to conclude that there is a significant relationship between green bond issuance and electric power consumption.

While the data did not support a significant relationship between green bond issuance and power consumption, other factors such as population growth, explicit fossil fuel subsidies, the size of the industrial sector, and the export share of high-technology goods were found to have significant associations with the power consumption per capita. These findings highlight the complex interplay of various factors in shaping electricity consumption patterns.

6.2.3 Conclusion hypothesis 4

The study examines the relationship between green bond issuance and fossil fuel subsidies, focusing on explicit and implicit subsidies. While the findings suggest a negative effect, indicating a potential decrease in subsidies with increased green bond issuance, this effect is not statistically significant, and firm conclusions cannot be drawn.

Other findings reveal that higher population levels are associated with reduced reliance on subsidies, possibly due to energy efficiency and renewable energy adoption. However, as GDP increases, a larger proportion of GDP is allocated to subsidizing fossil fuels, highlighting the trade-off between economic growth and environmental sustainability. Moreover, both implicit and explicit subsidies contribute significantly to supporting the fossil fuel industry. These findings shed light on the complex dynamics involved in energy policy and sustainability efforts, emphasizing the need for comprehensive approaches to reduce reliance on fossil fuels and promote greener alternatives.

6.3 Conclusion research question

Does a causal relationship exist between the issuance of green bonds and the development of sustainability projects?

The study presents contradictory evidence regarding the relationship between green bond issuance and the allocation of GDP to environmental protection. The coefficient for sustainable projects is negative and statistically insignificant, suggesting the absence of a significant link. This raises questions about the effectiveness of green bonds as a financing mechanism for sustainable projects and casts doubt on the reliability of the collected data. Moreover, when exploring the relationship using a lag regression and considering percentage changes, the results remain insignificant. This further raises queries about the methodological approach employed and the effectiveness of green bonds as a financing mechanism for sustainable projects.

However, when examining other variables, the study finds that environmental taxes have a positive and significant coefficient, indicating that an increase in environmental taxes is associated with a higher allocation of GDP to sustainable projects or environmental protection. This suggests the potential effectiveness of environmental taxation as a policy tool for promoting sustainable practices. The study also reveals that higher levels of CO_2 emissions are associated with a lower allocation of GDP to sustainable projects or environmental protection, highlighting the tension between economic growth and environmental sustainability. Furthermore, a greater contribution of agriculture, forestry, and fishing to a nation's GDP is positively associated with a higher allocation of GDP to sustainable projects or environmental protection. This suggests that countries heavily reliant on these sectors prioritize environmental sustainability.

6.4 Discussion

6.4.1 Limitations

Reliance on available data sources introduces limitations such as measurement errors and missing data, potentially introducing biases that affect the accuracy and reliability of the findings. Additionally, the data used may not encompass all relevant variables or factors that could potentially influence the relationship under investigation. Establishing a causal relationship between variables in this study faces challenges due to the nature of observational data, which makes it difficult to determine the direction of causality. Instead of a country panel dataset with the sum of green bonds per year, perhaps a cross-sectional dataset containing all green bonds would have been a more suitable dataset and would have been prone to fewer data collection limitations.

The study's findings may be influenced by the specific time frame considered, and the relationship between green bond issuance and environmental sustainability could evolve over time. The study's results may not capture long-term effects or trends that could emerge beyond the analyzed period. Moreover, endogeneity poses a potential challenge, as the independent variable (green bond issuance) and the various dependent variables could be simultaneously influenced by other unobserved factors. This creates complexities in establishing a clear causal relationship between the variables. Despite attempts to include relevant variables in the analysis, there may still exist additional omitted variables that could confound the relationship between green bond issuance and environmental sustainability. These unaccounted factors hold the potential to significantly shape the observed outcomes and contribute to the limitations of the study.

6.4.2 Contributions to the existing literature

This study significantly contributes to the existing literature on green bond issuance by offering valuable insights into the multifaceted motivations that drive issuers to engage in this form of sustainable finance. While previous research has predominantly focused on environmental concerns as the primary driver, this study goes beyond that by considering additional factors such as financial incentives, communication strategies, and market positioning. By incorporating these diverse perspectives, the study enhances our understanding of the complex decision-making processes behind green bond issuance. These contributions deepen our understanding of sustainable finance and provide valuable insights for policymakers, investors, and issuers seeking to advance environmental objectives through financial instruments.

Moreover, this research sheds light on the potential positive impact of green bonds on issuers' environmental performance. It suggests that the adoption of green bonds can act as a catalyst for issuers to intensify their commitment to greener strategies and operations. This finding has important implications for sustainable finance, as it demonstrates the effectiveness of financial instruments in driving tangible environmental outcomes. Besides that, the study adds to the literature by highlighting the role of communication strategies in promoting green bond issuance. By effectively communicating the environmental benefits and commitments associated with green bonds, issuers can attract a wider range of investors and enhance their market positioning. This insight provides practical guidance for issuers seeking to maximize the impact and success of their green bond initiatives.

6.4.3 Future research

Future research endeavors should extend their focus to examine the influence of diverse types of issuers, such as corporations, municipalities, and international organizations, on green bond issuance and the resulting environmental outcomes. This broader investigation would provide a deeper understanding of the roles played by different actors in advancing sustainability objectives. Furthermore, exploring the investor perspective would yield valuable insights into the factors shaping their investment decisions in green bonds, their perceptions of issuer motivations, and the anticipated outcomes from their investments.

To gain a comprehensive understanding of the relationship between green bond issuance and power consumption, future research should incorporate a broader range of factors into their analyses. This would involve delving into the specific mechanisms through which these factors impact power consumption and exploring potential policy implications for promoting sustainable and efficient energy utilization within industrial and technological sectors. Additionally, evaluating the effectiveness of alternative energy policies and identifying potential trade-offs between economic considerations and environmental sustainability would be essential for informing policymakers and stakeholders involved in sustainable energy transitions. In addressing these implications, policymakers should adopt a comprehensive approach that transcends short-term measures such as subsidies. Long-term strategies aimed at diversifying energy sources, fostering energy efficiency and conservation, and promoting the development and adoption of renewable energy technologies are crucial. By reducing reliance on fossil fuels and embracing sustainable energy practices, countries can mitigate the impact of inflation on energy costs, enhance energy security, and contribute to environmental sustainability.

Future research can also focus on conducting comprehensive impact assessments of green bond-funded sustainability projects to evaluate their environmental, social, and economic outcomes. Comparative studies across sectors, regions, and project types can provide valuable insights into best practices and areas for improvement. Moreover, examining the risks associated with green bond investments and sustainability projects, including financial and environmental risks, as well as the potential for greenwashing or misallocation of funds, is crucial for ensuring the long-term success and credibility of green bonds as an investment instrument. Additionally, investigating the role of policy frameworks and standards in promoting green bond issuance and driving sustainable development is essential. This includes analyzing the effectiveness of current regulations, incentives, and reporting requirements, and identifying opportunities for policy interventions to enhance the impact and transparency of green bonds.

By conducting research in these areas, we can gain a deeper understanding of the outcomes and risks associated with green bond-funded projects, improve policy frameworks, and contribute to the advancement of sustainable development goals.

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8 Appendix

The second model of hypothesis 1, which only includes country random effects.

$$EP\_GDP = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * CO2\ emissions + \beta_{14} * CO2\ emissions\ change + \beta_{15} * CO2\ per\ capita + \beta_{16} * poverty + \beta_{17} * GNI + \beta_{18} * GNI\ per\ capita + \beta_{19} * incomeshare\ lowest\ 20 + \beta_{20} * water\ productivity + \beta_{21} * energy\ use + \beta_{22} * electric\ power + \beta_{23} * agriculture + \beta_{24} * industry + \beta_{25} * technology\ export + \beta_{26} * debt + \mu_n * D_{country} + \alpha_i + u_{it} \quad (2)$$

The third model of hypothesis 1, which only includes year random effects.

$$EP\_GDP = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * CO2\ emissions + \beta_{14} * CO2\ emissions\ change + \beta_{15} * CO2\ per\ capita + \beta_{16} * poverty + \beta_{17} * GNI + \beta_{18} * GNI\ per\ capita + \beta_{19} * incomeshare\ lowest\ 20 + \beta_{20} * water\ productivity + \beta_{21} * energy\ use + \beta_{22} * electric\ power + \beta_{23} * agriculture + \beta_{24} * industry + \beta_{25} * technology\ export + \beta_{26} * debt + \theta_n * D_{year} + \alpha_i + u_{it} \quad (3)$$

The second model of hypothesis 2, which only includes country random effects.

$$CO2\ emissions\ per\ capita = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * electric\ power + \beta_{20} * agriculture + \beta_{21} * industry + \beta_{22} * technology\ export + \beta_{23} * debt + \beta_{24} * EP\_GDP + \mu_n * D_{country} + \alpha_i + u_{it} \quad (6)$$

The third model of hypothesis 2, which only includes year random effects.

$$CO2\ emissions\ per\ capita = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * electric\ power + \beta_{20} * agriculture + \beta_{21} * industry + \beta_{22} * technology\ export + \beta_{23} * debt + \beta_{24} * EP\_GDP + \theta_n * D_{year} + \alpha_i + u_{it} \quad (7)$$

The second model of hypothesis 3, which only includes country random effects.

$$Electric\ power = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * CO2\ emissions + \beta_{20} * CO2\ emissions\ change + \beta_{21} * CO2\ per\ capita + \beta_{22} * agriculture + \beta_{23} * industry + \beta_{24} * technology\ export + \beta_{25} * debt + \mu_n * D_{country} + \alpha_i + u_{it} \quad (10)$$

The third model of hypothesis 3, which only includes year random effects.

$$Electric\ power = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * explicit\ fossil\ fuel\ subsidies + \beta_{11} * implicit\ fossil\ fuel\ subsidies + \beta_{12} * total\ fossil\ fuel\ subsidies + \beta_{13} * poverty + \beta_{14} * GNI + \beta_{15} * GNI\ per\ capita + \beta_{16} * incomeshare\ lowest + \beta_{17} * water\ productivity + \beta_{18} * energy\ use + \beta_{19} * CO2\ emissions + \beta_{20} * CO2\ emissions\ change + \beta_{21} * CO2\ per\ capita + \beta_{22} * agriculture + \beta_{23} * industry + \beta_{24} * technology\ export + \beta_{25} * debt + \theta_n * D_{year} + \alpha_i + u_{it} \quad (11)$$

The second model of hypothesis 4, which only includes country random effects.

$$Total\ fossil\ fuel\ subsidies = \beta_0 + \beta_1 * green\ bonds + \beta_2 * population + \beta_3 * population\ change + \beta_4 * GDP + \beta_5 * GDP\ change + \beta_6 * inflation + \beta_7 *$$

$foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * poverty + \beta_{11} * GNI + \beta_{12} * GNI\ per\ capita + \beta_{13} * incomeshare\ lowest\ + \beta_{14} * water\ productivity + \beta_{15} * energy\ use + \beta_{16} * CO2\ emissions + \ \beta_{17} * CO2\ emissions\ change + \ \beta_{18} * CO2\ per\ capita + \ \beta_{19} * agriculture + \ \beta_{20} * industry + \ \beta_{21} * technology\ export + \beta_{22} * electric\ power + \ \beta_{23} * debt + \mu_n * D_{country} + \alpha_i + u_{it}$ (14)

The third model of hypothesis 4, which only includes year random effects.

$Total\ fossil\ fuel\ subsidies = \ \beta_0 + \ \beta_1 * green\ bonds + \beta_2 * population + \ \beta_3 * population\ change + \ \beta_4 * GDP + \ \beta_5 * GDP\ change + \ \beta_6 * inflation + \ \beta_7 * foreign\ direct\ investment + \beta_8 * GDP\ per\ capita + \beta_9 * environmental\ taxes + \beta_{10} * poverty + \beta_{11} * GNI + \beta_{12} * GNI\ per\ capita + \beta_{13} * incomeshare\ lowest\ + \beta_{14} * water\ productivity + \beta_{15} * energy\ use + \beta_{16} * CO2\ emissions + \ \beta_{17} * CO2\ emissions\ change + \ \beta_{18} * CO2\ per\ capita + \ \beta_{19} * agriculture + \ \beta_{20} * industry + \ \beta_{21} * technology\ export + \beta_{22} * electric\ power + \ \beta_{23} * debt + \theta_n\ * D_{year} + \alpha_i + u_{it}$ (15)