

Green Bonds as Drivers of
Sustainable Development: Insights
and Strategies for Local Authorities
in Advancing Environmental
Progress

Master's Thesis
of

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Contents

1	<i>Introduction</i>	1
1.1	<i>Green Bonds and Sustainable Development Goals</i>	2
2	<i>Literature Review</i>	6
3	<i>Green Bonds</i>	11
3.1	<i>Definition of Green Bonds: Key Concepts and Relevance</i>	11
3.2	<i>Global Trends and Growth of the Market of Green Bonds</i>	13
3.3	<i>Current Challenges: Obstacles Facing the Green Bonds</i>	20
4	<i>Municipal Green Bonds</i>	23
4.1	<i>Municipal Green Bonds and Their Impact</i>	24
4.2	<i>Examples of Municipal Green Bonds</i>	31
4.2.1	<i>Toronto Green Bonds</i>	32
4.2.2	<i>Gothenburg Green Bonds</i>	33
4.2.3	<i>Cape Town Green Bonds</i>	34
4.2.4	<i>Moscow Green Bonds</i>	34
4.3	<i>Exploring the “Greenium” in Municipal Bonds</i>	38
5	<i>Empirical Analysis</i>	41
5.1	<i>Research Design. Green Bonds and SDG Score</i>	42
5.2	<i>Data Collection</i>	42
5.3	<i>Correlation Between Green Bonds and SDG-score</i>	44
5.4	<i>Impact of Green Bonds on Sustainability Metrics</i>	49
5.4.1	<i>Reverse Causality and IV Model</i>	55
5.4.2	<i>Green Bonds and Effect on SDGs</i>	56
5.5	<i>Limitations of the Research</i>	61
5.6	<i>Implications</i>	63
6	<i>Conclusion</i>	64
	<i>Bibliography</i>	67

List of Figures

1	<i>Global green, social and sustainable bond annual issuance by type, USD bn, from 2019 to 2024</i>	
	<i>Source: Environmental Finance Bond Database; S and P Global Ratings . .</i>	14
2	<i>Green bonds issuance by country, (USD bn) in 2013 - 2025</i>	
	<i>Source: Eikon Redifinitiv LSEG</i>	16
3	<i>Share of green bonds in different countries in 2022, percentages</i>	
	<i>Source: IMF</i>	17
4	<i>Percentage of green bond issued by corporates and governments per Member State, 2023</i>	
	<i>Source: ESMA</i>	18
5	<i>Amount of issued green bonds by type of issuer worldwide, 2014-2023, bn US dollars</i>	
	<i>Source: CBI</i>	18
6	<i>Distribution of green bond by type of issuer in 2024 (percents): Government, Corporate, and Municipal</i>	
	<i>Source: Bloomberg, March 2025</i>	19
7	<i>SDG-score in 2023</i>	
	<i>Source: UN</i>	20
8	<i>Share of green bonds in total amount of bonds issued by local authorities, in the EU-27, 2014-2024</i>	
	<i>Source: European Securities and Markets Authority (ESMA)</i>	28
9	<i>Scatter plot of dependence of SDG score from the amount of green bonds issued in different countries</i>	
	<i>Source: IMF, UN</i>	47
10	<i>Correlation matrix of SDG, GB, GDP, FDI, CO₂</i>	
	<i>Source: World Bank, Climate Bond Initiative, UN</i>	47
11	<i>Scatter plots of dependent and independent variables (SDG, GB, GDP, FDI, CO₂) over the period of years by countries</i>	
	<i>Source: World Bank, IMF, UN</i>	48
12	<i>Histogram of residuals, model 8</i>	61

List of Tables

1	<i>Advantages and Disadvantages of Green Bonds for Different Stakeholders: Investors, Issuers and Municipalities</i>	22
2	<i>Roadmap for Local Authorities to Issue Green Bonds</i>	31
3	<i>Green bond issued by Toronto</i>	33
4	<i>Comparative analysis of municipal green bonds issuance cases</i>	37
5	<i>Model 1</i>	41
6	<i>Variable Definitions and Measurements</i>	44
7	<i>Average SDG-scores</i>	49
8	<i>Model 2</i>	51
9	<i>Regression Results for Model 3</i>	53
10	<i>Regression Results for GB(fit)</i>	56
11	<i>Model 6: OLS Model with CO₂ as Dependent Variable</i>	57
12	<i>Model 7</i>	58
13	<i>Model 8 Estimation Results</i>	59

Abstract

This thesis explores the role of green bonds as catalysts for sustainable development, focusing on the strategies that local authorities can employ to advance environmental progress. The research assesses the impact of green bond issuance on the achievement of Sustainable Development Goals (SDGs) and its correlation with the reduction in CO₂ emissions.

Furthermore, the study investigates whether it is perspective to use green bonds for local authorities. Case studies of municipal green bonds issuance illustrate real-world applications, and the efficiency of the way local authorities leverage these financial instruments to foster sustainable urban infrastructure. The findings shed the light on the issue how local authorities can rationally utilize green bonds as a financial tool to enhance local environmental development. To sum up, this research is dedicated to the understanding of the role green bonds play in the promotion of sustainability and to the analysis of various strategies for local governments. Thus, the work investigates the role of green bonds in advancing sustainable development, with a focus on their efficiency as financial instruments for local authorities. The study addresses two core questions: whether green bond issuance accelerates progress toward sustainable development and reductions in CO₂ emissions and whether a “greenium” (yield advantage for green bonds) exists helping municipalities efficiently utilize these instruments to fund sustainable infrastructure.

Using econometric analysis and case studies of municipal green bond programs, the research demonstrates that green bond issuance is significantly associated with improved SDG performance. The study confirms the presence of a greenium, reducing borrowing costs for local governments. Case studies reveal that cities leveraging green bonds enable investments in renewable energy, climate-resilient infrastructure, and sustainable transportation. In today’s context, where municipalities can play an important role addressing climate change and contributing to sustainable practices, green bonds offer a possibility to finance expensive initiatives that align with environmental goals. By harnessing the potential of green bonds, municipalities can not only drive local environmental progress but can also be considered as crucial integrators in the global transition towards a more sustainable future. The thesis validates green bonds as dual-purpose tools lowering financing costs for municipalities while directly funding SDG-aligned projects.

Keywords: Green bonds, sustainable development, greenium, municipal green bonds, SDGs, CO₂ emissions, local sustainable development, climate finance.

1 Introduction

For much of modern economic history, the spheres of economics and environmental sustainability have been treated as distinct, often competing, narratives. Conventional economic paradigms have largely operated on a model of perpetual growth, frequently quantifying progress through metrics that externalize ecological degradation. In parallel, the integrity of natural systems and the foundation of long-term prosperity and stability has been depreciated as an externality. This dissonance has precipitated a critical juncture. The escalating climate crisis and biodiversity loss now present an incontrovertible imperative: the architecture of global finance must be reconfigured to serve not only economic imperatives but also planetary boundaries. This necessity births a central and pressing research question: How can such a specific financial instrument as green bonds be effectively mobilized by local authorities to fund the transition to a sustainable and low-carbon economy, and is it true that green bonds' role as innovative financial instruments consists in aligning profit with environmental objectives? It is within this context that at a local level municipal green bonds emerge as a pivotal innovation, purportedly designed to bridge this very divide by channeling investment towards environmentally beneficial projects. This thesis will interrogate the efficacy of this instrument in fulfilling that promise.

The research design of this study is meticulously structured to provide comprehensive insights into the role of green bonds in sustainable development and the existence of a "greenium." Utilizing econometric analysis, the study develops multiple models to address two primary research questions. The first set of models examines the existence of a "greenium," or yield difference between green and conventional municipal bonds. The second set of models investigates whether green bond issuance positively contributes to sustainable development at the national level, focusing on indicators such as SDG scores and CO₂ emissions. Econometric modeling is chosen for its ability to provide a structured framework for quantitative analysis, enabling the assessment of causality, control for external factors, and analysis of panel data. Data for the study is sourced from solid institutions such as Eurostat, the IMF, and the Climate Bonds Initiative, ensuring a robust and multi-dimensional perspective. The analysis uses panel data, incorporating variables such as GDP, FDI, and CO₂ emissions to control for economic and environmental influences. This study aims to contribute to existing knowledge on sustainable finance by providing insight into the role of green bonds in achieving sustainable development goals and for efficient mechanisms and results of green bond issuance by municipalities. By analyzing the role of green bonds in financing environmentally beneficial projects, the research will contribute to a deeper understanding of how these financial instruments can support sustainable development. In addition, this thesis may lead to an understanding of how green bonds can be leveraged effectively

in different regulatory and market environments, offering strategies for policymakers, financial institutions, and environmental advocates. By highlighting successful practices and existing challenges, the research aims to promote greater investment in sustainable projects through innovative financial instrument.

1.1 Green Bonds and Sustainable Development Goals

In the contemporary landscape, a variety of interconnected sustainability challenges pose significant threats to society's future, necessitating global collaboration. These challenges encompass climate change, rising temperatures, biodiversity loss, pollution, resource depletion, and an increase in natural disasters, affecting numerous facets of life. To effectively tackle these pressing issues, it is essential to develop comprehensive global strategies and promote international cooperation to mitigate the associated risks. This requires the involvement of a wide array of human activities to ensure that all aspects of these challenges are addressed. To support such initiatives, substantial financial investments are crucial, making sustainable finance an essential tool in confronting global challenges (Schoenmaker and Schramade, 2018). This paper focuses specifically on one aspect of sustainable finance: green bonds. Green bonds represent a transformative financial instrument engineered to integrate environmental sustainability into the core of capital markets by channeling investment exclusively towards projects with positive ecological impacts (Ehlers and Packer, 2017). Unlike conventional bonds, their issuance is fundamentally predicated on a commitment to four core principles: the transparent earmarking of proceeds for predefined green projects, a rigorous process for evaluating and selecting eligible initiatives, the meticulous management of raised capital, and the ongoing reporting of both allocation and environmental impact. This framework, largely guided by voluntary standards like the International Capital Market Association (ICMA), Green Bond Principles, that seek to mitigate risks of greenwashing and provide investors with verifiable assurance Association 2024). Consequently, green bonds serve a dual purpose: they provide issuers - including corporations, municipalities, and sovereigns with access to a growing pool of sustainability - focused capital, often while potentially benefiting from a "green premium" or lower yield due to high demand (Zerbib, 2019), and they offer investors a vehicle to align their portfolios with environmental, social, and governance (ESG) criteria without necessarily sacrificing financial returns. Thus, they function as a critical mechanism for financing the transition to a low-carbon and climate-resilient economy, bridging the gap between ambitious environmental targets and the requisite capital needed to achieve them. The World Bank introduced the concept of green bonds by issuing the first labeled ones in 2007 to support projects targeting environmental challenges. The European Investment Bank (EIB) was

The first to issue green bonds, marking a pivotal moment in the development of green finance. Following the Paris Agreement in 2015, the green bond market experienced significant growth, as 195 countries recognized the urgent need to reduce greenhouse gas emissions to limit temperature increase. The adoption of the 2030 Agenda for Sustainable Development by the United Nations further propelled the green bond market, as it officially established 17 SDGs with the target of addressing climate change, energy inefficiency, poverty, lack of clean water, global cooperation challenges, gender inequality, food scarcity, social injustice, and other acute pressing issues. This global commitment enhanced the awareness of urgency of green investments, signaling a formal acknowledgment of the critical role finance may play in addressing environmental challenges and facilitating economic transitions.

Today, understanding the concept and significance of green bonds is becoming more and more important and, particularly, as the market constantly faces with issues such as greenwashing and the need for standardized metrics. At the same time, this type of financial instrument presents substantial opportunities for innovation and growth in sectors like renewable energy, sustainable agriculture, and infrastructure, which require significant resources to mitigate the adverse effects of climate change. This study examines the relationship between the efficiency of sustainable development efforts and the volume of green bonds issued worldwide, with the aim of determining whether the issuance of green bonds significantly contributes to sustainability across various countries. Additionally, the research analyzes the yield differences between green bonds and traditional bonds and presents comparative case studies on the significance of green bond issuance by local authorities. By reviewing existing literature and selecting case studies from diverse countries, this study tries to assess whether green bonds serve as an effective financing tool for sustainability at local level. The findings provide recommendations for policymakers, local authorities, financial institutions, and investors. This research tries to enrich the understanding of sustainable finance and offer insights into optimization of the use of green bonds as a mechanism for promoting a more sustainable future at both global and local levels.

The thesis is structured in such a way as to consistently explore the efficiency of green bonds in achieving the SDGs, their contribution to environmental progress, the peculiarities of green bond pricing and the opportunities for municipal governments in this field. The first chapter provides an introduction, including the problem statement, research objectives, research questions and hypotheses, objectives, significance of the work. The second chapter is devoted to the literature review, the third one to the theoretical aspects of green bonds, their definition, role in sustainable development, market evolution and current challenges. The fourth chapter includes case studies illustrating the successful application of green bonds by local governments and

provides an overview of strategies for municipalities and analysis of “greenium”. The fifth chapter describes the research methodology, including design, data collection and analysis methods, as well as models for evaluating the impact of green bonds. The final chapter summarizes the results of the study and makes recommendations for practitioners and policy makers. Thus, the structure of the work logically leads analysis from theoretical aspect to practical implications, which allow for a deeper understanding the role of green bonds in sustainable development.

The central issue addressed in this work is the need to evaluate the impact of green bonds issuance on sustainable development. A cross-country investigation can shed light on the role of green bonds in both developed and developing countries in terms of contribution to transition towards a greener economy. By assessing the effect of green bond investments on the environmental outcomes at the national level, this research may contribute to enhanced awareness of the process of creating a more sustainable economies and facilitate a smoother green transition both on national and local levels. Based on previous research (Flammer, 2021; Partridge, 2019), this work seeks to examine the efficiency of green bonds in achieving SDGs and the extent to which they contribute to progress. Moreover, this study explores the potential advantages of green bond usage by local governments in advancing sustainability goals exploring realized projects of leading cities and the empirical cost of green bonds, whose disposability may incentivize local authorities to use green bonds. The main objective of this study is to assess how green bonds contribute to sustainability in different countries constructing an econometric model that capture the correlation between achievements in sustainability (countries’ SDG scores incorporated in SDG index) and amount of green bonds issued in countries at the macro level (number of issued bonds, amount in total sum of money and share of green bonds issued among total debt). The second objective is to provide or reject evidence regarding the existence of difference between green bond yields and conventional bond yields. Finally, the thesis tries to compare case studies in different countries that illustrate successful implementation of green bonds by local authorities with efficient realization of green projects. The research is dedicated to investigation of the potential role of green bonds in promoting sustainable development across different countries at the level of municipalities. As environmental concerns already have become a hotly debatable issue with the increase of the essential need for sustainable financing, green bonds have a bright perspective as a financial instrument designed to fund sustainable projects.

Thus, the goal of the study is to perform a quantitative analysis of the number of green bonds issued in different countries and the level of SDG achievement, to explore whether the “greenium” exists, and to immerse into real-world cases of green bond issuance by municipalities, where the work looks for evaluation of the efficiency of realization of projects funded by green bonds in

chosen countries and assessment of their environmental and social impacts. Therefore, comparing the efficiency of green bond markets in countries identify best practices and lessons learned that could inform future policies and initiatives. This study poses the following research questions: Do green bonds have positive impact on the achievement of sustainable development goals? Can local authorities rationally utilize green bonds to enhance local environmental development due to lower costs or successfully realized projects? These questions lead to the requirement of presented below hypotheses of the work:

Hypothesis № 1: The issuance of green bonds positively influences the achievement of sustainable development goals, leading to a higher level of progress in sustainability outcomes in countries that issue more green bonds.

Hypothesis № 2: Local authorities can utilize green bonds in an efficient way as a financial tool to enhance local environmental development and promote sustainable urban infrastructure due to lower costs of debt.

Based on the stakeholder capitalism framework (Schwab, 2021), the first hypothesis posits that the issuance of green bonds leads to tangible corporate improvements in environmental, social, and governance (ESG) performance. This is supported by empirical evidence demonstrating that firms exhibit higher ESG ratings and reduced carbon footprints following such issuances (Flammer, 2021). Furthermore, by channeling capital toward environmentally responsible businesses, sustainable investing is shown to generate meaningful social benefits (Pástor, Stambaugh, and Taylor, 2022). The ability of green bonds to drive environmentally transformative investments at a global scale (Carmichael and Rapp, 2024) is further evidenced by a pronounced inverse correlation between green bond issuance volumes and subsequent carbon intensity reductions (El Bannan and Löffler, 2024).

The second hypothesis is grounded in sustainable finance theory (Schoemaker and Schramade, 2018) and centers on the existence of a financial premium for sustainability, where investors accept lower returns for sustainable assets. A body of research demonstrates this investor preference, including a willingness to accept marginally reduced yields for infrastructure projects with tangible community benefits (Baldi and Pandimiglio, 2022) and an average yield discount for environmental considerations (Zerbib, 2019). This phenomenon is further explained by investors who exhibit dual aversion to both financial risk and unethical practices, potentially accepting lower returns from socially responsible entities (Renneboog, Horst, and Zhang, 2008). Some authors attribute this observed negative ESG premium to investor willingness to pay for sustainability and the covariance structure of climate transition risks. Empirical analyses of the bond market corroborate this, revealing a statistically significant yield concession of 1-2 basis points for sustainable bonds and showing that SRI bond funds can generate outperformance compared to the same conventional funds (Henke, 2016).

While some studies explore discount in the risk-return profiles of green versus conventional bonds (Hachenberg and Schiereck, 2018; Painter, 2020), other evidence rejects debt cost reduction (Tang and Zhang, 2020).

Based on the hypotheses provided above and previous studies, research tasks and methodologies aim to thoroughly evaluate the role of green bonds in advancing sustainability and supporting local environmental development. The first step involves conducting an in-depth review of the existing literature on the relationship between green bond issuance and progress toward the SDGs, summarizing key findings from academic articles, reports, and policy documents that examine how green bonds contribute to financing sustainability. This review also identifies gaps in the literature, particularly concerning the direct impact of green bonds on achieving SDGs. To assess this relationship, different models are developed and tested using regression analysis to determine whether the amount of green bond issuance is positively correlated with improvements in sustainability outcomes, utilizing panel data methods such as fixed effects models to control for external factors. The analysis provides insights into the role of green bonds in advancing global sustainability. In addition, the study examines the yield difference between green and brown bonds and how local governments utilize green bonds as financial instruments for environmental development, identifying the benefits, challenges, and unique advantages of green bonds compared to other financing mechanisms. Through case studies of municipalities or cities that have issued green bonds for urban infrastructure projects, the research investigates the types of projects funded and assesses the financial structure and environmental impact of these bonds. This includes identifying best practices and suggesting policy improvements to promote green bonds as a viable financing option. Finally, by synthesizing the findings from both hypotheses, the research provides a comprehensive understanding of how green bonds can promote both global sustainability and local environmental development. The study also explores opportunities for expanding the use of green bonds in various contexts, discussing potential challenges, and suggesting policy recommendations to improve their efficiency for governments and financial institutions at the local level.

2 Literature Review

Green bonds represent a relatively recent financial instrument that has seen significant growth in various countries since their launch in 2007. Consequently, evolving academic literature developed around the topic of green bonds remains limited, and this study seeks to contribute to the expansion of this field. In particular, the research is focused on studying the actual impact of green bonds on environment, the green bonds application by local governments as well as the green bonds yields (El Bannan and Löffler, 2024; Zamani and Dessì, 2017; Zerbib, 2019).

The meaning of green bonds in addressing environmental challenges and promoting sustainable development has been met with some skepticism. As a result, the academic discourse on green bonds reflects both optimistic and critical points of view regarding their role in the advancement of sustainability. Firstly, this section focuses on different studies that demonstrate how green bonds contribute to enhanced sustainability performance. For example, many scientists prove that green bond issuance has demonstrated a strong ability to enhance transparency and accountability in the use of proceeds for environmentally beneficial projects (Ehlers and Packer, 2017). By requiring issuers to provide detailed reporting on how funds are allocated and the environmental impacts of financed projects, green bonds promote a higher standard of disclosure and reporting compared to conventional bonds and offer insights for future green bond applications that presumably support the expansion of the Paris Agreement and the Sustainable Development Goals. The findings of further research underscore the commitment of both firms and investors to climate action (SDG 13) and reaffirm that green bonds are a crucial mechanism for advancing the SDGs (Rizwan and Fatima, 2024). This commitment is further supported by the analysis which suggests that green finance promotes innovation in green technologies across European nations (K. Chang, Luo, Xing, and Mi, 2025). Moreover, another study reveals that, compared to traditional (brown) bond issuers with similar financial profiles and environmental ratings, green issuers demonstrate a significant and long-lasting reduction in carbon dioxide intensity. This decline in emissions is particularly notable when green bonds issued for refinancing are excluded, aligning with an increase in climate-related activities (Flammer, 2021). The findings are consistent with previous and following works, reinforcing the idea that by issuing green bonds, companies often demonstrate a genuine commitment to environmental sustainability (Flammer, 2020). This commitment is further validated in regression analysis that indicates a significantly negative impact of green bonds on CO₂ emissions (Ma et al., 2020). Additionally, the analysis highlights that the issuance of green bonds can be an effective tool for reducing ESG greenwashing. By promoting greater transparency in information related to environmental, social, and governance (ESG) practices, green bonds help ensure that funds are used for genuinely sustainable projects. Furthermore, they alleviate financial constraints, making it easier for organizations to invest in green initiatives (Shishlov, Morel, and Cochran, 2016). These studies, coherently, illustrate the multi-faceted benefits of green bonds, from driving technological innovation and reducing emissions to enhancing transparency and alleviating financial barriers, thereby contributing significantly to the global sustainability agenda.

For instance, econometric analysis that employ logit models, demonstrates robust investor preferences for sustainable investment products, alongside a very

significant willingness to pay for these offerings (Gutsche and Ziegler, 2019). Finally, it is stated that an extensive body of research has examined the relationship between corporate social responsibility (CSR) and financial outcomes, seeking to determine whether ethical business practices yield competitive advantages where the prevailing empirical evidence points to a positive, statistically significant correlation between sustainability performance and financial performance metrics (Dam and Scholtens, 2015). However, another study employs QQ methodology to characterize the distributional dependence between sustainable finance instruments and environmental innovation outputs confirming the technology-stimulating role of green finance while highlighting non-uniform effects across the conditional distribution and necessitating precisely targeted policy interventions (L. Chang, Taghizadeh-Hesary, Chen, and Mohsin, 2022). As well as investigation which establishes that green bonds function as dual-purpose instruments that simultaneously advance technological and urban environmental outcomes, albeit with substantial effect heterogeneity (Chang, 2023).

This part of the work is dedicated to the peculiarities of green bond pricing. The existence of a "greenium" - a lower yield for green bonds compared to conventional equivalents - is highly dependent on market conditions. While green bonds can be utilized as a tool to assess the influence of non-financial incentives, particularly environmental preferences, on bond market pricing, employing a matching method followed by a two-step regression approach to determine the yield difference between green bonds and conventional bonds from 2013 to 2017. The findings indicate a negative premium, suggesting that the yield of green bonds is slightly lower than that of ordinary bonds. According to different academic papers, these results highlight the minimal effect of investors' pro-green preferences on bond pricing, indicating that, at this stage, it does not deter potential investors from supporting the growth of the green bond market (Zerbib, 2019). However, the findings of another paper align with an alternative interpretation that markets are already pricing in carbon risk premiums, suggesting investors require compensation for climate-related financial exposures regardless of green bond labeling (Bolton and Kacperczyk, 2021). The next aspect of the issue discloses the longitudinal association between ESG ratings and corporate bond pricing, revealing that issuers with superior composite ESG scores benefit from statistically significant, albeit modest, spread compression relative to comparable financial risk profiles (Polbennikov, Desclée, Dynkin, and Maitra, 2016). In coherence with the discussed papers that assess the role of ESG financial instruments on returns, scientists verify the positive role of green bonds and the issue of lower yields. Other authors show that the application of ESG metrics in selecting projects funded by green bonds is negatively correlated with yields for both public and corporate green bonds. This suggests that investors may be willing to accept lower returns in exchange for a

greater anticipated impact of the infrastructure on the sustainability of the target community (Baldi and Pandimiglio, 2022). As well as the study that also explores whether investors are ready to sacrifice returns for societal benefits by leveraging the special features of the municipal bonds market. By comparing green securities to nearly identical securities issued for different purposes by the same issuers on the same date, the authors find that the pricing for both green and brown bonds is economically equivalent. This stands in contrast to several recent theoretical and experimental studies, as in actual market conditions, investors show no willingness to forgo wealth in favor of investing in environmentally sustainable projects. When risk and returns are kept constant and are known to investors, they perceive green and non-green securities from the same issuer as nearly perfect substitutes, resulting in a greenium that is effectively zero (Larcker and Watts, 2020). The 28-country analysis, otherwise, confirms green bonds' unique dual advantage: delivering both environmental impact and tangible financial returns for issuers, however, demonstrating no consistently significant premium for green bonds (Tang and Zhang, 2020). While another work analyzes how green and brown bonds react to the materialization of climate change risks, particularly severe natural disasters. The authors document a pronounced divergence in market responses: brown bonds face rising yields and worsening liquidity as investors price in higher climate risk, while green bonds exhibit stable or declining yields alongside resilient liquidity, reflecting a shift in demand toward sustainable assets. These findings highlight how climate events trigger a structural repricing of carbon-intensive securities and underscore green bonds' role as climate-resilient investments (Del Giudice, Rigamonti, and Signori, 2025). The greenium existence is also explored providing advantages to different stakeholders and confirmed by another study. The findings on China's green bond market indicate that certification labels create immediate market rewards, transparency mechanisms enhance but cannot sustain greenium alone (Hu et al., 2024). Another study shows that while empirically isolating causal effects between security characteristics and asset prices remains challenging, their findings reject the ESG-adapted Modigliani-Miller neutrality by demonstrating that green bond issuance can reduce an issuer's cost of capital beyond its underlying ESG profile (Feldhütter, Halskov, and Krebbers, 2024). Overall, these findings suggest that green bonds play a crucial role in fostering accountability and credibility in the ESG landscape. The studies confirm the positive role of green bonds in enhancing the green transition and sustainable development, despite the varying perspectives on the existence and magnitude of the greenium.

Let me pay attention to research papers demonstrating eventual negative implications and challenges that derive from green bonds where various instances of greenwashing associated with green bonds. For example, in the attention is paid

to the fragility of the existence of possibility that corporations will be engaged in greenwashing practices. According to authors investors demonstrate willingness to accept reduced financial returns when financing infrastructure initiatives that deliver measurable sustainability benefits to local communities. However, they demand increased risk premiums to offset potential exposure to greenwashing practices by bond issuers. Analysis reveals that manufacturing companies exhibit greater susceptibility to greenwashing allegations compared to service-oriented firms, with financial institutions showing the highest incidence of such risks (Baldi and Pandimiglio, 2022). On the other hand, it is indicated that companies issuing green bonds do not significantly increase their alignment to green agenda; rather, they only tend to strategically prioritize their efforts in this area. Finally, the issuance of green bonds appears to reduce the efficiency of stock pricing, supporting the hypothesis that these financial instruments may be used for greenwashing purposes in China. This tendency for greenwashing is particularly evident among institutions that experience fewer budget constraints, have closer relationships with government entities (Huang, Tang, Liu, and Ge, 2025). Limited role of green bond financing as a driver of sustainable and green transformation in Sweden was found (Nykqvist and Maltais, 2022). The above-mentioned studies suggest that green bonds have no significant effect on sustainable development presenting findings that contrast with those of the first part of literature review.

A review of the existing literature on green bonds, their role in sustainable finance, and their impact on environmental projects reveals that there are widespread differing opinions on the subject. Despite the growing interest in green bonds and their potential role in funding sustainable projects, wide range of aspects require further exploration such as issues related to greenwashing; significant gap in research regarding the heterogeneous distribution of green bonds; the absence of harmonization in national and international policies, incentive opportunities; the way green bonds fit into broader ESG investment strategies; real environmental, social, and economic impacts of green bonds; existence of specific pricing. Research addressing these gaps are crucial for enhancing the efficiency of green bonds in achieving climate and sustainability objectives.

Green bonds have emerged as a significant financial instrument for funding environmentally beneficial projects, yet their actual impact remains a subject of debate. On one hand, research demonstrates their potential to reduce carbon emissions, enhance transparency, and align with global sustainability goals. Studies show measurable declines in CO₂ intensity among green bond issuers, particularly when proceeds fund new projects rather than refinancing (Ma et al., 2020). Enhanced reporting requirements also mitigate greenwashing risks while investor demand for sustainable assets - sometimes accepting lower yields supports market growth (Baldi and Pandimiglio, 2022).

Additionally, green bonds exhibit resilience during climate-related disruptions, reinforcing their role as hedges against carbon risk (Del Giudice et al., 2025). However, critiques highlight persistent challenges. Greenwashing remains a concern, with some issuers leveraging green bonds for reputation gains without substantive environmental benefits (Huang et al., 2025). Market efficiency is also debated: while some studies identify a “greenium” (Hu et al., 2024), others find yield parity with conventional bonds (Larcker and Watts, 2020), suggesting investor skepticism. Regulatory gaps, particularly in emerging markets, further undermine credibility, as weak oversight permits symbolic compliance over tangible impact (Shishlov et al., 2016). The implications call for stricter certification standards, policy incentives, tax benefits, and deeper research into long-term effects. While green bonds hold promises for sustainable finance, their potential hinges on addressing credibility gaps through coordinated efforts among regulators, issuers, and investors.

3 Green Bonds

3.1 Definition of Green Bonds: Key Concepts and Relevance

To start the introduction to the analysis of the role of green bonds in promoting sustainability, it is crucial to provide a definition of green bonds. Green bonds can be characterized as a category of debt issued by public or private entities to raise funds for financing needs, which should be essentially sustainably oriented. In contrast to other credit instruments, the proceeds from green bonds are dedicated specifically and exclusively to projects that address environmental concerns or climate change. For example, OECD defines green bonds as "debt instruments for green projects that provide environmental advantages". Green bonds are "debt securities issued to fund projects that offer environmental or climate-related benefits" according to (Ehlers and Packer, 2017).

From the legislative sight, green bonds are subjects to regulations at different levels and various frameworks ensuring that the proceeds are transparent and applied to realize environmentally beneficial projects. For instance, the below-mentioned regulations represent rules developed by institutions that promote transparency, accountability, and consistency in the issuance and investment of green bonds: Green Bond Principles proposed by the International Capital Market Association (International Capital Market Association, 2024); EU Green Bond Standard in European Union that is developed in accordance with the EU Taxonomy (European Commission, 2024); Securities and Exchange Commission (SEC) Regulations in the USA. Moreover, international impact reporting standards such as Global Reporting Initiative (GRI) serve to help investors clarify alliance with sustainability requirements of the projects' final goals. However, being a relatively new instrument, the concept of green bonds is still at the launch stage of

development, especially in some countries where the public awareness is scarce which requires careful elaboration of a regulatory and legislative framework. While in other countries sustainable finance has been in active use for a longer period and has already successfully performed in different fields but still need continuous regulation improvements. The principles of green bonds accepted by the main international standards include targeted use of funds for financing or refinancing environmentally advantageous projects, strict project assessment, precise determination of the environmental benefits and necessity to meet the established criteria for projects, management of funds ensuring transparent reporting, independent review or evaluation to confirm their compliance with established environmental criteria. These details are disclosed not uniformly at a global scale occasionally creating misunderstanding and confusion. Summing up, the definition to green bonds as a fixed-income financial instrument focused on funding environmental initiatives may be given.

Green bonds can be divided in different categories. Two types of classification are taken into consideration: by type of issuer and by type of funded projects. This classification may clarify the process of green bonds emission and further exploitation. In such classification, government green bonds are debt securities issued by national, regional, or local authorities to raise funds specifically for environmentally beneficial projects while corporate green bonds are fixed-income securities issued by private companies to finance environmentally sustainable initiatives. Municipal green bonds, on the other hand, are issued by state or local governments, municipalities, or other public entities to support projects with positive environmental impacts (World Economic Forum, 2023). Another way to categorize green bonds is by the type of projects they fund. Renewable energy bonds focus on financing solar, wind, and other clean energy projects. Energy efficiency bonds support initiatives aimed at reducing energy consumption. Water management bonds fund sustainable water supply and wastewater treatment systems, while waste management bonds are dedicated to recycling and waste reduction projects. These classifications help investors identify bonds that align with their sustainability goals.

Therefore, identifying green bonds, the work sheds the light on the key role green financial instruments play in sustainable development and implementation of environmental initiatives. Green bonds allow investors to direct their funds to projects that promote eco-sustainable projects, reduce carbon emissions and transition to more sustainable forms of economy. By financing energy-efficient and low-carbon initiatives, the issuer creates the image of an innovative corporation that is focused on long-term development. It is reasonable to assume that investors, may be attracted such issuers. In addition, these bonds may attract fundamentally new investors who were not previously ready to place their funds in conventional projects but may begin to finance in order to support innovative

environmental projects. The involvement of the private sector in this process is becoming significant, which brings the need for coordination between different market participants to achieve sustainable development goals.

3.2 Global Trends and Growth of the Market of Green Bonds

This section is dedicated to trends that are experienced by the market of green bonds. In general, the market of green bonds shows a substantial growth. It is important to mention that an exponential expansion of green bond market may be seen not immediately after the first launch of green bonds in 2007 but in the following years. So, the market started to expand from 2007 when the first green bond was issued by the European Investment Bank (EIB) that initiated the issuance of the world's first green bond, known as the climate awareness bond, intended for the 27 countries of the European Union (EIB, 2023). This step became the initial point for the formation of the global green bond market.

Between 2009 and 2012, the Climate Bond Initiative (CBI) was established and developed, contributing to the adoption of the concept of climate finance by the United Nations Framework Convention on Climate Change. International organizations such as the G20 and the IMF have recognized the importance of green bonds. OECD and IEA have followed actively starting to recommend that governments use green bonds to address climate finance challenges. During this period, multilateral organizations played a significant role in building consensus on the development of green bonds. The market has increased from about \$4 billion in 2010 to around \$270 billion in 2020 according to EEA based on data retrieved by ESMA. From 2013, the private sector has become more actively involved in issuing green bonds, including corporations and commercial banks. The first municipal bond to officially adopt the green bond label in its offering documents, rather than acquiring the label through market convention, was issued by Massachusetts in 2013 while municipal bonds issued in 2010 under the federal clean renewable energy bonds and qualified energy conservation bond programs are recognized as labeled green bonds by market convention.

International issuers of green bonds have gradually expanded their presence, moving from financial institutions established based on public policy and under the auspices of governments or central banks that satisfied ordinary financial needs or sought to achieve certain goals set by the government. In 2014, green bonds worth 47 billion US dollars were issued. Municipalities, local governments, commercial banks and corporations have now joined them. New innovative types of green bonds appeared. As part of the 2015 Paris Agreement, 27 global investors managing \$11.2 trillion in investment capital issued the Paris Green Bond Statement. This statement calls on the signatories to support policies that promote the development of the global green bond market. This highlights

the importance of coordinating efforts between different market participants to achieve sustainable financing and the implementation of environmentally friendly projects (International Capital Market Association, 2024).

In 2019, the green bond market continued to show significant growth, increasing by 40%, resulting in a volume of new issues of 250 billion US dollars. This indicates a growing interest on the part of both investors and issuers in sustainable financial instruments that facilitate the financing of environmentally friendly projects. The participation of the private sector, including companies and commercial banks, has become a key factor in this process, which confirms the importance of coordinating efforts between various market participants to achieve the Sustainable Development Goals and implement the initiatives provided for in the Paris Agreement according to CBI. While in 2023, applying to Climate Bond Initiative, the total amount of green, social, sustainability, and sustainability-linked bonds issued in the market was equal to nearly \$ 4,5 trillion with the fact that green bond issuance dominated in GSS bond market (GSS stands for Green, Social and Sustainable) covering more than 60% of the overall amount of bonds that aim to address global problems while total issuances in 2023 achieved \$ 1 trillion according to World Bank.

The data in Figure 1 clearly shows that the green bond market has experienced increasing growth in terms of the number of bonds issued. The rise in the share of green bonds within the bond market reflects greater investor appetite for sustainable and climate-related investments. This suggests that green bonds are becoming a more attractive asset class as investors seek to align their portfolios with environmental goals.

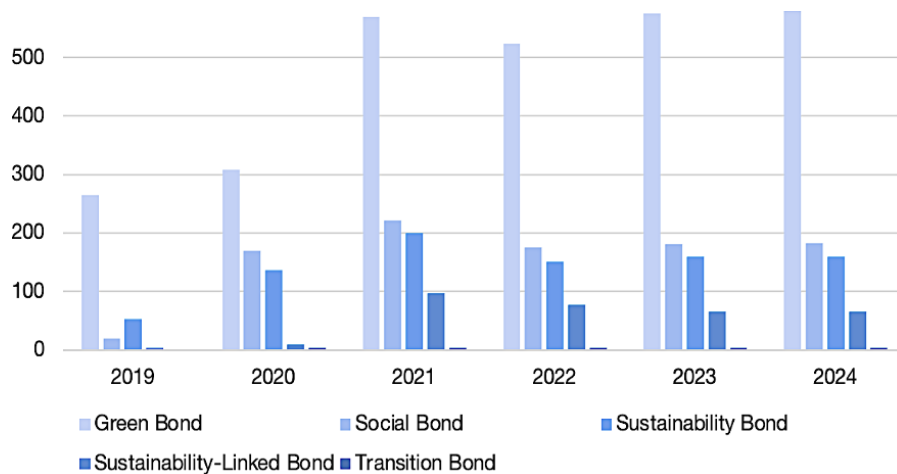


Figure 1: Global green, social and sustainable bond annual issuance by type, USD bn, from 2019 to 2024

Source: Environmental Finance Bond Database; S and P Global Ratings

The increasing number of green bonds and their growing share of the global

bond market indicates the maturation of the green bond market. Green bonds have chance to be transitioned from niche financial products to mainstream instruments, supported by institutional investors, governmental policies, and the broader global commitment to the UN SDGs and the Paris Agreement. This figure provides a comprehensive overview of the growth of green bonds as a financial instrument and their increasing role in the global bond market. It is observed that there is the growing size of the market of green bonds from 2019 to 2024. It is also clear that most bonds linked to sustainable development are categorized as green. However, other types are also important in sustainable finance. A continuous increase can be noted till 2021 followed by slight decline and later recovery.

The figure 2 illustrates the global distribution of green bond issuance across various regions between 2013 and 2025. Geographically, it is not surprising that developed economies dominate the green bond markets. The graph clearly shows the dominance of European countries in the green bond market, with the largest share of issuance consistently coming from this region over the specified period. Europe's leadership can be attributed to the region's strong commitment to climate action, developed sustainability regulations, and the European Union's green finance initiatives, such as the EU Green Deal or the EU Taxonomy for Sustainable Activities (European Commission, 2024), which have fostered significant investments in green projects. Following Europe, North America emerges as the second largest issuer of green bonds. The U.S. and Canada have both seen substantial growth in green bond issuance during these years, driven by both government initiatives and corporate investments in renewable energy and sustainable infrastructure.

The increase in green bond issuance in North America also reflects the growing interest in such investments among both institutional and retail investors. The third largest issuer after the USA and Europe is China (indicated in figure 3), which, despite its relatively recent entry into the green bond market, has been rapidly scaling its green bond offerings. Figure 3 shows the share of green bonds issued by different countries in 2022 demonstrating geographical representation (heat map) of green bonds distribution across the world.

According to United Nations report, the Chinese government's push towards carbon neutrality by 2060 and its strong commitment to green infrastructure projects, such as renewable energy, electric vehicles, and green buildings, have significantly contributed to the rise in green bond issuance in the country. Overall, the chart and the heat map reveal that Europe, North America, and China are the key regions driving the global growth of the green bond market. However, there are also notable issuance from other regions such as Asia-Pacific and Latin America, though these areas still represent a smaller share of global green bond issuance.

The data underscores the increasing global recognition of green finance as a

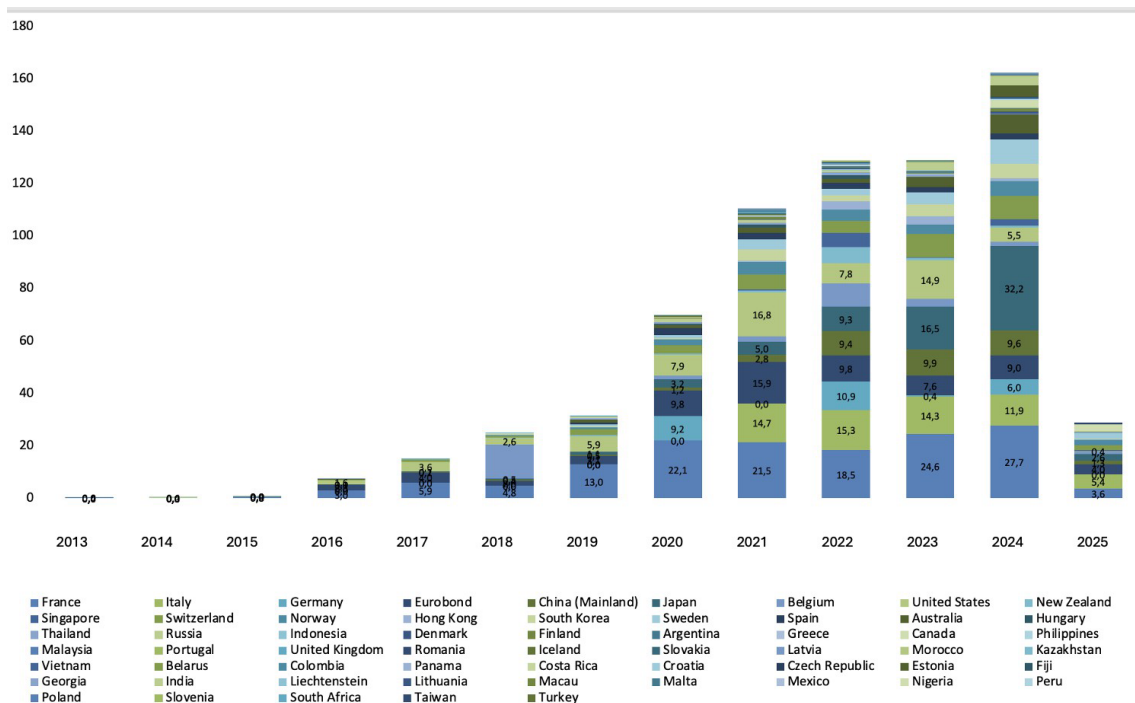


Figure 2: Green bonds issuance by country, (USD bn) in 2013 - 2025
 Source: Eikon Redifinitiv LSEG

crucial tool in achieving sustainability and combating climate change, particularly in developed regions, but also increasingly in emerging markets. The growth of green bonds aligns with regional policy frameworks, the prioritization of ESG criteria by investors, and the broader global shift towards sustainable finance. Moving forward, these trends suggest that green bond markets will continue to expand as nations and financial markets strive to meet their climate goals and implement SDGs. The leaders regarding the share of issued green bonds in Europe are Germany, France and Netherlands. While in Asia, undoubtedly the leader in this field is China that is overcoming the share of 10% in total debt (The World Bank, 2022). However, in general, developing countries are at the most initial stage of green bonds development. The region of Africa lacks countries where green bonds are issued. In Russia, the outstanding amount of debt securities classified as green bonds is 223 billion rubles (is approximately 2.78 billion US dollars). In 2021, Russia’s sustainable finance market remained nascent, with \$2.9 billion worth of bonds issued in the sustainability sector. This volume represented a mere 0.18% of the global sustainable debt market, highlighting the country’s limited participation compared to international peers (CBI, Moscow Exchange, RBC).

Now, a deeper the involvement of European countries in green bond agenda is highlighted (figure 4). Northern European countries (Denmark, Sweden, Finland) lead in green bond issuance, reflecting strong environmental policies and investor interest in sustainability. Southern and Eastern European countries (Malta, Latvia,

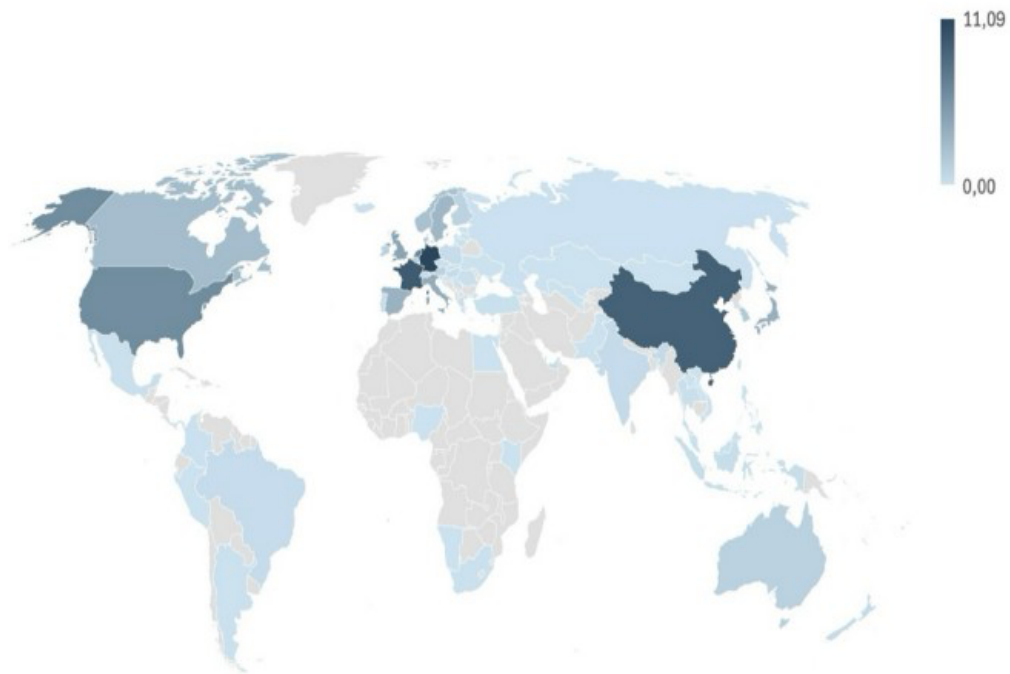


Figure 3: Share of green bonds in different countries in 2022, percentages
Source: IMF

Romania) have lower percentages, possibly due to smaller financial markets or less developed green finance frameworks. The geographical distribution of green bonds is intricately linked to several key drivers that have propelled the growth of the green bond market. As investors increasingly seek sustainable finance options, regions with a strong commitment to environmental initiatives tend to attract greener bond issuance. This growing interest is often supported by a robust regulatory framework that encourages the issuance of green bonds, providing a clear set of guidelines and incentives for both government and corporate issuers.

Additionally, corporate involvement in sustainability initiatives plays a crucial role in shaping the landscape of green bond distributions, as companies that prioritize environmental responsibility are more likely to issue green bonds to fund their projects. Furthermore, the international recognition of climate change challenges has heightened awareness and urgency around sustainable investments, prompting various regions to enhance their green finance offerings. Together, these factors not only drive the issuance of green bonds but also influence their geographical distribution, creating a dynamic market that reflects the varying levels of commitment to sustainability across different regions.

Figures 5 and 6 present a breakdown of green bond issuance by the type of issuer, categorizing them into 6 main groups in bar chart: issued by development bank, local government, financial corporate, non-financial corporate, government-backed entity, sovereign; and into three main groups in pie chart: government issuers, corporate issuers, and municipal issuers. The bar chart demonstrates the trend of green bond market subdividing each bar into types of issuers while the pie chart

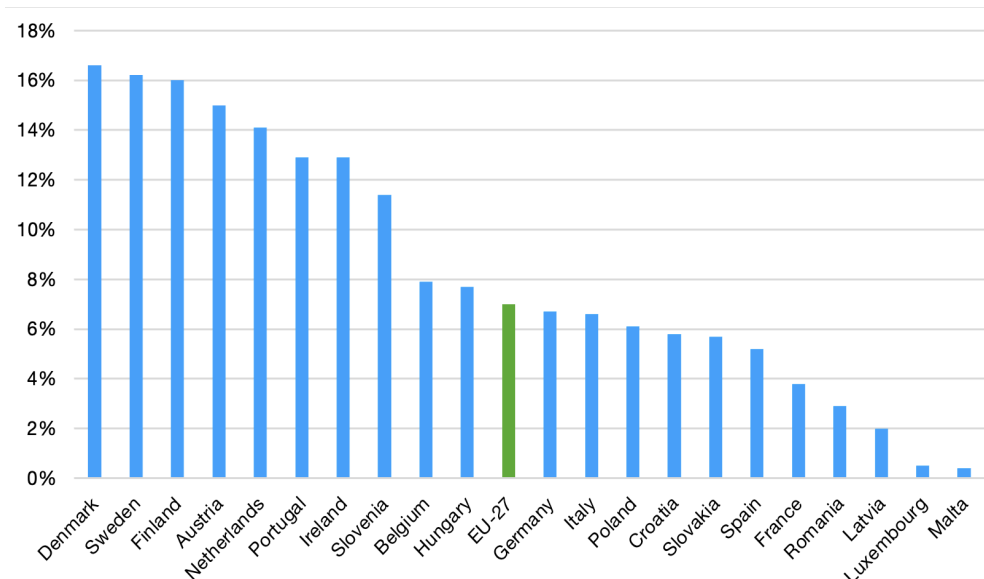


Figure 4: Percentage of green bond issued by corporates and governments per Member State, 2023
Source: ESMA

provides a visual representation of the share of total green bond emissions accounted for by each category of issuer, highlighting the relative contribution of each sector to the growth of the green bond market.

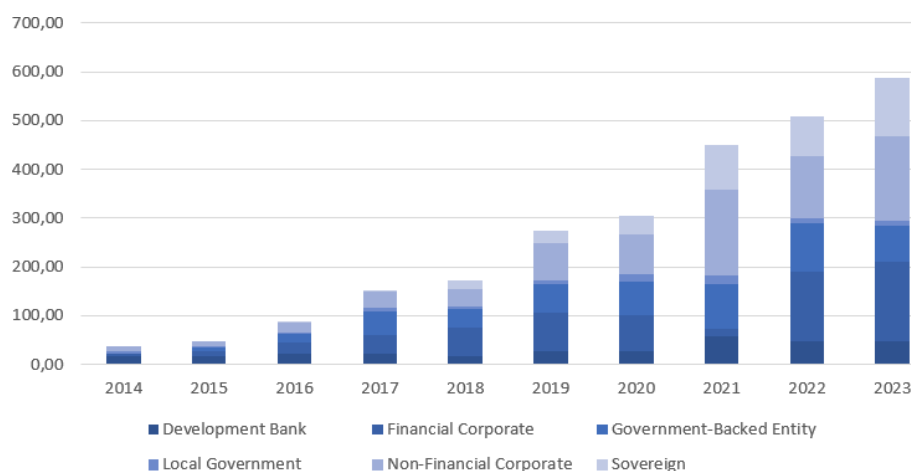


Figure 5: Amount of issued green bonds by type of issuer worldwide, 2014-2023, bn US dollars
Source: CBI

The graph clearly highlights the dominance of corporate issuers in the green bond market, with 67% of all green bonds issued by corporations. Governments, while still significant, contribute a substantial share but are less dominant compared to corporations. Municipalities contribute a very small percentage because only slightly above 3% of green bonds are issued by local governments or municipal entities. Despite the relatively minor share, municipal issuance is important for financing local and regional projects, such as public transportation, energy-efficient

buildings, and waste management systems. Municipal issuers focus on projects that have an immediate impact on urban sustainability and local climate resilience, but their presence in the green bond market remains limited compared to corporate and government issuers (Partridge, 2019).

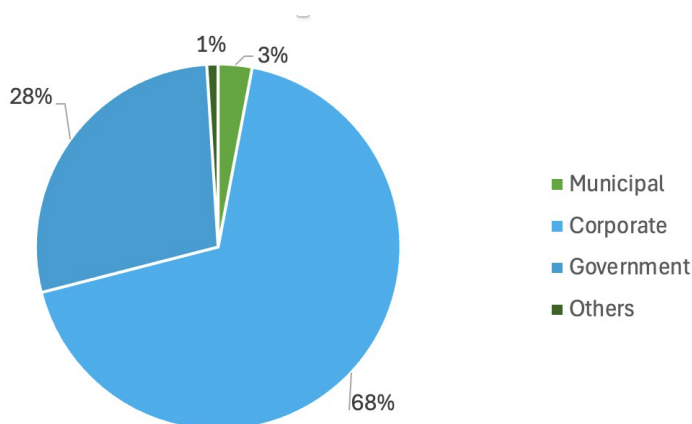


Figure 6: Distribution of green bond by type of issuer in 2024 (percents): Government, Corporate, and Municipal
Source: Bloomberg, March 2025

Now, it is important to pay attention to the levels of sustainable development in different countries. Moving further, the geographical map which illustrates SDG development in 2022 across the world may be observed (figure 7). SDG index is used for transparent and clear representation. Below the provision of a deeper description of the index can be found. The data reveals clear geographical patterns in SDG performance, with Nordic countries (Finland 86.4, Sweden 85.8, Denmark 84.8) leading globally, followed by a strong European cluster comprising 15 of the top 20 positions, demonstrating the region’s policy efficiency. High-income nations generally score above 78, while emerging economies cluster between 65-75 and developing countries trail behind (Nigeria 54.7, Pakistan 56.9), highlighting the strong correlation between development levels and SDG achievement. Notable variations exist within regions, such as Costa Rica (73.1) outperforming its Latin American peers and the United States (74.1) underperforming relative to its economic stature, suggesting that while wealth is an important determinant, policy choices and governance frameworks play equally crucial roles in driving sustainable development outcomes.

The substantial 31.7-point gap between top and bottom performers underscores persistent global inequalities in implementing the 2030 Agenda. Russia’s SDG Index score is 74.1, placing it 72nd out of 167 countries. This score reflects the country’s progress towards achieving the 17 Sustainable Development Goals (SDGs). Overall, the green bond market is on an upward trend, characterized by increasing issuance and a diverse range of participants, but it also faces challenges

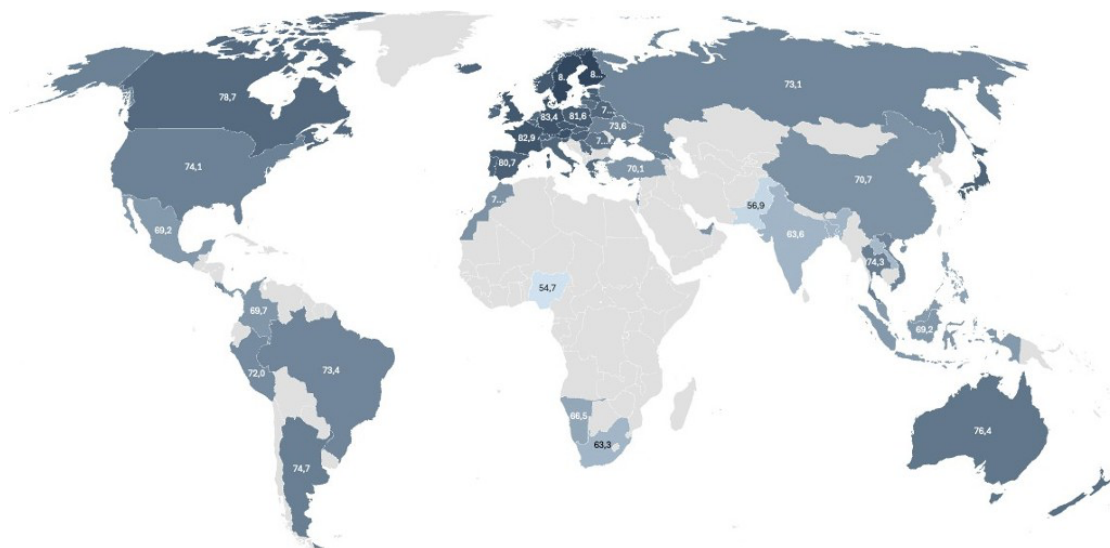


Figure 7: SDG-score in 2023
Source: UN

needed to be addressed to ensure its continued growth and relevance in financing sustainable projects. This growth is driven by increasing awareness of climate change, regulatory support, and the demand for sustainable investment options from both institutional and retail investors. A wide range of entities are issuing green bonds, including governments, municipalities, corporations, and financial institutions. While in general, the green bond market is growing globally, there are significant regional disparities. Countries like the United States, China, European nations lead in issuance. Emerging markets are also beginning to participate, but the scale and scope of their involvement can vary widely. The green bond market is expected to continue its upward trajectory as more investors prioritize sustainability and as governments and corporations commit to sustainable targets.

3.3 Current Challenges: Obstacles Facing the Green Bonds

Despite promising potential of the green bonds market, it faces with a wide range of significant challenges that could negatively impact market’s development and contribution to sustainability. The key challenges are connected with the lack of standardized definitions, non-harmonized disclosure requirements for green bonds, limited market liquidity comparing to traditional bonds, particular pricing and yield concerns, absence of sufficient data (lack of consistent, transparent, and reliable data on the environmental impact of green bond-financed projects), eventual exploitation of the opportunities provided by green bonds, policy uncertainty, public awareness and other problems. Addressing these issues requires collaborative efforts from governments, financial institutions, regulatory bodies, and investors. As the market evolves and stronger regulatory frameworks, reporting standards, and best practices are put in place, green bonds have the potential to become a real key

instrument in funding the transition to a more sustainable global economy.

For example, studies discuss various difficulties that arise around green bonds: starting from opaque definition of the concept to the necessity of structural law regulation (Park, 2018). It is also demonstrated that there are different types of challenges that emerge around green bond market including transparency, particular financial cons and difficulties in local, state and international policies, addressing the environmental integrity of green bonds, examining the issues surrounding definitions and processes. They suggest how, in addition to enhancing transparency, both market driven initiatives and public support mechanisms can help boost the tangible financial impact of green bonds on the transition to a low carbon economy. The report concludes with several steps that policymakers and financial stakeholders can take to address the current limitations of green bonds. The primary conclusions indicate that the legal framework, the official interest rates for green bonds, and overall economic stability are the crucial elements that directly influence the growth of the green bond market (Shishlov et al., 2016).

According to observed studies, the main problematic issues associated with the green bonds include concerns about greenwashing, doubts regarding the efficiency of the green bond market in real contributing to environmental protection, and the limited financial benefits generated by these issuances. It is pointed out that the absence of suitable institutional frameworks for regulating properly green bonds, alongside their minimum issuance sizes and elevated transaction costs, represents significant obstacles to the advancement of green bonds in developing nations (El Ghouli, Guedhami, Kwok, and Mishra, 2011).

The authors of another research mention key reasons to explain the currently limited presence of the green bond market: first, there is a prevailing perception of uncertain benefits associated with issuing green bonds; second, the process is often linked to higher costs and complexity procedures; third, the lack of standardization for all market participants; fourth, the green bond market is still relatively nascent, lacking the credentials and supply that investors typically expect; and fifth, concerns about greenwashing pose a substantial risk for all stakeholders. These challenges differently influence market participants. As for issuers, reluctance arises from a complex process that lacks transparent financial incentives, a scarcity of identifiable projects to fund, and considerable risks associated with greenwashing. For investors, the main concerns include the lack of standardized frameworks, stringent requirements, and issues related to liquidity. Nevertheless, findings collectively suggest that green bond issuance generates tangible benefits for existing shareholders, highlighting its value beyond mere cost-of-debt considerations. Meanwhile, financial institutions face operational and management hurdles when supporting clients in the issuance of green bonds (Tang and Zhang, 2020).

Table 1: Advantages and Disadvantages of Green Bonds for Different Stakeholders: Investors, Issuers and Municipalities

Stakeholder	Advantages	Disadvantages
Investors	<ul style="list-style-type: none"> Risk-adjusted financial returns with ecological benefits ESG requirements Risk assessment through increased control Hedge climate policy risks Opportunity to diversify portfolios Reassure information advantage from detailed coverage Tax incentives or favorable regulatory treatment Growing demand may lead to price appreciation 	<ul style="list-style-type: none"> Small market may lack liquidity Lack of unified standards Volatility and price fluctuations May offer lower yields compared to traditional bonds Challenges in distinguishing genuinely green projects May prioritize environmental impact over financial returns Regulatory changes can impact project viability
Issuers	<ul style="list-style-type: none"> Robust demand can result in over-subscription Diversification of investor base Image benefits from marketing green credentials Enhanced credibility of sustainability strategy Can differentiate from peers in competitive markets Stable funding sources Increased transparency can build trust May offer lower yields due to high demand 	<ul style="list-style-type: none"> Reputation risk May not cover full financing needs of large-scale projects May struggle to find suitable projects Funds are typically earmarked for specific projects Pool of investors is limited Risk of public scrutiny if projects do not meet expectations Ongoing transaction costs for labeling and reporting
Municipalities	<ul style="list-style-type: none"> Access to funding for sustainable projects Enhanced public image and community engagement Long-term economic benefits Lower interest rates Source of funding for sustainable projects Local sustainability goals 	<ul style="list-style-type: none"> Increased public expectations for transparency Funds are typically earmarked for specific projects Regulatory landscape is still evolving Uncertainties regarding compliance requirements Changes in regulations could impact attractiveness Projects may fail to deliver anticipated environmental benefits

The work reassesses possible advantages and disadvantages of green bonds for different stakeholders: investors, issuers and municipalities in the table below. Green bonds offer distinct pluses and minuses for various stakeholders, including investors, issuers, and municipalities highlighted as a specific interest of the research. For instance, investors can align their portfolios with sustainability goals and meet environmental mandates, but they may encounter challenges such as

market liquidity issues and a lack of unified standards. Issuers benefit from stronger investor demand, enhanced credibility, and a diversified investor base, yet face upfront costs and reputational risks. Local authorities gain improved access to funding for sustainable projects and enhanced public engagement, but they must manage the complex structure of project, reporting and the risk of public reaction if outcomes do not meet expectations. Overall, while green bonds present opportunities for promoting sustainability, they also require careful navigation of associated challenges (table 1). The process of overcoming the above-mentioned challenges seems to require collaborative efforts from regulators, standard-setting organizations, issuers, and investors to develop a more transparent, standardized, and attractive green bond market capable of channeling significant funds toward sustainability objectives. So, despite their growing popularity, green bonds face several challenges, including higher issuance costs due to the need for external reviews, impact reporting, and compliance with green standards, which can deter smaller municipalities. Additionally, the lack of universally accepted definitions and certification frameworks creates risks of "greenwashing," where projects may not deliver genuine environmental benefits (Baldi and Pandimiglio, 2022). Limited investor awareness and liquidity in secondary markets can also restrict demand, while the mismatch between long-term project timelines and investor preferences for shorter maturities complicates financing. Finally, local governments may struggle with capacity constraints, such as insufficient expertise in structuring green bonds or tracking environmental impacts, further hindering adoption. These barriers must be addressed to unlock the full potential of green bonds in sustainable finance.

4 Municipal Green Bonds

Now the focus is on municipal green bonds. Municipal green bonds are a critical subject of study because they provide a crucial mechanism for financing sustainable infrastructure projects at the local level, addressing pressing environmental challenges such as climate change, pollution, and resource management. By enabling funding for renewable energy, eco-friendly transport systems, and energy-efficient infrastructure, these financial instruments contribute to strengthening community resilience, driving economic development, and generating employment opportunities. Understanding municipal green bonds also informs public policy development by highlighting effective governance practices and stakeholder engagement, while promoting transparency and accountability in green finance. Municipal green bonds are typically issued through a process similar to conventional municipal bonds, often involving public offerings. The process includes certification when the issuer (municipality) must align the bond with international standards (ICMA) to ensure transparency and credibility. This

involves detailing the use of proceeds for eligible green projects. Then goes underwriting when local or international banks act as underwriters, facilitating the bond issuance, assessing credit risk, structuring the bond, and marketing it to investors. Finally, listing on exchanges (Luxembourg Green Exchange, LSE Sustainable Bond Market) to enhance visibility and accessibility.

4.1 Municipal Green Bonds and Their Impact

The part of the work is dedicated to the second research question (stated in hypothesis № 2) primarily targets the area of knowledge around green bonds issued by local authorities. Municipal bonds can be defined as debt securities issued at different level by local authorities to finance various public projects while green municipal bonds are a specialized type of municipal bond aimed at funding environmentally oriented projects, such as renewable energy installations, energy efficiency infrastructure, sustainable water management, and public transportation initiatives. These bonds attract sustainably conscious investors due to provision of stable income while simultaneously contributing to positive environmental results, with proceeds specifically directed to projects that meet specific sustainability requirement. Many green municipal bonds undergo certification from recognized third party organizations to validate their environmental claims, adhering to standards like the Green Bond Principles, which promote transparency and accountability (International Capital Market Association, 2024).

As more municipalities recognize the importance of sustainable development, the market for green municipal bonds has slightly grown, reflecting a rising awareness and demand for financing that addresses climate change and promotes sustainability. While generally considered not high-risk investments, the actual levels of uncertainty depend on the credit quality of the issuer and the specific features of projects being financed. This focus also arises from the observation that most existing literature whether concentrates on corporate green bonds or does not pay attention to difference between types of issuers. Hence, the realm of research concerning green bonds from public sector entities at the local level remains notably overlooked. Green bonds can become an important financial instrument for local authorities that aim to fund sustainable development initiatives. Although the study of issuance of green bonds presents certain challenges, such as lack of sufficient information about gaps in expertise and limited access to markets of green finance, the variably increasing demand for energy efficient sustainable infrastructure and the growing interest in green investments offer significant opportunities for local governments to assume a leadership role in sustainability. Through strategic planning, adherence to recognized standards, and transparent reporting practices, local governments can effectively utilize green bonds to finance projects that contribute to sustainability within their communities. The above-mentioned statement is to be proved in this section.

According to World Bank approximately 31% of all cumulative GSSS (green, social, sustainability, and sustainability-linked) bond issuances to date have originated from public sector institutions, encompassing municipal, subnational, and national government entities (The World Bank, 2022). This section analyzes literature that illustrate the results and perspectives regarding the role of local authorities issuing green bonds. Investigating the role of green bonds, different academic papers explore how municipal units of all types are addressing challenges related to water quality, exacerbated by the impermeability of developed areas and changing precipitation patterns due to climate change. A significant constraint identified across studies is the chronic underfunding of infrastructure adaptation within tight municipal budgets. Research based on surveys of 233 municipalities and interviews with local officials reveals that while transitioning to green infrastructure and climate resilience planning is a priority for most local governments, existing funding mechanisms often prove insufficient. This financial gap has prompted municipalities to explore innovative financing instruments such as credit and mitigation banking, alongside social and green bonds (Cousins and Hill, 2021).

The potential advantages of municipal green bonds are further explored advising investors that seek to reduce greenwashing risk to consider underwriting public sector green bonds issued by local governments (Baldi and Pandimiglio, 2022). As climate urgency grows, green bonds have emerged as a significant financial market response. Analysis of U.S. corporate and municipal green bond markets supports an asset pricing framework that incorporates non-financial preferences, confirming that green bonds are issued at a premium with yields several basis points lower as certain investors accept lower returns to support environmental objectives (Baker, Bergstresser, Serafeim, and Wurgler, 2018).

However, the disadvantages of municipal green bonds, including limited flexibility and higher climate risks, are highlighted in different academic works. The analysis of over 920 U.S. counties reveals that natural disasters significantly reduce bond prices issued by local authorities, with an average return decline of less than 0.5% within four months, making green bonds less attractive to investors. The study suggests that both rational assessments and investor biases influence bond prices following natural disasters. Additionally, without modifications to federal aid policies, municipalities in disaster-prone areas face rising local costs (Auh, Choi, Deryugina, and Park, 2022). It occurs that municipal counties are more vulnerable to climate change and tend to pay higher underwriting fees and yield premiums for long-term bonds compared to less affected counties. This disparity disappears for short-term bonds, indicating that the market prices climate change uncertainty primarily for long-term securities. The higher issuance costs for climate-affected municipalities are particularly pronounced for bonds with lower

credit ratings. The release of the 2006 Stern Review on climate change amplified investor attention, further increasing fee costs for climate-risky counties. This underscores the importance of analyzing climate risks in financial decision-making (Painter, 2020). The integration of sea-level rise (SLR) risks into municipal bond markets since 2013 reveals additional financial fragility. This is especially evident for long-maturity bonds and is not fully explained by immediate flood exposure. Using a structural credit model, researchers show that SLR-exposed issuers face markedly higher borrowing costs, reflecting investor concerns over long-term uncertainty rather than immediate devaluation (Goldsmith-Pinkham, Gustafson, Lewis, and Schwert, 2023).

On the other hand, the benefits of municipal green bonds, such as budget funding, environmental improvement, and increased investor confidence are highlighted. The study explores the potential of municipal green bonds as a financing tool and emerging trends, along with the motivations of municipalities in various countries for issuing green bonds (Zamani and Dess`i, 2017). The importance of fostering growth in the green municipal bond market is emphasized with the example of U.S. cities attracting socially responsible investors and accessing more funding for green infrastructure projects. The performance of U.S. green municipal bonds compared to traditional ones is found out to show the green municipal bond index outperformed equivalent S&P indices from 2014 to 2018. It is also identified that a statistically significant green premium, enabling cities to continue issuing green bonds for sustainable infrastructure projects (Partridge and Medda, 2020).

Evidence of a "greenium" in the U.S. municipal bond market is documented in different academic works. A comparison of green and conventional bonds from 2013 to 2022 shows that green bonds have consistently been issued at lower yields since 2018, with an average greenium exceeding 2 basis points, reflecting rising ESG investment interest (Painter, 2020). Insights into the role of municipalities in advancing sustainable development through green bonds, with the examples from Indian cities to assess the impact of green bond proceeds on sustainability indicators such as CO₂ emissions are presented in the work of (Lau et al., 2025). Scholars outline three core requirements for public intervention in municipal green bonds: alignment with sustainability targets, support for underfunded sectors, and maximization of environmental impact through additionality and outcome reporting (Shishlov et al., 2016). Finally, the relevance of green bonds for local governments is highlighted, particularly in Italy, where awareness of green bonds should be increased according to authors. While financially stable cities in Northern Italy show interest, only Milan is actively considering their use. The study underscores the need for pioneering municipalities to demonstrate the potential of green bonds, which could encourage broader adoption and align Italy with European trends in sustainable finance (Zamani and Dess`i, 2017).

Thus, different controversial findings of scientists around the topic of green bonds both in general and around municipal green bonds are found. However, it is clear that by issuing green bonds, municipalities can attract environmentally conscious investors and assist funds that prioritize sustainability. Green bonds also offer local governments the opportunity to lead environmental sustainability, enhancing their reputation and, thereby, attracting further investment and public approval. Nevertheless, there are challenges, including the need for precise expertise in the market, uncertainty surrounding the regulatory framework for qualifying "green" projects, difficulties faced by municipalities in accessing capital markets, climate and transitional risks. The challenges are discussed in the previous and following sections of the work. But as the green bond market grows, local governments may also benefit from increased demand, promoting better market liquidity and more advantageous terms for bond issuance. Moreover, investigation of this field allows for comparative assessments across various cities, highlighting best practices and aiding in the realization of local, national, and global climate objectives. Specifically, instances of urban sustainable development are presented resulting from green bond issuance by local governments. The focus of this research is on cities as they are primary municipalities that act as key administrative and economic hubs within their regions, characterized by high population density, a strong concentration of services and infrastructure, advanced economic activity, and a potential governance role. These municipalities typically provide a wide range of essential services, including transportation, healthcare, and educational institutions, all of which enhance the quality of life for their residents. Additionally, they often act as cultural epicenters, fostering social activities and events that contribute to regional identity. Exactly cities can be at the forefront of environmental initiatives, engaging in innovative practices such as issuing green bonds to finance sustainability projects. According to World Economic Forum, cities also are responsible for approximately two-thirds of global energy use and contribute over 70% of annual carbon emissions worldwide. To attain decarbonization in urban environments, it is crucial to move beyond traditional public sector financing approaches (World Economic Forum, 2023).

The study emphasizes the capacity of green bonds as a funding instrument for urban sustainability initiatives by illustrating how municipalities can utilize this cutting-edge financial approach. Successful examples are presented and implemented practices that enable local authorities to address climate-related issues. By utilizing green bonds, cities can finance projects designed to boost energy efficiency, improve public transit, and invest in renewable energy solutions, thereby cultivating a more robust urban ecosystem. The examples below emphasize collaboration among stakeholders, providing insight into how cities can navigate the complexities of the

green bond market to effectively engage in climate action and drive sustainable development. Figure 8 illustrates increasing trend of the share of green bond of total debt amount issued by local governments from 2014 to 2021 and a slight drop in 2022 and 2023. This fluctuation may highlight the dynamic nature of the green bond market and the ongoing challenges and opportunities it faces in promoting sustainable investment practices. Municipal green bonds offer a promising avenue for financing, particularly as municipalities gain greater access to capital markets. These bonds are a specialized form of fixed-income securities issued by local governments to raise funds from debt capital markets. Like traditional municipal bonds, they allow cities to borrow a fixed amount from investors, who receive regular interest payments at a predetermined rate until the bond matures, at which point the principal is repaid. However, unlike conventional municipal bonds, which may fund a wide range of projects without specific environmental criteria, municipal green bonds are exclusively allocated to initiatives that deliver measurable environmental benefits. This ensures that funds are channeled towards projects aimed at mitigating climate risks, improving energy efficiency, and fostering eco-friendly practices.

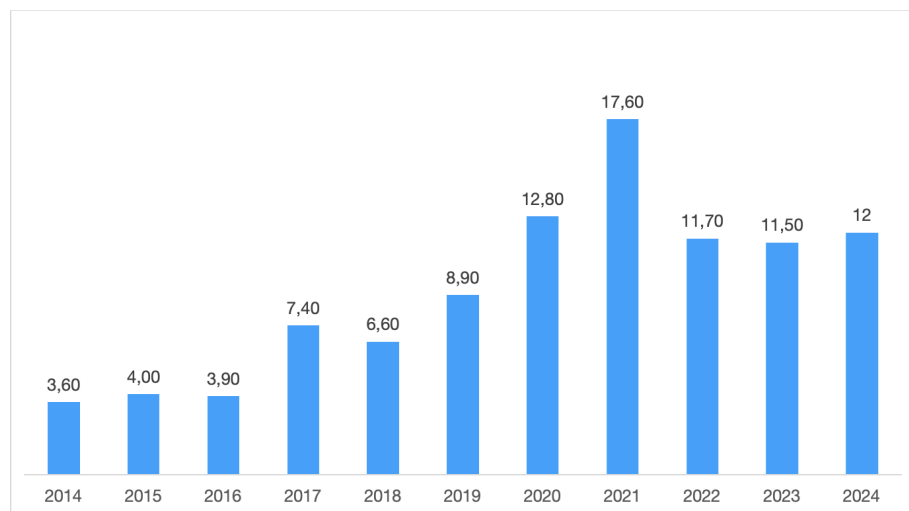


Figure 8: Share of green bonds in total amount of bonds issued by local authorities, in the EU-27, 2014-2024

Source: European Securities and Markets Authority (ESMA)

The issuance of green bonds introduces a layer of political and regulatory risk, as changes in local or national government priorities can directly alter support and funding for the underlying projects. Beyond traditional municipal risks, the green element introduces unique considerations, including execution risk, that is the possibility that a funded project faces delays, cost overruns, or fails to deliver its projected environmental impact and significant reputational risk, often termed "greenwashing" risk. This occurs if a bond is perceived as not being sufficiently green, which can damage the issuer's reputation and affect the pricing of future debt.

This risk is primarily mitigated through the adoption of robust external frameworks and independent third-party reviews. The investor base for these instruments is a strategic blend of traditional and specialized capital. Traditional municipal bond investors, such as large asset managers, pension funds, and insurance companies, are increasingly attracted to green labels as their own ESG mandates evolve. They are joined by a growing cohort of dedicated ESG and thematic funds, which are specifically mandated to invest in positive environmental outcomes. Furthermore, local banks and credit institutions, particularly in Europe, are key participants, drawn by their strong ties to regional development and a desire to support local public projects that align with their sustainability goals.

The regulatory landscape for this market is evolving rapidly from voluntary principles to hard law. Initially built on voluntary frameworks like the International Capital Market Association (ICMA) Green Bond Principles (GBP), the market is now seeing significant regulatory hardening, especially in the European Union. While some countries have developed national taxonomies, the trend is toward harmonization under the EU's comprehensive framework. The pivotal development is the EU Green Bond Standard, which creates a voluntary "gold standard." To use the coveted "EU GB" designation, issuers must align 100% of the use of proceeds with the EU Taxonomy, publish a pre-issuance Green Bond Fact Sheet reviewed by an external auditor, and report annually on both the allocation of proceeds and the environmental impact of the funded projects. This rigorous regulation provides a transparent and comparable framework designed to directly address greenwashing concerns and is poised to become a global benchmark against which all municipal issuers, regardless of location, will be measured (Pyka, 2023). A key distinction lies in the reporting requirements. While traditional municipal bonds may not mandate detailed disclosures on how funds are used, green bonds typically require rigorous reporting on the environmental outcomes of financed projects. This promotes greater transparency and accountability, aligning with the growing demand for sustainable investment opportunities. This demand can enhance market liquidity and potentially lead to lower yields for green bonds compared to their conventional counterparts. By combining financial returns with environmental impact, municipal green bonds stand apart from traditional financing tools, highlighting their essential role in driving urban sustainability and resilience. Their unique features not only cater to investor preferences for sustainability but also support cities in achieving long-term environmental and economic goals. The impact of transparency and interdealer trading on municipal bond pricing, particularly following the implementation, shows that while price dispersion decreases significantly post-reform, average markups remained largely unchanged for smaller trades but increased for transactions and reveals that municipal bonds typically undergo multiple interdealer transactions before reaching buy-and-hold investors,

with each successive trade characterized by decreasing trade sizes and increasing prices (Schultz, 2022). An analysis of COVID-19's impact on municipal bond spreads (where lockdowns increased yields by 15%) provides crucial context for the broader examination of municipal market dynamics. The pandemic's state-specific effects on pricing that means particularly how health risks and economic shocks translated to yield changes directly inform the thesis' investigation of how exogenous factors interact with the market's microstructure. These findings complement the core analysis of transparency and interdealer trading effects by demonstrating how crisis conditions can amplify the pricing of municipal green bonds' mechanisms that have identified (Tran and Uzmanoglu, 2022).

The report of Capital Monitor reveals that those from advanced economies primarily invest their proceeds in clean transportation initiatives. The predominant allocation of funds from green bonds has been directed towards the development of green buildings. Among the 11 sustainable bond issuers with available post-issuance allocation data, eight have channeled over 50% of their proceeds into this sector. For instance, the canton of Basel-Stadt in Switzerland has fully utilized its green bond proceeds to construct and renovate public facilities, all aimed at enhancing energy efficiency using low-emission materials. While clean transportation also received some attention, it attracted significantly less funding compared to green buildings. North Rhine-Westphalia in Germany and the Spanish region of Galicia have focused their social investments on improving access to essential services. For North Rhine-Westphalia, this has involved enhancing educational access, while Galicia has directed its efforts mainly towards healthcare, including the provision of Covid-19 vaccines and the construction of a new hospital. Support for enhancing urban climate resilience is currently available through various.

Table 2 presents a compact six-phase roadmap for local authorities to issue green bonds, synthesizing global best practices with emerging market considerations. The structured approach guides municipalities from initial institutional preparation through post-issuance impact reporting, with each phase detailing key actions, responsible stakeholders, and realistic timelines. Particularly relevant for developing financial markets, this framework addresses both technical requirements (project selection, documentation) and strategic elements (investor engagement, credibility building), while emphasizing the critical link between transparent reporting and long-term financing costs. The roadmap's modular design allows adaptation to varying local capacities and regulatory environments, serving as both implementation guide and policy benchmarking tool. The roadmap offers actionable guidance for municipalities - a previously underserved segment in green finance research. By systematizing the issuance process into discrete phases with success metrics, it enables comparative analysis of municipal green bond programs across jurisdictions.

Table 2: Roadmap for Local Authorities to Issue Green Bonds

Phase	Key Actions	Timeline
Preparation	Conduct feasibility study and needs assessment Establish legal and regulatory framework Build internal capacity (train staff on green bond processes)	3-6 months
Project Selection	Identify eligible green projects (renewable energy, clean transport, etc.) Define project selection criteria aligned with ICMA Green Bond Principles Conduct environmental impact assessments Estimate financing needs and project timelines	2-4 months
Documentation	Prepare offering memorandum/prospectus Obtain second-party opinion (SPO) or verification Develop framework for impact reporting	3-5 months
Approval and Compliance	Secure local government approvals Meet regulatory requirements (securities laws) Obtain credit rating (if applicable)	2-3 months
Marketing and Issuance	Roadshow to potential investors Finalize terms and pricing Execute bond issuance	1-2 months
Post-Issuance	Allocate funds to designated projects Monitor project implementation Provide annual impact reports to investors	Ongoing

The inclusion of the green bond issuance roadmap in this thesis is particularly valuable because it provides a structured, phase-based framework that transforms a complex financial process into an actionable guide for local authorities because it breaks down the issuance process into six manageable phases (preparation, project selection, documentation, compliance, marketing, post-issuance), making it accessible even for municipalities with limited capital markets experience, where each phase includes concrete steps, responsible actors, and realistic timelines, ensuring feasibility for resource constrained local governments. It is a practical tool that advances both academic discourse and on the ground climate finance execution.

4.2 Examples of Municipal Green Bonds

Initiatives aimed at improving city creditworthiness and facilitating access to sustainable financing. Developing cities require long-term financial resources to implement climate-smart urban infrastructure plans. However, only a small percentage of these cities (approximately 4%) can access international capital markets, while only 20% have access to domestic markets that enable private financing through bonds (The World Bank, 2022). However, to access bond markets, many cities must either enhance their credit ratings or explore alternative financing options, such as loans from financial institutions, development agencies, and public-private partner-

ships. Although the green bond market has had a limited impact on financial flows to cities in developing regions thus far, it is experiencing rapid growth, with increasing engagement from investors and local participants. Therefore, cities should consider how a green bond strategy could improve their long-term access to affordable capital. For cities that lack the capacity to issue their own green bonds, partnering with other participants in the bond market to utilize the use of proceeds framework can facilitate funding for environmentally sustainable urban initiatives and investment approaches. Potential partners of municipal authorities in this field are city-affiliated agencies or entities, national development banks or agencies, private sector entities, such as financial institutions or corporations, multilateral development banks or agencies.

Regardless of the immediate options selected, they should align with long-term objectives by increasing awareness of cities' green investment initiatives among different types of investors: both domestic and international investors. Additionally, adopting a strategy to attract capital for green urban projects can yield several common benefits. Starting with strengthening the city's financial reputation by enhancing clarity in fiscal reporting and encouraging collaboration among municipal departments. Moreover, it allows confirmation that urban infrastructure initiatives are in accordance with established green bond guidelines, thus fulfilling relevant performance criteria. Raising awareness within the investment community about sustainable urban development initiatives, which can enhance confidence in city planning and administration. Overall, leveraging city-specific green bond evaluation metrics, such as public health, air quality, and social conditions, can make investments in certain projects more attractive, particularly to investors who prioritize environmental and social outcomes. Now, cases where local authorities successfully realized local sustainable projects issuing green bonds are presented. Municipal green bonds not only provide cities with funding but also foster active participation from local citizens and environmentally conscious investors in climate initiatives. This engagement enhances civic involvement in climate strategies, such as net-zero plans, by allowing citizens to contribute to their development and implementation at the municipal level.

4.2.1 Toronto Green Bonds

Toronto is making significant progress in its climate action efforts by issuing its sixth green bond, which further reinforces its commitment to sustainable development. This initiative not only generates crucial funding for environmental projects but also invites residents and environmentally conscious investors to actively participate in the city's climate strategies. Toronto issued more than hundred million dollars green bond to help finance transformative climate action projects. By engaging with the green bond market, Toronto seeks to finance a diverse ar-

ray of projects that align with its sustainability objectives, including efforts aimed at enhancing energy efficiency, minimizing waste, and developing green infrastructure. The issuance of this bond underscores the city’s commitment to cultivating a resilient urban environment while tackling urgent climate challenges. The city of Toronto issued its first green bonds in 2018 (City of Toronto, 2023).

Table 3: Green bond issued by Toronto

Year	Coupon	Maturity	Currency	Amount	CUSIP
2024	4%	2034	CAD	\$200 mln	891288EJ7
2023	4.40%	2042	CAD	\$100 mln	891288ED0
2022	4.40%	2042	CAD	\$300 mln	891288ED0
2021	2.20%	2031	CAD	\$150 mln	891288DZ2
2020	2.60%	2039	CAD	\$130 mln	891288DT6
2019	2.6%	2039	CAD	\$200 mln	891288DT6
2018	3.2%	2048	CAD	\$300 mln	891288DR0

The green bond is expected to attract a wide range of investors, including both individuals and institutions interested in socially responsible investment opportunities. This increasing interest in sustainable finance is fueled by a desire for investments that not only provide financial returns but also have a positive impact on the environment and society. Toronto has maintained transparency with its investors regarding the use of funds raised through the green bond, clearly outlining how the proceeds will be allocated to support local climate initiatives. This openness not only fosters trust among investors but also enhances community involvement, as residents are kept informed about how their contributions are making a tangible difference in the fight against climate change.

Beyond addressing immediate environmental issues, the city’s green bond strategy is designed to support long-term goals, such as advancing technological innovations for energy conservation and promoting sustainable transportation alternatives. Through these initiatives, Toronto is empowering its citizens to take an active role in shaping a greener, more sustainable urban landscape.

4.2.2 Gothenburg Green Bonds

In 2013, Gothenburg launched its first green bonds, successfully raising SEK 500 million. This was succeeded by a SEK 1.8 billion issuance in 2014, followed by SEK 1 billion in both 2015 and 2016, culminating in a total of SEK 4.36 billion raised through the financial markets. These green bonds are notable as the first financial instruments that allow mainstream investors, who constitute approximately 98% of the capital market, to participate in climate financing without incurring extra costs. Gothenburg’s commitment to ambitious environmental and climate objectives has driven the city to integrate its financial strategies with sustainability principles. Green bond initiatives in Gothenburg are mainly aimed at projects focusing on

mitigation and adaptation of climate change, with 80% of the funds allocated to these areas and a maximum of 20% directed toward sustainability efforts not explicitly related to climate change. Investments have been made in various projects, including zero-emission electric vehicles, a biogas facility capable of preventing 36,000 tones of CO₂ emissions annually, and the CELSIUS project, which advocates for innovative district heating solutions that could potentially cut CO₂ emissions by up to 60%.

The issuance of green bonds contributes to the city's financial resilience by diversifying risks, allowing resources to be directed towards projects that benefit the entire community. Notable financed projects include the pioneering Lackareback waterworks, the GoBiGas biogas production facility, and the integration of electric vehicles for municipal operations. Gothenburg aspires to motivate and support other organizations globally in adopting similar green initiatives through transparency and knowledge sharing, actively engaging in international forums, including COP conferences. The city's green bond program has established itself as a model for other municipalities in Europe and developing regions seeking to explore climate finance (UNFCCC, 2023).

4.2.3 Cape Town Green Bonds

One notable instance of this is Cape Town, South Africa, which launched a green bond in response to a serious water crisis that unfolded between 2015 and 2018. The city's ZAR 1 billion Green Bond was judiciously earmarked to fund and refinance water management initiatives that align with local needs, ultimately aiming to create a water-resilient urban landscape. By motivating residents to invest in these green bonds, Cape Town effectively broadened its pool of investors.

Moreover, there is an increasing interest among investors for opportunities that fit within socially and environmentally responsible practices, which also assist in meeting their non-financial reporting obligations. The city has taken proactive steps to inform investors about the explicit projects supported by the green bonds and the revenue generated, which not only draws in capital but also enhances community engagement and nurtures a collective commitment to tackling local issues. In addition to addressing urgent challenges, this green bond initiative aims to support long-term objectives, including the adoption of technological advancements for water conservation and improvements in low-carbon transportation infrastructures (Sullivan, 2020).

4.2.4 Moscow Green Bonds

Moscow's green bonds for the public represent a unique financial instrument that allows citizens to invest in environmentally sustainable projects, such as the replacement of the city's bus fleet with electric buses. These bonds initially are not traded on the stock exchange and can only be purchased by individuals, making

them accessible to a wide range of investors.

The Exchange amended its listing rules, enabling securities from all constituent entities of the Russian Federation to be admitted to the sustainable development sector in 2023. The distinctive feature of these green bonds is that the funds raised are directed towards financing environmental initiatives. Their "green" status is confirmed by the independent rating agency "Expert RA," which verifies that the proceeds will be used for sustainable development projects. This includes specific commitments from the city of Moscow to utilize the funds primarily for eco-friendly projects, such as the procurement of electric buses. By replacing diesel buses with electric alternatives, the city significantly reduces emissions of pollutants and green-house gases. For example, data shows that replacing one diesel bus with an electric bus leads to a reduction in emissions of approximately 172-233 kg of annually. In total, Moscow has created nearly 50 km of rail tracks, got 21 repaired or new BCL stations and bought more than 470 electric buses.

Furthermore, Moscow's green bonds benefit from a high credit rating of AAA, which enhances their investment reliability and minimizes risks for bondholders. This combination of sustainability, accessibility, and strong credit quality makes Moscow's green bonds an attractive option for citizens looking to support environmental initiatives while also making a sound investment (Stelmakh and Sergeeva, 2023; Vymyatnina and Chernykh, 2024).

Different cities face unique environmental challenges and have varying levels of resources, governance structures, and community engagement. By comparing green bond initiatives, stakeholders can identify which strategies are most effective in different contexts, allowing for tailored approaches that consider local conditions. Comparing municipal green bonds across different cities is useful for identifying effective strategies, sharing best practices, benchmarking performance, building investor confidence, informing policy development, understanding impacts on SDGs, and encouraging collaboration. This comparative approach can ultimately enhance the efficiency of green bonds as a tool for sustainable development.

According to the comparative analysis of cities' reports they appear to be clear and transparent with concrete targets and straightforward outcomes. The financial landscape has witnessed a significant shift towards sustainable investing, with green bonds emerging as a prominent instrument for financing environmentally friendly projects. As municipalities seek to address pressing issues such as risks caused by increased number of natural disasters, floods, droughts, transitional risks, infrastructure underdevelopment, and achievement of social equity, the issuance of green municipal bonds has gained traction (Auh et al., 2022).

Municipalities play a vital role in achieving the Sustainable Development Goals (SDGs) and climate objectives, as they are directly responsible for local

infrastructure, transportation, and urban planning. Engaging local municipalities in the green bond movement is essential for driving meaningful environmental change at the regional level. Municipalities possess a unique ability to address localized environmental challenges, such as improving air quality, reducing waste, and mitigating urban heat, through targeted green initiatives. By issuing green bonds, they can consolidate smaller projects into larger offerings, making them more attractive to institutional investors. Furthermore, local authorities are well-positioned to engage citizens directly in sustainability efforts, fostering greater community support for environmental initiatives.

Additionally, municipalities can serve as innovation hubs, testing cutting-edge solutions like smart city technologies and circular economy practices, which can later be scaled up for broader national or international applications. Despite these advantages, municipalities often face significant hurdles when attempting to issue green bonds. Many lack the technical expertise required to structure and promote green bonds effectively. Smaller municipalities, in particular, may struggle to secure favorable credit ratings, which are critical for attracting investors. Complicated regulatory frameworks further deter local governments from entering the green bond market.

A recent NBER working paper examining inaugural green bond issuances (2013-2022) revealed only 2% of proceeds financed truly novel projects not duplicating prior initiatives (Baker et al., 2018). The study found approximately 30% of corporate and 45% of municipal green bond funds served as conventional debt refinancing vehicles, while most remaining allocations supported project expansions or near-replicas of existing developments. The study also reveals 38% of municipal green bond issuances demonstrate instances of impact misrepresentation, wherein pre-existing projects were rebranded as environmentally transformative without substantive additionality (Baldi and Pandimiglio, 2022). To overcome these challenges, support from national governments and international organizations is crucial. This support could include training and technical assistance to help municipalities develop effective green bond frameworks, financial backing such as guarantees or subsidies to enhance creditworthiness, and the establishment of clear, straightforward guidelines to streamline the issuance process. By addressing these barriers, municipalities can play a pivotal role in advancing the global green bond movement.

Overall, municipal green bonds are specialized debt instruments issued by local governments to fund socially important environmentally sustainable projects, including renewable energy infrastructure, public transit systems, or energy-efficient buildings. These bonds align with global climate goals at national and local levels by directing capital toward low carbon and resilience focused initiatives while offering both investors a responsible investment opportunity and local authorities

Table 4: Comparative analysis of municipal green bonds issuance cases

Aspect	Moscow	Cape Town	Toronto	Gothenburg
Purpose	Fund eco-friendly projects like electric buses	Finance water management projects for resilience (water supply shortages)	Finance sustainability projects (water management, electric buses, coastal structures, biodiversity)	Fund projects focused on climate change mitigation and sustainability
Accessibility	Tradable, available to individual investors	Open to a diverse investor base, including residents	Open to both individuals and institutions	Available to mainstream investors, 98% of market
Environmental Focus	Earmarked for projects reducing emissions	Focused on water conservation and management, flood protection measures	Broad focus on energy efficiency and green infrastructure (public charging)	80% for climate change mitigation, 20% for other sustainability initiatives
Verification	Green status confirmed by "Expert RA"	Certified by the CBI and Moody's international rating agency	Transparent allocation of funds to specific initiatives	Emphasizes transparency and knowledge sharing
Credit Rating	AAA by Analytical Credit Rating Agency and Expert-RA	GB1 (excellent = AAA) by Moody's	AA credit rating by S&P Global	S&P Global Rating Standard Poor's AA+ with stable outlook, E2
Community Engagement	Promotes citizen investment in local projects	Enhances citizen engagement through communication	Builds trust and informs residents about contributions	Aims to inspire and assist other entities worldwide
Long-term Goals	Reduce emissions and promote electric transport	Establish water-resilient urban environment, support the city's strategy of adapting to climate change	Support technological innovations and sustainable transport, fund transformative climate action	Support projects like zero-emission vehicles and innovative district heating
Market Demand	Limited to local investors	Low awareness among African investors hampers demand for green bonds.	Increasing interest in socially responsible investments, strong investor demand	The interest from the market has been strong, engaging mainstream investors in climate financing
Amount issued	1.27 billion EUR (126.5 billion RUB)	77.2 million EUR (1 billion ZAR)	93 million EUR (100 million USD)	2.17 billion EUR (24.95 billion SEK)
Years	7 years	10 years	10-20 years	6 years
Maturity	May 2025	July 2027	December 2042	November 2025
Nominal rate	7.38%	10.17%	2.2 - 4.40%	9.65%

funds for development of this direction because by issuing green bonds, municipalities can access new pools of capital, often at favorable terms, due to growing demand from ESG conscious investors. Additionally, green bonds enhance transparency and accountability, as issuers must report on the environmental impact of funded projects, fostering trust among stakeholders and improving the municipality's reputation (ICMA, 2024).

To successfully leverage green bonds, local authorities should first identify eligible projects with clear environmental benefits, ensuring alignment with international standards like the Green Bond Principles (GBP) or EU Taxonomy. Engaging with investors and credit rating agencies early in the process can improve marketability and potentially lower borrowing costs. Municipalities should also establish robust monitoring and reporting frameworks to track project performance and demonstrate impact, which strengthens investor confidence and supports future issuances. Partnerships with development banks or national green finance initiatives can provide technical assistance and credit enhancements, mitigating risks for first-time issuers. Finally, local governments should integrate green bonds into broader sustainable urban planning strategies, ensuring long-term fiscal and environmental sustainability while meeting community needs.

4.3 Exploring the “Greenium” in Municipal Bonds

As it has been already stated, the “greenium” refers to the premium that investors are willing to pay for green bonds compared to conventional bonds. This premium comes from the perceived benefits associated with investing in environmentally friendly projects, which are financed through this financial instrument. Greenium can be shown as lower yields on green bonds, bringing the idea that issuers of this specific green debt securities can borrow at a cheaper rate than they would for traditional bonds. The phenomenon may be driven by a growing demand for sustainable investment options, as more investors seek to align their portfolios with their environmental, social, and governance (ESG) values. A premium attached to green bonds emerges from various interconnected factors. First, surging investor interest in ESG compliant assets has intensified demand for green bonds, compressing their yields relative to conventional bonds. Second, issuers benefit from reputational gains and enhanced market positioning by aligning with sustainability goals, making them willing to accept marginally lower financing costs. Third, regulatory tailwinds, including tax incentives, subsidy programs, and preferential treatment in central bank collateral frameworks, artificially amplify the appeal of green debt instruments. Together, these demand side preferences, corporate signaling incentives, and policy-driven market distortions create the conditions for a persistent greenium in sustainable finance markets. However, the existence of greenium is a hotly debatable issue. Some studies suggest it is real and even significant, while others argue that the pricing

difference is negligible or inconsistent. The results regarding greenium depends on market conditions, issuer credibility, and the transparency of the bond's environmental impact. The importance of the greenium lies in its ability to motivate issuers to finance projects that contribute to environmental improvement through this mechanism. By offering lower borrowing costs, the greenium encourages more companies and governments to issue green bonds, thereby increasing the flow of capital and eliminating financial constraints. The process allows flows into renewable energy, energy efficiency, and other sustainable initiatives. This can lead to a significant positive impact on climate change mitigation and the transition to a zero-carbon economy. Additionally, the greenium reflects the growing recognition of the financial materiality of sustainability, as investors increasingly consider the long-term risks associated with climate change. The greenium benefits a wide array of stakeholders. For issuers, the opportunity to secure capital at reduced costs can significantly improve their financial outcomes and bolster their sustainability initiatives. Investors, on the other hand, can leverage the greenium to channel funds into projects that resonate with their principals or values while still pursuing competitive returns. Additionally, society at large reaps the rewards of enhanced investment in environmentally friendly projects, which can stimulate job creation, foster technological advancements, and lead to better public health results. In summary, the greenium is supposed efficient in advancing sustainable finance and tackling the pressing issues associated with climate change. Numerous studies have analyzed the yield differences between green bonds and traditional (or "brown") bonds, revealing that green bonds often command a premium from the issuer's perspective, commonly referred to as a greenium as it was already mentioned above. According to different studies, this phenomenon has been observed both at the time of issuance and in secondary market transactions. However, the literature lacks a consensus on the magnitude of the greenium, with estimates varying significantly from low changes in basis points bps (Zerbib, 2019); to high ones (Flammer, 2021). Notably, the presence of a third-party certification, such as that provided by the Climate Bonds Initiative, appears to enhance the size of the greenium (Flammer, 2021).

Conversely, a smaller subset of studies suggests that there may be no significant yield difference between green and brown bonds, indicating a complex and evolving landscape in the green bond market (Larcker and Watts, 2020). This body of research underscores the importance of understanding the financial dynamics of green bonds, particularly for local authorities seeking to leverage these instruments for sustainable development initiatives. The econometric model developed to analyze bond yields incorporates a dummy variable for green bonds. This study aims to assess the presence of a greenium in the yield spreads of green municipal bonds compared to conventional municipal bonds. The analysis is based on data sourced from Eikon Refinitiv LSEG, focusing exclusively on bonds issued

by municipalities. It consists of 9384 observations that represent information of 19 variables for each bond with years of issuance from 1986 to 2025 from 17 different countries (later called market) from 136 unique municipalities. In analysis Australia is a base market, 2005 is a base year. The dataset includes key bond characteristics such as yield, maturity, market conditions, coupon rate, and duration, which are critical in understanding the pricing dynamics of green versus non-green municipal bonds. To quantify the greenium, it is employed a regression model where the yield spread is the dependent variable. The model 1 is specified as follows:

$$\text{Yield}_{it} = \beta_0 + \beta_1 \cdot \text{GB}_{it} + \beta_2 \cdot \text{Mat}_{it} + \beta_3 \cdot \text{CR}_{it} + \beta_4 \cdot \text{D}_{it} + \gamma_j \cdot \text{Country}_j + a_i + \varepsilon_{it} \quad (1)$$

In this model 1: GB - green bond dummy is a binary variable indicating whether the bond is green (1) or conventional (0); Mat stands for maturity and represents the time to maturity of the bond; Country or market captures location where bonds are issued; CR or coupon rate is the bond's coupon rate; D or duration measures the bond's sensitivity to interest rate changes; ε is the error term. The coefficient β_1 is of particular interest, as it captures the "greenium" - the yield differential attributable to the bond's green status. A negative and statistically significant β_1 indicate that green municipal bonds trade at a premium (lower yield) compared to their conventional counterparts, reflecting investor willingness to accept lower returns for environmentally beneficial investments.

This analysis contributes to the growing body of literature on sustainable finance by providing empirical evidence on the pricing of green municipal bonds, offering insights for policymakers, investors, and issuers in the municipal bond market. The study estimates a linear regression model to examine the determinants of bond yields, with a focus on the existence of a green premium. Here green premium analysis of municipal bonds can be observed. The coefficient for green bond dummy is -0.078 and is highly significant ($p < 0.001$), indicating that green bonds have yields that are, on average, 0.078 percentage points lower than conventional bonds.

This suggests the existence of a green premium. Maturity has a positive and significant coefficient (0.028), meaning that longer maturities are associated with higher yields. The market coefficients reflect significant differences in yields across issuer countries. For example, bonds from Argentina have yields 47.7 percentage points higher than the baseline, while bonds from Germany have yields 2.5 percentage points higher. Both coupon rate and duration have positive and significant coefficients, indicating that higher coupon rates and longer durations are associated with higher yields. The model 1 explains 99.9% of the variance in bond yields ($R^2 = 0.99$). The residual standard error is 0.095, indicating a good fit, though there are some outliers. The results of regression model can be found below. Adjusted R^2 :

Table 5: Model 1.

Variable	Estimate	Std. Error	t-value	p-value
green bond dummy β_1	-0.08	0.02	-4.02	<2e-16 **.
maturity	0.03	0.00	17.04	<2e-16 ***.
coupon rate	0.03	0.00	16.40	<2e-16 ***.
duration	0.04	0.00	17.81	<2e-16 ***.
Argentina	47.67	0.11	417.67	<2e-16 ***.
Austria	2.58	0.10	27.03	<2e-16 ***.
Belgium	3.11	0.01	300.70	<2e-16 ***.
Canada	2.69	0.02	173.46	<2e-16 ***.
China (Mainland)	1.53	0.01	260.63	<2e-16 ***.
Eurobond	13.47	0.10	137.59	<2e-16 ***.
France	3.21	0.01	438.87	<2e-16 ***.
Germany	2.47	0.07	36.68	<2e-16 ***.
Hong Kong	2.18	0.03	70.27	<2e-16 ***.
India	6.53	0.01	532.48	<2e-16 ***.
Macau	2.01	0.04	46.36	<2e-16 ***.
Norway	4.64	0.07	68.48	<2e-16 ***.
Portugal	2.94	0.03	86.80	<2e-16 ***.
Spain	2.74	0.01	251.64	<2e-16 ***.
Sweden	2.57	0.03	75.94	<2e-16 ***.
Switzerland	0.54	0.01	59.48	<2e-16 ***.
United States	4.05	0.02	228.41	<2e-16 ***.

Variable	Observations	Median	Min.Max
Green Bonds	9384	-	0.1
Coupon Rate (%)	9384	3.37	0.00.40.73
Amount Issued (USD)	9384	171.8M	692.9.42B
Yield to Maturity (%)	9384	2.02	-10.36.58.17
Years to Maturity	9384	4.00	0.00.29.00
Issue Year	9384	2021	1986.2025
Maturity Year	9384	2029	2025.2054

0.99; F-statistic: 1.05e+06 on 21; p-value: < 2.2e-16.

The results confirm the existence of a green premium, with green bonds yielding significantly less than conventional bonds. The model also highlights the importance of issuer country, maturity, coupon rate, and duration in determining bond yields. The high value of R^2 indicates an excellent fit, although further analysis of outliers may be warranted.

5 Empirical Analysis

The empirical analysis presented in the previous section provides robust evidence for the existence of a statistically significant green premium, confirming that investors are willing to accept lower yields for green bonds compared to conventional bonds with similar characteristics. The strong explanatory power of the model (as indicated by the high R^2 value) underscores the importance of both financial

fundamentals such as maturity, coupon rate, and duration and non-financial factors, including issuer country and environmental credentials, in determining bond pricing. These findings set the stage for a deeper investigation into the broader societal and economic implications of green bond issuance. While the presence of a green premium reflects market recognition of environmental value, it remains essential to examine whether this financial mechanism translates into tangible progress in sustainable development. The following section expands the analytical scope beyond financial markets to explore the relationship between green bond activities and actual sustainability outcomes, particularly through the lens of Sustainable Development Goals (SDG) achievement. Using econometric models tailored to different dimensions of sustainability, we assess whether green bonds serve not only as instruments of financial innovation but also as catalysts for meaningful environmental and social change.

5.1 Research Design. Green Bonds and SDG Score

Econometric analysis is applied to create several models for present research. Second set of models (models 2, 3, 4, 5, 6, 7, 8) try to answer the question whether the issuance of green bonds positively contributes to sustainable development at national level, while above-mentioned model (model 1) is designed to study the existence of "greenium", a concept which is described in detail below. In general, choosing an econometric modeling as a tool to empirically investigate the research questions and to understand the role of green bonds in sustainable development offers such advantage as provision of a structured framework for analyzing quantitative data, enabling to assess the relationship between green bond issuance (in terms of share of total debt or in terms of total cumulative amount) and various indicators of sustainable development (SDG-score, CO₂ emissions) effectively due to quantitative analysis. Besides, it allows for capturing causality and impact assessment.

What is more, econometric model can control for external factors that may influence the results, ensuring that the analysis isolates the effects of green bonds from other economic and environmental influences. It is also important that this type of approach enables the analysis of data over time, which is useful for assessing the long-term effects of green bonds on sustainable development. Econometric modeling as a valuable tool for analyzing both the role of green bonds in sustainable development is employed, providing insights that can guide investments and policies predestinated at fostering environmental sustainability and the existence or absence of yields difference between green and conventional bonds.

5.2 Data Collection

For the analysis presented in this thesis, the work utilized multiple data sources to ensure a comprehensive understanding of green bonds and their impact

on sustainable development. Specifically, retrieved data on the shares of green bonds among European countries from Eurostat provided valuable insights into the distribution and trends of green bond issuance across the region. Additionally, it was sourced data from the International Monetary Fund (IMF) regarding the total amount of green bonds issued in various countries worldwide. This combination of data allowed us to construct robust models that reflect the dynamics of green bond markets and their role in promoting environmental progress. The Climate Bond Initiative Data platform where the main data was obtained for this research provides comprehensive datasets related to climate variables and their economic implications. The Climate Bonds Initiative (CBI) is a global, not-for-profit organization that aims to promote investment in projects and assets necessary for a rapid transition to a low-carbon economy. The organization provides standards, certification, and resources to facilitate the growth of the green bond market, helping to align capital with climate solutions (International Capital Market Association, 2024). The dataset derived from the platform encompasses a detailed analysis of climate variables and their economic repercussions, the analysis specifically focusses on green bond issuances across various countries.

Green bond issuance (in analysis indicated as GB) is chosen as a variable of interest (it is specified in detail later: whether the use of total amount of issued green bonds or of the indicator as a share of green bonds in total amount of issued debt is used). So, GB captures the total amount of green bonds issued by countries in each year, measured in billions of US dollars in models: 3, 4, 5, 6, 7, 8; while it represents share in model 2. The time observed in the analysis includes years from 2007 to 2022. As a control variable, the data set for GDP per capita is sourced from the World Bank database, US dollars. These variables serve as controls in the analysis in different models to account for economic differences across countries, enabling a more nuanced examination of the relationship between economic performance and green bond issuance. To assess the relationship between the achievement of sustainability, the United Nations SDG-score is used in models: 2, 3, 5. This sustainability metric represents a composite score designed to assess countries' progress toward achieving the sustainable development goals and provides context regarding each country's contribution, alignment, and progress towards green or social practices, helping to evaluate how sustainability efforts correlate with financial mechanisms like green bonds. SDG-score is discussed in detail later in the work. FDI (US dollars, as a control variable for models 6, 7) and CO₂ emissions (carbon dioxide emissions from industrial combustion (energy) (Mt) as an alternative dependent variable used for model 6) are also retrieved from World Bank dataset. The dataset is structured as panel data, which captures information across multiple countries over various time periods containing 1156 observations (16 years, 68 countries), 7

variables. The dataset is classified as unbalanced, indicating that different countries have varying numbers of observations throughout the years. This is due to differences in green bond issuance activity and data availability. Table 6 demonstrates the scale of some main variables. This dataset presents a multi-dimensional perspective of how financial instruments like green bonds contribute to the sustainability agenda across different economies. By leveraging both economic indicators and sustainability scores, the analysis aims to elucidate potential relationships and patterns that can inform policy and investment decisions in the context of climate change and sustainable development.

Table 6: Variable Definitions and Measurements

Variable	Description	Unit/Scale
GB	Logarithm of amount of green bonds (models 3, 4, 5, 6)	Billions of USD (log)
	Logarithm of share of green bonds of total debt (model 2)	Billions of USD (log)
GDP	Logarithm of gross domestic product per capita	USD (log)
FDI	Logarithm of foreign direct investment	USD (log)
SDG score	Composite index measuring progress toward SDGs	0-100 scale
Income level	Categorical measure of national income	1 = High income 2 = Medium income 3 = Low income
CO₂	Carbon dioxide emissions	Metric tons (Mt)

In order to estimate the existence of "greenium" data from Euronext stock exchange is used (Euronext, 2025) and from Refinitiv LSEG data. While to demonstrate dynamics in municipal bond market U.S. municipal bond indices from S&P Global are used (S&P Global, 2025).

5.3 Correlation Between Green Bonds and SDG-score

As the critical intersection of finance and sustainable development has gained prominence, particularly in terms of how financial instruments, such as green bonds, can contribute to the achievement of Sustainable Development Goals the model to estimate efficiency of this financial instrument is introduced. The SDG score (or SDG index) is a composite measure of a country's performance in achieving the United Nations Sustainable Development Goals. Developed by the Sustainable Development Solutions Network (SDSN) and the Bertelsmann Stiftung, the index offers a method to evaluate and compare progress between various countries, taking into account progress in the achievement of 17 established goals subdivided into 64 targets. The Sustainable development goals, known as the Global goals, were established by the United Nations in 2015 as a collective appeal to overcome poverty problems, protect the planet, and guarantee that by 2030, everyone experiences peace and prosperity.

The 17 SDGs are closely interconnected, acknowledging that efforts in one domain will influence results in others, emphasizing the necessity for development to harmonize social, economic, and environmental sustainability. Nations have pledged to focus on the advancement of those who are the most disadvantaged. The SDGs also aim to eliminate hunger worldwide, reduce climate change risks, fight gender-based and social discrimination.

Explaining the theoretical base of the first hypothesis it should be repeated that green bonds are debt instruments specifically earmarked to raise funds for climate and environmental projects as they play a significant role in advancing the Sustainable Development Goals (SDGs). SDG 7 (affordable and clean energy) - green bonds finance renewable energy projects like solar, wind, and hydropower, reducing reliance on traditional sources such as fossil fuels. SDG 9 (industry, innovation, and infrastructure) - they support sustainable infrastructure, including energy-efficient buildings and green transportation. SDG 11 (sustainable cities and communities) - green bonds fund urban projects like public transit, waste management, and green spaces. SDG 13 (climate action) - they directly contribute to climate mitigation and adaptation projects, such as reforestation and flood defenses. SDG 15 (life on land) - green bonds can finance biodiversity conservation and sustainable land use projects (The World Bank, 2022). By channeling capital toward environmentally friendly initiatives, green bonds align investor interests with global sustainability objectives (Flammer, 2020). The purpose of this section is to present analysis conducted before creation of an initial model aimed at assessing the efficiency of green bonds in achieving SDGs, particularly in how they interact with various economic variables. The model incorporates several important components starting with green bonds issuance; the primary focus of this research while measuring their impact on SDGs is integral to understanding their role as a financing tool for sustainable development. GDP serves as a control variable in this model. It is a critical indicator of economic performance and growth.

By controlling for GDP, the aim to isolate the specific impact of green bonds on SDGs from the broader economic context appears. This allows for a more accurate assessment of the influence of these financial instruments on sustainable development. FDI is included as another control variable to account for investments that flow across borders into projects or industries aimed at generating returns. Like GDP, FDI can affect the achievement of SDGs by injecting capital into sustainable projects. Understanding its relationship with green bond issuance helps gauge external investment dynamics towards sustainability initiatives. As an alternative metric to directly assess sustainability outcomes, CO₂ emissions are included in the model. Carbon dioxide emissions represent an environmental outcome that can be influenced both by green bonds and economic activity, providing a tangible measure of the environmental impact associated with different

development efforts. To refine the analysis, dummy variables representing years and countries are employed. These fixed effects help control for time-based trends and country-specific factors, allowing for a more precise understanding of how green bonds operate in different social and economic contexts as well as how they evolve over time. Investigating the relationships between green bond issuance with the economic indicators such as GDP, FDI as control variables is crucial to comprehensively understand their role in achieving SDGs.

Exploring the relationships among these variables through scatter plots and correlation matrices is essential initial insight into relationships. This empirical analysis may provide valuable insights into the efficiency of green bonds in driving sustainable development. By elucidating these relationships through visual and statistical analysis, this part of research contributes to the creation of more complicated models, ensuring that the selected variables reliably capture the dynamics between green bonds and SDGs while accounting for key economic factors. Besides, in models involving multiple predictors, understanding the correlation between variables is significant for assessing multicollinearity, where predictor variables are highly correlated. Estimation of coefficients can be distorted by high level of multicollinearity. Figure 9 presents a scatter plot that visualizes the relationship between the amount of green bonds issued by various countries and their respective SDG scores. Each point on the graph corresponds to a country, with the y-axis representing the logarithm of total amount of green bonds issued (in monetary value) and the x-axis representing the country's SDG score, which is a composite indicator of how well each country is performing in terms of achieving the UN's SDGs. The scatter plot suggests a positive correlation between the amount of green bonds issued development and the SDG scores. In general, countries with higher SDG scores (indicating better progress towards sustainable development) tend to issue larger volumes of green bonds. This suggests that nations committed to sustainability and environmental goals are more likely to use green bonds as a tool for financing sustainable projects.

Moving forward, correlation matrix that quantifies the strength and direction of relationships between variables is explored. Such matrix is a statistical tool that presents the coefficients between multiple variables. In the context of this analysis, the correlation between three variables is examined: SDG (sustainable development goals), GB (green bonds emissions), GDP (gross domestic product), FDI (foreign direct investments), and CO₂ (carbon dioxide emissions) (figure 10). The correlation matrix provides valuable insights into the relationships between dependent variable, variable of interest and control variables. While there are positive correlations among SDG, GDP, GB, FDI, the strength of these relationships varies.

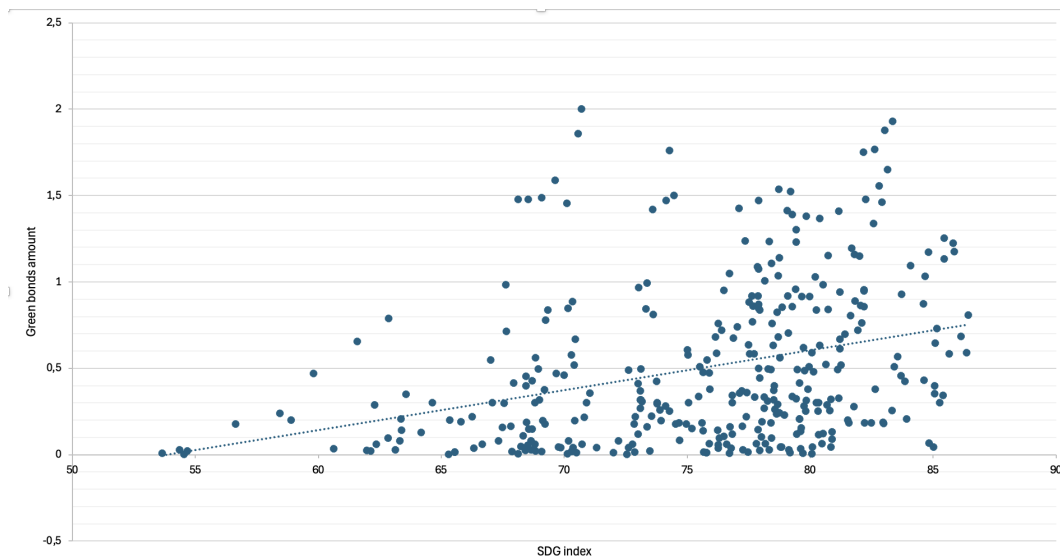


Figure 9: Scatter plot of dependence of SDG score from the amount of green bonds issued in different countries
 Source: IMF, UN

The correlation matrix reveals important insights into the interplay between economic factors and sustainability initiatives. The positive correlations between Sustainable Development Goals, green bonds, and GDP suggest that financial resources and economic growth can support sustainable development efforts. Specifically, the moderate positive correlation (0.29) between SDG and GB indicates that as efforts towards achieving SDGs increase, there is a corresponding increase in green bond investments.



Figure 10: Correlation matrix of SDG, GB, GDP, FDI, CO₂
 Source: World Bank, Climate Bond Initiative, UN

Additionally, the strong positive correlation (0.45) between GDP and FDI suggests that a growing economy attracts more foreign investment, which is crucial for funding sustainable initiatives. However, the positive correlation (0.47) between

FDI and CO₂ emissions raises concerns about the environmental impact of foreign investments, as it may indicate that increased foreign investment is associated with higher carbon emissions. Furthermore, the negative correlation (-0.13) between CO₂ emissions and SDG reinforces the idea that higher emissions are associated with lower progress towards achieving sustainable development goals. Overall, these correlations highlight the need for careful consideration of how investments, particularly in green bonds, can be aligned with broader sustainability goals to ensure that economic growth does not come at the expense of environmental health. The figure 11 demonstrates a pool of scatter plots, histograms and correlation matrix, where each point represents a country's GDP, amount of issued green bonds, SDG-score values, CO₂ emissions or FDI over the years. Positive relation between green bonds issuance and SDG can be observed. By visualizing GDP against SDG score, it is possible to understand whether higher GDP correlates with better SDG outcomes. A positive correlation suggest that wealthier countries tend to perform better on sustainable development metrics. Positive trend can be seen in relation between green bonds amount and GDP. CO₂ emissions with green bonds demonstrate negative direction of dependence.

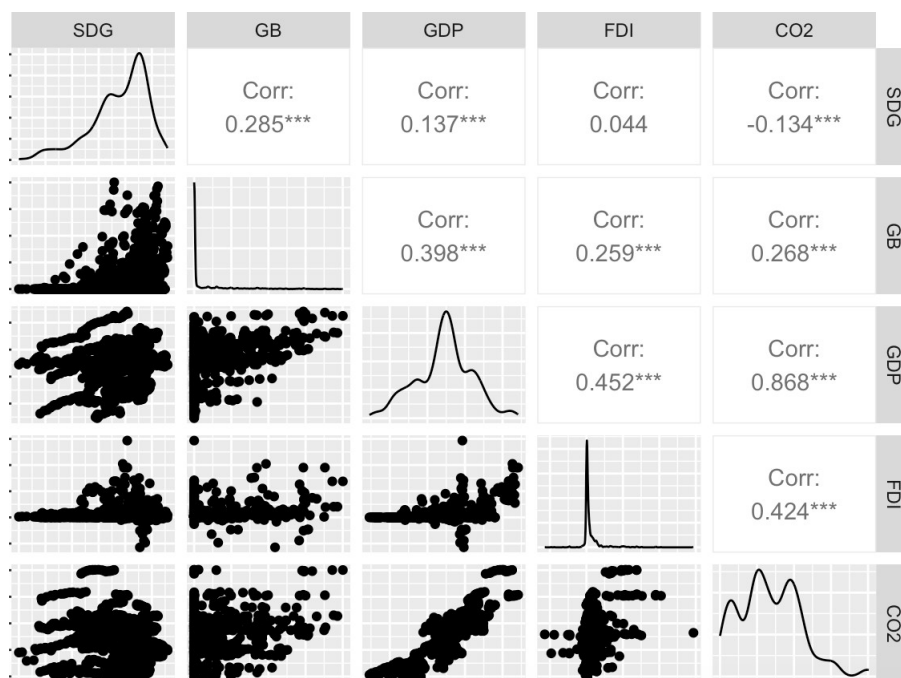


Figure 11: Scatter plots of dependent and independent variables (SDG, GB, GDP, FDI, CO₂) over the period of years by countries
 Source: World Bank, IMF, UN

Table 7 shows differences in average SDG-scores. The attention is paid to the difference between the development of index of countries that has high share of issued green bonds and of countries that has low share of issued green bonds. However, countries low share of issued green bonds are those whose share of green

bonds is lower than 0.04% of total amount of issued debt. The average SDG score for all countries increased from 71.3 in the period 2007-2015 to 74.0 in 2015-2022, resulting in a positive difference of 2.7. This indicates an overall improvement in SDG performance across all countries. The difference in average SDG scores between countries with high and low share of issued green bonds was 5.7 in the earlier period (2007-2015) and decreased to 4.7 in the later period (2015-2022). This change represents a reduction of 1, indicating that the gap in SDG performance between these two groups has not narrowed over time.

Table 7: Average SDG-scores

	2007-2015	2015-2022	Difference
All	71.3	74.0	2.7
Countries high share of issued green bonds	76.7	78.5	1.8
Countries low share of issued green bonds	71.0	72.0	1.0
Difference (high share of issued green bonds - low share of issued green bonds)	5.7	4.7	1

As for the models that are constructed to research greenium: the yield differential between green and conventional bonds is a dependent one, dummy variable of green bond issuance captures the direct effect of the green label, isolating its impact on yields. Maturity accounts for the time to repayment. The market variable controls for differences in macroeconomic and regulatory conditions across issuer countries, which can significantly affect bond pricing. Coupon rate is included because higher coupon payments generally lead to higher yields, while duration measures the bond's sensitivity to interest rate changes, reflecting its exposure to interest rate risk.

Together, these variables ensure the model isolates the greenium by controlling for confounding factors, providing a robust framework to analyze how green bonds are priced relative to conventional bonds and offering insights into investor preferences for sustainable finance, while controlling for key factors that influence bond pricing. The green bond dummy captures the direct effect of the green label, isolating its impact on yields. The market variable controls for differences in macroeconomic and regulatory conditions across issuer countries, which can significantly affect bond pricing.

5.4 Impact of Green Bonds on Sustainability Metrics

Several models are created to measure the impact of green bonds on sustainability. Step by step, they are presented in this section. Model 2 covers only the data from European countries (Eurostat) serving to understand the main pattern and proceed with deeper analysis. Model 2:

$$SDG_{it} = \beta_1 \cdot \log (GB)_{it} + \beta_2 \cdot Country_i + \varepsilon_{it}. \quad (2)$$

Country $_i$ is a dummy variable for each country; GB $_it$ is a share of green bonds among all issued bonds in each country. Residual standard error: 0.006 on 80 degrees of freedom. Multiple R^2 : 0,99, Adjusted R^2 : 0,99. F-statistic: 2190000 on 28 and 80 DF, p-value: $< 2.2e-16$. The data is based on observations from 2019 to 2022 within the European Union. The coefficient estimate for GB is 0.16, indicating a positive relationship between the share of green bonds and the sustainability outcome. The t-value of 6.6 and a p-value of 0.00001 suggest that coefficient behind the share of green bonds is statistically significant at conventional levels (0.001 level), meaning that changes in the GB share are significantly related to changes in the SDG-score which is a score measuring progress on Sustainable Development Goals. The regression model was designed to explore how the share of green bonds affects the SDG-score while controlling for other factors, in this case individual fixed effect presented by each country. The statistical significance of the GB coefficient implies that a 1% increase in the share of green bonds is associated with a positive change in SDG index. The results for GB are highly significant, while other coefficients associated with the country-specific factors are also significant, indicating varied impacts of different country contexts on the dependent variable concerning the green bonds share. The model fit indicators show a multiple R^2 of 0.99, indicating that the model explains a majority of the variability in the dependent variable based on the predictors used. The residual standard error of 0.0058 indicates low variability in the regression errors, suggesting that predicted values are very close to observed values. The observations are focused on the years from 2019 to 2022, which is particularly relevant given the growing emphasis on sustainable finance and ESG (Environmental, Social, and Governance) criteria during this period in the EU. The increase in issuance of green bonds and regulatory frameworks supporting green finance during this time may reflect the positive relationship observed. The regression results indicate that the share of green bonds has a statistically significant positive influence on the outcome variable being measured, with the implications supporting the notion that an increased focus on sustainable finance through green bonds can correlate positively with various economic or sustainability metrics. Moreover, considering the context of the data from 2019 to 2022, the findings are relevant to understanding the evolving landscape of sustainable investments in the European Union.

This is an initial model that is clearly and simply interpretable however it has disadvantages. Nevertheless, it serves to introduce the first step of the econometric analysis of the role of green bonds in the achievement of SDGs. Strengths of this model are the use of logarithmic transformation (the log-transformed variables for both green bonds and GDP can be useful for reducing the effect of outliers and capturing diminishing returns or non-linear relationships between variables) and simplicity (the model is straightforward, which can make

Table 8: Model 2.

Variable	Estimate	Std. Error	t-value	p-value
θ_1	0.04	0.00	14.98	3.400e-09 ***
Fixed effect for: Belgium	4.28	0.01	728.77	<2.2e-16 ***
Bulgaria	4.30	0.01	728.42	<2.2e-16 ***
Croatia	4.40	0.01	746.86	1.950e-09 ***
Cyprus	4.08	0.01	695.37	<2.2e-16 ***
Czechia	4.35	0.01	740.17	2.727e-10 ***
Denmark	4.34	0.01	737.13	5.489e-07 ***
Estonia	4.27	0.01	726.76	<2.2e-16 ***
Finland	4.33	0.01	727.51	<2.2e-16 ***
France	4.32	0.01	733.95	7.018e-13 ***
Germany	4.17	0.01	682.31	3.951e-06 ***
Greece	4.22	0.01	717.82	<2.2e-16 ***
Hungary	4.26	0.01	725.62	<2.2e-16 ***
Ireland	4.26	0.01	725.70	<2.2e-16 ***
Italy	4.38	0.01	745.64	<2.2e-16 ***
Latvia	4.41	0.01	745.83	<2.2e-16 ***
Lithuania	4.20	0.01	715.59	<2.2e-16 ***
Luxembourg	4.35	0.01	740.70	<2.2e-16 ***
Malta	4.23	0.01	720.10	1.950e-09 ***
Netherlands	4.44	0.01	752.79	<2.2e-16 ***
Poland	4.36	0.01	709.05	<2.2e-16 ***
Portugal	4.27	0.01	727.56	<2.2e-16 ***
Romania	4.37	0.01	717.65	<2.2e-16 ***
Slovakia	4.33	0.01	737.17	<2.2e-16 ***
Slovenia	4.37	0.01	743.25	<2.2e-16 ***
Spain	4.35	0.01	741.38	<2.2e-16 ***
Sweden	4.05	0.01	688.28	<2.2e-16 ***

easy to interpret and estimate). The complexity of the SDG achievements (the SDG score is likely to be influenced by a variety of economic, social, political, and environmental factors, many of which might not be captured by GDP and green bond issuance alone; for instance, factors like education quality, healthcare, income inequality, or climate change policies could all impact SDG outcomes), endogeneity (there could be re-verse causality between SDG scores and green bond issuance - countries with higher SDG scores might attract more green bonds, rather than green bonds causing improvements in SDG outcomes). This would require more sophisticated techniques, such as instrumental variables.

Possible improvements are applied in further research: incorporation of additional variables considering adding other control variables that could affect SDG performance, such as foreign direct investment (FDI, applied in the following models) and GDP; use of panel data as it accounts for within-country variations over time and provide a more robust estimation of the relationship; addition of alternative

dependent variables choosing instead of a single SDG score implementation of CO₂ emissions which might provide more granular insights into how green bonds affect different aspects of sustainability; as well as resolving endogeneity issues by use of an instrumental variable (IV) approach or a two-stage least squares (2SLS) regression to better address the issue of reverse causality which is left for further research.

The work proceeds with regression analysis creating second OLS regression model in order to evaluate the effect of green bond issuance on SDG score of 68 countries across the world. As a variable of interest sum of issued green bonds in each country is taken while GDP is taken as control variable. SDG Index plays role of dependent variable in presented OLS regression. GDP and amount of issued green bonds are logarithmically transformed to normalize them and perform better interpretation. All the coefficients jointly and separately are significant at a 5% level of significance according to F-statistics and p-value. Ordinary least squares (OLS) model is described with time and fixed effects using panel data collected from Climate Change Initiative (Green Bonds), OECD (SDG-score), World Bank (GDP). The model specified in your analysis employs Ordinary Least Squares (OLS) regression with the inclusion of both time and fixed effects, allowing for a proper examination of the relationship between the achievement of Sustainable Development Goals (SDG) and green bonds amount (GB), while accounting for the influences of GDP, year, and country as control variables. Below, is an outline of the model setup, the results, and their interpretation and the characteristics of the model are provided (tables 9; 10). The model is specified as follows - Model 3:

$$SDG_{it} = a + \beta_1 \cdot \log(GB)_{it} + \beta_2 \cdot GDP_{it} + \beta_3 \cdot Country_i + \beta_4 \cdot year_t + \varepsilon_{it}. \quad (3)$$

Dependent variable is SDG-score. Explanatory variable is the amount of green bonds (GB) that represents the independent variable of interest. Gross domestic product is a control variable accounting for economic performance. A time fixed effect that accounts for variations over time and is represented by variable year. Country is a fixed effect that controls for differences unique to each country. The coefficient estimate for green bonds is -0.48 with a standard error of 0.1. The t-value of -4.6 and a low p-value of indicate a statistically significant negative relationship, suggesting that, holding other variables constant, an increase in green bond investment is associated with a decrease in the SDG score. This may be caused by wrong specification of the model because previous analysis showed positive correlation. The coefficient for GDP is 2.3 with a standard error of 0.33. The positive and statistically significant coefficient indicate that, all else being equal, an increase in GDP correlates with an increase in SDG scores.

The residual standard error is 0.817, which shows how far the data points typically deviate from the regression line. Multiple R^2 is approximately 0.99, which

Table 9: Regression Results for Model 3

Variable	Estimate	Std. Error	t-value	p-value
β_1	0.04	0.00	14.98	<2e-16 ***
Fixed Effects (Country Intercepts):				
Argentina	4.28	0.01	728.77	<2e-16 ***
Australia	4.30	0.01	728.42	<2e-16 ***
Austria	4.40	0.01	746.86	<2e-16 ***
Bangladesh	4.08	0.01	695.37	<2e-16 ***
Belarus	4.35	0.01	740.17	<2e-16 ***
Belgium	4.34	0.01	737.13	<2e-16 ***
Brazil	4.27	0.01	726.76	<2e-16 ***
Canada	4.33	0.01	727.51	<2e-16 ***
Chile	4.32	0.01	733.95	<2e-16 ***
China	4.17	0.01	682.31	<2e-16 ***
Colombia	4.22	0.01	717.82	<2e-16 ***
Costa Rica	4.26	0.01	725.62	<2e-16 ***
Cyprus	4.26	0.01	725.70	<2e-16 ***
Czechia	4.38	0.01	745.64	<2e-16 ***
Denmark	4.41	0.01	745.83	<2e-16 ***
Egypt, Arab Rep.	4.20	0.01	715.59	<2e-16 ***
Estonia	4.35	0.01	740.70	<2e-16 ***
Fiji	4.23	0.01	720.10	<2e-16 ***
Finland	4.44	0.01	752.79	<2e-16 ***
France	4.36	0.01	709.05	<2e-16 ***
Georgia	4.27	0.01	727.56	<2e-16 ***
Germany	4.37	0.01	717.65	<2e-16 ***
Greece	4.33	0.01	737.17	<2e-16 ***
Hungary	4.37	0.01	743.25	<2e-16 ***
Iceland	4.35	0.01	741.38	<2e-16 ***
India	4.05	0.01	688.28	<2e-16 ***
Indonesia	4.16	0.01	706.09	<2e-16 ***
Ireland	4.34	0.01	736.22	<2e-16 ***
Israel	4.27	0.01	727.09	<2e-16 ***
Italy	4.34	0.01	731.03	<2e-16 ***
Japan	4.35	0.01	731.37	<2e-16 ***
Korea, Rep.	4.31	0.01	726.97	<2e-16 ***
Lao PDR	4.07	0.01	693.82	<2e-16 ***
Latvia	4.36	0.01	743.02	<2e-16 ***
Lithuania	4.33	0.01	737.46	<2e-16 ***
Luxembourg	4.30	0.01	726.96	<2e-16 ***
Malaysia	4.19	0.01	712.95	<2e-16 ***
<hr/>				
Statistic	Value			
Residual standard error	0.82 on 1085 degrees of freedom			
Adjusted R^2	0.99			
F-statistic	1.299e+05 on 71			
p-value	< 2.2e-16			

indicates that the model explains nearly all the variability of the response data around its mean while R^2 is also 0.99, confirming the model's relevance even after

adjusting for the number of predictors. The F-statistic is 129900 with a p-value less than $2.2e-16$, indicating that the model is statistically significant overall beyond the included predictors.

The findings from the OLS regression model reveal substantial insights into the relationships between the investment in green bonds, GDP, and annual improvements in SDG scores. The significant negative coefficient for green bonds raises questions that warrant further investigation, potentially indicating that while green bond investments are intended to improve sustainable outcomes, their current impact may not align with expectations. Conversely, the positive association of both GDP with SDG scores highlights broader trends in economic development and temporal improvements in sustainability efforts.

The assertion that the "instrument strength supports the validity of the causal inference" indicates that the model confronted the central challenge of endogeneity. A simple correlation between green bond issuance and sustainability gains could be misleading, as it might be driven by an omitted factor like a pre-existing corporate ethos of environmental responsibility. A county deeply committed to sustainability is both more likely to issue a green bond and to implement other effective initiatives, making it difficult to isolate the bond's true effect. The instrumental variable method addresses this by introducing a quasi-experimental tool or an "instrument" that influences sustainable outcomes only through its impact on the decision to issue a green bond, thereby isolating an exogenous source of variation and allowing for a cleaner estimate of causation.

The finding of a "modest" yet "statistically robust" effect size is a classic and compelling outcome of a well-executed IV analysis. It suggests that while the average impact of a green bond might not be transformative, the identified relationship is not a statistical artifact but a genuine causal link. This robustness underscores the instrument's strength and validates the core thesis: green finance mechanisms are a viable policy tool

The empirical analysis employs an instrumental variable approach to address endogeneity concerns in estimating the relationship between green bond issuance and sustainable development performance. Market size serves as the instrument for green bond issuance, based on the theoretical justification that larger financial markets enhance the capacity for green debt issuance through deeper investor bases and more robust underwriting capabilities, while presumably affecting sustainable development outcomes only indirectly through this financing mechanism. The model specification includes country and year fixed effects to account for unobserved heterogeneity and common temporal shocks, with standard errors clustered at the country level to address residual correlation within countries over time. Results from the instrumental variable regression indicate a statistically

positive relationship between instrumented green bond issuance and SDG performance. A one percent increase in green bond issuance corresponds to approximately a 0.01 percent increase in SDG scores, with this effect statistically significant at the 5 percent level. The first-stage F-statistic of 13.48 exceeds the conventional threshold of 10, indicating that market size represents a sufficiently strong instrument for green bond issuance after controlling for country and year fixed effects. This suggests the instrument effectively captures exogenous variation in green bond markets, lending credibility to the causal interpretation of the estimated relationship.

5.4.1 Reverse Causality and IV Model

The findings provide evidence that green bond issuance contributes positively to sustainable development outcomes, with the instrument strength supporting the validity of the causal inference. The results suggest that expanding green finance mechanisms can play a meaningful role in advancing sustainability objectives, particularly through channeling capital toward environmentally beneficial projects. While the effect size appears modest, the statistical robustness of the relationship underscores the potential of sustainable debt instruments as policy tools for promoting sustainable development. Future research could build on these findings by examining potential heterogeneity in effects across different types of green projects or country income levels.

Market Size is often chosen as an instrumental variable for a country's decision (issuing a green bond) because it can arguably satisfy the two key conditions for a valid instrument: relevance and exclusion.

First, relevance requires that the instrument (Market Size) is strongly correlated with the endogenous variable (Green Bond Issuance). There is a clear logical and empirical case for this. Larger market size creates a bigger pool of potential investors, greater liquidity, and more sophisticated financial institutions. This makes it significantly easier, more attractive, and more feasible for government to issue a specialized debt instrument like a green bond. A developed economy is simply more likely to have the necessary infrastructure and investor demand to issue a green bond than a firm in emerging bond market.

Second, and more crucially, it is supposed that the instrument must satisfy the exclusion restriction. This means Market Size affects the sustainable development outcome only through its effect on the likelihood of issuing a green bond, not through any other direct or indirect channel. It is claimed that the sheer size of the overall bond market itself does not directly cause a specific county's environmental performance. The strength of the IV analysis rests on the plausibility of this exclusionary claim.

The first stage regresses the endogenous variable, $\log(GB)$, on the instru-

mental variable MS and all exogenous variables in the model. This stage isolates the exogenous variation in green bond issuance that is driven by market size.

$$\log(GB_{it}) = a_0 + a_1 \cdot MS_{it} + a_2 \cdot GDP_{it} + a_3 \cdot \text{Country}_i + a_4 \cdot \text{Year}_t + v_{it}. \quad (4)$$

MS_{it} is the Market Size instrument for country i and year t , v_{it} is the error term for the first-stage regression, a_1 is the key coefficient; its strength is tested by the first-stage F-statistic.

The second stage regresses the outcome variable, SDG , on the predicted values of $\log(GB_{it})$ from the first stage $\log(\hat{GB})_{it}$, along with the other exogenous variables. This stage estimates the causal effect of the exogenous portion of green bond issuance on SDG scores.

$$SDG_{it} = a + \beta_1 \cdot \log(\hat{GB})_{it} + \beta_2 \cdot GDP_{it} + \beta_3 \cdot \text{Country}_i + \beta_4 \cdot \text{year}_t + \varepsilon_{it}. \quad (5)$$

Subject to the instrument constraint: $\text{Cov}(MS_{it}, \varepsilon_{it}) = 0$. This compact form clarifies that the model is identified under the critical assumption that the instrument (MS) is uncorrelated with the error term in the main equation.

Table 10: Regression Results for GB (fit)

	Estimate	St Err.	t-value	p-value GB
(fit)	0.0101	0.0054	1.865	0.0665
Residual standard error: 0.0083 on 468 degrees of freedom				
Multiple R-squared (full model): 0.993				
F-statistic 3.48, p-value: 0.0665				
Significant at the 10% level ($p < 0.1$).				

5.4.2 Green Bonds and Effect on SDGs

Further exploration into the nature of the potentially complicated relationship between green bonds and SDG scores could provide additional clarity and inform policy recommendations. Additional analyses with which the research proceeds using robustness checks, interaction terms, and considering alternative specifications is also beneficial to validate and deepen these findings. It is outlined that the procedure for fitting linear regression models and calculating robust standard errors is applied. Robust standard errors are essential for valid inference when the assumption of homoskedasticity is violated. Standard errors derived from ordinary least squares (OLS) estimates can be biased in the presence of heteroskedasticity.

It is also important to check the influence of green bonds issuance on CO_2

emissions creating following OLS model (table 11). Model 6:

$$CO2_{it} = a + \beta_1 \cdot \log (GB)_{it} + \beta_2 \cdot \log (GDP)_{it} + \beta_3 \cdot Country_i + \beta_4 \cdot year_t + \beta_5 \cdot \log (FDI)_{it} + \varepsilon_{it} \quad (6)$$

Table 11: Model 6: OLS Model with CO₂ as Dependent Variable

Variable	Estimate	Std. Error	t-value	P-value
GB	-0.038	1.700e-02	2.512	0.012 *
GDP	0.08702	5.635e-02	13.579	<2e-16 ***

Statistic	Value
Residual standard error	0.1374 on 1085 degrees of freedom
Adjusted R²	0.99
F-statistic	8561 on 71
p-value	< 2.2e-16

Green bonds coefficient means that for each unit increase in GB, the CO₂ decreases by about 0.038 % indicating a negative relationship. The p-value (0.01) is less than 0.05, indicating that this coefficient is statistically significant. The residual standard error suggests that, on average, the predictions deviate from the actual values by about 0.13.

Multiple R² indicates that about 99.83% of the variance in the log of CO₂ can be explained by the model. This is very high and suggests a good fit. Adjusted R²: 0.998 adjusts for the number of predictors in the model, which is still very high, further confirming the model's fit. The F-statistic tests the null hypothesis that all the regression coefficients are equal to zero (meaning that the model has no explanatory power) shows 8904 with a very low p-value (< 2.2e-16). Overall, this model appears to have a very strong fit based on the R² values, and at least some of the predictors, particularly GDP, are statistically significant contributors to explaining the variation in CO₂ levels.

The final linear model from the provided ones, which explores the relationship between green bonds and Sustainable Development Goals, while controlling for various factors FDI, year and income level. GDP was excluded because of the insignificance of the coefficient in this model. Model 7:

$$SDG_{it} = a + \beta_1 \cdot \log (GB)_{it} + \beta_2 \cdot \text{income level}_i + \beta_3 \cdot year_t + \beta_4 \cdot \log (FDI)_{it} + \varepsilon_{it} \quad (7)$$

The analysis shows strong evidence that green bonds are positively associated with Sustainable Development Goals, indicating that promoting green finance can be

beneficial for sustainability targets. Yearly improvements in SDG scores highlights made over time, suggesting successful policy implementations or social changes play a crucial role in SDG outcomes, implying that efforts to improve sustainable development could be more effective when coupled with strategies to enhance economic prosperity. The unexpected relationship with FDI should be investigated further to explore potential underlying factors contributing to this negative effect (table 12).

Table 12: Model 7

Variable	Estimate	Std. Error	t-value	P-value
GB	0.002	1.700e-02	3.3	0.001203 **
FDI	-0.0003	2.293e-12	-3.9	<2e-16 ***
Income level	0.012	1.910e-01	40.5	0.000118 ***

Statistic	Value
Residual standard error	0.013 on 1070 degrees of freedom
Adjusted R²	0.99
F-statistic	1.487e+06 on 86
p-value	< 2.2e-16

Approaching model 8 where lag of one year in green bonds issue is included. Presenting model description and interpretation, it is demonstrated that the implication of analysis of fixed effects regression model that examines the determinants of Sustainable Development Goal (SDG) scores, with the following specification (model 8):

$$SDG_{it} = \beta_1 \cdot GB_{it} + \beta_2 \cdot GB_{it-1} + \beta_3 \cdot GDP_{it} + \alpha_i + \varepsilon_{it} \quad (8)$$

Where SDG_{it} represents the SDG score for country i in year t ; GB_{it} is the log of current amount of green bond issuance (standardized); GB_{it-1} is the log of one-period lagged green bond issuance; GDP_{it} is the log of GDP per capita; α_i represents country fixed effects; ε_{it} is the error term.

Green Bonds: Current green bond issuance shows a strong positive association with SDG scores ($\beta = 0.024$, $p < 0.001$), while lagged issuance has a smaller negative effect ($\beta = -0.005$, $p = 0.012$). GDP demonstrates the strongest positive relationship ($\beta = 0.148$, $p < 0.001$), suggesting wealthier countries tend to have higher SDG scores. The country fixed effects reveal substantial baseline differences in SDG performance, ranging from 2.23 (India) to 2.83 (Iceland). The regression explains virtually all variation in SDG scores ($R^2 = 0.999$), with a residual standard error of 0.02. The F-statistic (843,7) confirms the model's overall significance ($p < 2.2e-16$).

Table 13: Model 8 Estimation Results

	Estimation	Std. Error	p-value
GB	0.02	0.002	<0.001***
GB lag	-0.01	0.002	0.012*
GDP	0.15	0.007	<0.001***
Country Fixed Effects (Selected Examples):			
Argentina	2.55	0.083	<0.001***
Australia	2.51	0.086	<0.001***
Austria	2.68	0.083	<0.001***
:	:	:	.
Italy	2.52	0.087	<0.001***

*p < 0.05, **p < 0.01, ***p < 0.001

Note: p-values based on two-tailed tests

The findings suggest that while green bond markets show potential to contribute to sustainable development (as evidenced by the positive contemporaneous effect), the observed negative lagged effect requires further investigation to understand potential delayed adjustment mechanisms or crowding-out effects. Economic development emerges as the strongest driver of SDG achievement, highlighting the importance of maintaining economic growth alongside sustainability initiatives. Furthermore, the significant country fixed effects indicate that nation specific institutional, cultural, and geographical factors play a crucial role in determining SDG performance, suggesting that policy solutions should be tailored to local contexts rather than adopting a common approach to sustainable development.

Then, the work approaches model validation assessing the model's assumptions (linearity, homoscedasticity, normality of residuals) and evaluating multicollinearity to ensure robustness. A dataset is analyzed containing 1156 samples with 4 predictors (independent variables) using Model 5. The analysis employed a 10-fold cross-validation approach to assess the model's performance, and no preprocessing of the data was performed prior to fitting the model. Root mean squared error (RMSE) is a measure of the average magnitude of the errors in the predictions of the model. An RMSE of approximately 4.51 suggests that, on average, the model's predictions deviate from the actual values by about 4.51 units. Therefore, lower RMSE values are preferable, indicating better predictive performance. The R^2 value (the coefficient of determination) measures the proportion of the variance in the dependent variable that can be predicted from the independent variables. An R^2 value of approximately 0.63 indicates that about 63% of the variance in the dependent variable is explained by the model. This

suggests a moderate level of fit, meaning the model captures a substantial amount of the variability in the data, but there is still about 37% of the variance that is not explained by the predictors.

Mean absolute error (MAE) measures the average magnitude of the errors in a set of predictions, without considering their direction (whether they are over or under predictions). An MAE of approximately 3.48 implies that, on average, the model's predictions deviate from the actual values by about 3.48 units. Compared to RMSE and MAE, this suggests a generally acceptable level of predictive accuracy, but there is room for improvement. By using cross-validation (10-fold), it ensures that the model is robust and not overfitting to a particular subset of the data. In this case, the training data was divided into 10 groups, and the model's performance was evaluated by training on 9 folds and testing on the 1 remaining fold, repeating this process for all combinations. The summary of sample sizes indicates that in each fold, around 1040 to 1041 samples were used for training. Thus, the results of the linear regression analysis indicate that the model explains a moderate portion of the variance in the dependent variable, demonstrating reasonable predictive accuracy as evidenced by the RMSE and MAE metrics. While the model exhibits a satisfactory level of predictive capability, there are visible opportunities for enhancement. These may include feature engineering, the incorporation of interaction terms, or the exploration of alternative modeling techniques. Further examination of the residuals and an assessment of the underlying data assumptions will be critical in identifying avenues for improving model performance. Overall, while the current model serves as a solid foundation, there exists potential for refinement to achieve greater accuracy and explanatory power in future analyses.

To evaluate the potential multicollinearity among the predictor variables in the regression model, the variance inflation factor (VIF) was calculated. The VIF values provide an indication of how much the variance of the estimated regression coefficients increases due to multicollinearity among the predictors. The conventional threshold for VIF to indicate potential multicollinearity is a value greater than 10. In this analysis, the predictor "year" exhibits a GVIF of 18.7, which exceeds this threshold, suggesting that multicollinearity may be present among the dummy variables associated with the year. Additionally, the variable income level also shows a GVIF of 13.6, indicating a concerning level of multicollinearity. Conversely, the GVIF values for GB (1.9) and FDI (1.3) suggest that these predictors do not suffer from significant multicollinearity issues, as their values are well below the threshold. To assess the assumption of homoscedasticity, the studentized Breusch-Pagan test was conducted. The results of the test yielded a test statistic (BP) of 28.1 with 18 degrees of freedom, resulting in a p-value of 0.06128. These findings suggest that it is impossible to reject the null hypothesis of homoscedasticity at the commonly used significance level of 0.05.

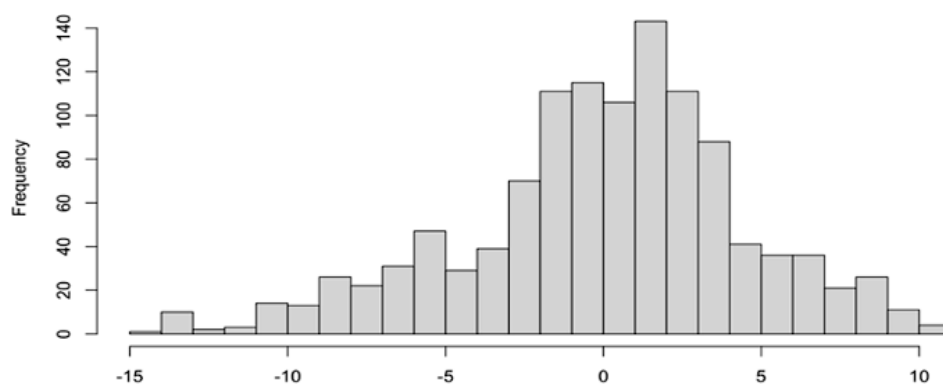


Figure 12: Histogram of residuals, model 8

To evaluate the assumption of normality of residuals in the regression model, a histogram was generated to visualize the distribution of the residuals. The histogram serves as a graphical representation that allows for the assessment of how closely the residuals follow a normal distribution, which is a fundamental assumption for valid inference in regression analysis. The histogram of the residuals displayed practically bell-shaped curve that is characteristic of a normal distribution. The frequency of residual values is concentrated around the mean (which is close to zero) and showed not ideal but symmetric tapering off towards both ends, aligning well the theoretical expectations of normality. Now, the focus is on the model, which deals with the problem of reverse causality (figure 12).

The empirical analysis demonstrates that green bonds (GB) have a statistically significant but modest negative impact on CO₂ emissions, with a 1% increase in GB issuance associated with a 0.04% reduction in emissions, while GDP remains a stronger driver of CO₂ levels. In terms of Sustainable Development Goals (SDGs), current GB issuance positively influences SDG scores ($\beta = 0.024$, p-value is less than 0.001), though a lagged negative effect ($\beta = -0.005$, $p = 0.012$) suggests potential short-term trade-offs, with income level playing a crucial role in SDG performance. Additionally, the study confirms the existence of a "greenium," where green bonds yield 0.078 percentage points less than conventional bonds (p-value is less than 0.001), reflecting investor preference for sustainable assets. Overall, the findings support the use of green finance as a policy tool for sustainability, while highlighting the need for tailored approaches considering economic and country-specific factors.

5.5 Limitations of the Research

The dataset, while comprehensive, may fail to fully capture the variability of green and conventional bonds across all markets. For instance, the analysis of municipal bonds is limited to data from Eikon Refinitiv LSEG, which may exclude smaller or less liquid markets. Besides, the data in greenium analysis covers a very

specific time frame, which may not account for long-term trends or structural changes in the green bond market and might miss the impact of recent regulatory changes or shifts in investor sentiment toward sustainability. What concerns model limitations, the presence of multicollinearity among independent variables could inflate the standard errors of the coefficients, damaging the reliability of the estimates. Even though diagnostic tests (Breusch-Pagan test, Q-Q plots) suggest that the assumptions of homoscedasticity and normality are approximately accepted, minor deviations could still affect the validity of the results. Moreover, the models may miss important variables that influence bond yields or Sustainable Development Goal (SDG) scores (dependent variables), such as macroeconomic conditions, political stability, or issuer-specific factors.

The greenium may vary across different markets due to regulatory frameworks, investor preferences, and market liquidity. The analysis does not fully account for these variations. As about causality and endogeneity, the positive relationship between green bonds and SDG scores may not necessarily imply causation. For example, countries with higher SDG scores may be more likely to issue green bonds, rather than green bonds driving SDG improvements. It brings limitations as well as unobserved factors, such as issuer reputation or market sentiment, could influence both green bond issuance and yields, leading to biased estimates. Another issue is that the analysis of greenium in municipal bonds may not generalize to other types of bonds, such as corporate or sovereign green bonds, which may have different pricing dynamics. The dataset is heavily weighted toward certain regions (Europe, North America), which may introduce bias in the implications to emerging markets or less-developed economies. The analysis does not fully explore the role of government incentives or regulatory frameworks in driving the greenium. For example, tax benefits or subsidies for green bonds could influence their pricing. What is more, the models do not account for behavioral factors, such as investor sentiment or ESG preferences, which could play a significant role in the pricing of green bonds.

There is a potential for reverse causality between green bond issuance and Sustainable Development Goals scores because it can be a case when a country with a high pre-existing commitment to the SDGs (a high SDG score) is more likely to create the policy environment and market demand for green financial instruments like green bonds. Strong environmental regulations, carbon pricing, and sustainability mandates drive the need for green financing. It might overestimate the true impact of green bonds by capturing the effect of the country's underlying, pre-existing sustainability commitment. To overcome this issue in the future research an IV method might be a solution. For instance, global green bond market size for each year can be an instrumental variable. The total global issuance of green bonds each year captures worldwide investor sentiment and liquidity, which influences a single country's ability to issue (relevance).

It's unlikely that global issuance directly affects one specific country's SDG score (exclusion). This method was applied to model 3 (see model 4-5).

The research provides valuable insights into the existence of a greenium and the relationship between green bonds and SDG scores, however, it is subject to several limitations. Addressing these limitations through expanded datasets, improved model specifications, and deeper exploration of causal mechanisms could enhance the robustness and generalizability of the findings. Future research should also consider the role of policy incentives and investor behavior in shaping the green bond market.

While this thesis presents robust evidence supporting its hypotheses, it is essential to recognize certain limitations. The econometric models may be subject to bias due to the use of the dependent variable, SDG scores, while controlling for the volume of green bonds issued by each country. Without careful consideration, these variables could exhibit causal relationships that affect the results. Further research could delve into the nuances of various municipal green bonds to provide a more comprehensive understanding. Additionally, the long-term effects of green bond financing on sustainability outcomes remain underexplored and warrant deeper investigation to establish their true impact. Future studies could broaden the scope by including a wider range of countries and examining the significance of diverse green bond projects in achieving sustainability objectives. The comparative analysis in this study, particularly the section on municipalities' role in green bond development, relies heavily on data from a limited number of regions. This may not fully capture the diverse contexts in which green bonds are issued. Subsequent research should prioritize refining impact measurement techniques, addressing market inefficiencies, enhancing transparency, and exploring the broader implications of green bonds in financing a sustainable global economy. This thesis aims to contribute to the growing body of knowledge on the tangible environmental impacts of green bonds.

5.6 Implications

The paper makes significant contributions to society by empirically validating the positive impact of green bonds on sustainable development and local governance. The study confirms that green bonds actively contribute to progress to-ward SDGs by financing environmentally beneficial projects. Countries with higher participation in green bond issuance show measurable improvements in sustainability outcomes. Policymakers and financial institutions can use these findings to justify increased green bond adoption, accelerating global sustainability efforts. The paper demonstrates that municipalities using green bonds can efficiently fund ecological and infrastructural developments, such as energy-efficient buildings, climate-resilient infrastructure, and sustainable transport systems.

Local authorities gain a viable financial tool to address climate change without straining budgets, making sustain-ability initiatives more feasible.

The study also confirms the existence of a "greenium" (yield discount on green bonds compared to conventional bonds), reducing borrowing costs for issuers. This makes green projects more financially attractive, incentivizing governments and corporations to pursue sustainable investments while offering investors diversified, eco-friendly portfolios. By demonstrating the real-world efficiency of green bonds (through case studies), the research encourages broader adoption across different regions and economic contexts, promoting inclusive and sustainable economic growth worldwide.

6 Conclusion

The analysis carried out in the current work provides important signs of evidence that do not allow the rejection of the hypotheses proposed regarding the role of green bonds in the promotion of sustainable development and regarding the beneficial opportunities for local authorities. According to hypothesis № 1, the issuance of green bonds has a real positive influence on the achievement of sustainable development goals, which means green bonds are leading to a higher level of progress in sustainability outcomes in different countries involved in responsible financing. The econometric models that are used in this study consistently demonstrate that the issuance of green bonds is associated with significant improvements in sustainability. The data empirically indicates that countries where the share of participation in green bond issuance agenda is higher experience progress towards SDGs. The positive correlation suggests that this type of debt instrument serve as an effective financial tool for funding environmentally beneficial projects, thereby facilitating the transition to more sustainable world. Consequently, hypothesis № 1 cannot be rejected.

In terms of hypothesis № 2, local authorities can use green bonds in a highly efficient way to manage local ecological or infrastructural development. This happens also due to the advantage of lower costs of green bonds. The comparative analysis conducted across different municipalities further supports the second hypothesis. The findings reveal that local authorities leveraging green bonds have successfully financed a range of projects aimed at improving environmental quality and developing sustainable urban infrastructure. The case studies illustrate how green bonds have enabled cities to invest in innovations, climate change fighting solutions, such as projects dedicated to constructing resource-efficient buildings and transportation systems, climate resilience initiatives. This evidence underscores the impact of green bonds as a strategic financial source for local governments aspiring to elevate their environmental efforts. Furthermore,

the study investigates the existence of a specific yield discount or greenium as a potential benefit associated with the nature of green bonds compared to the yields of identical conventional bonds, providing insights into the financial viability of green investments, especially when in today's context, municipalities are often obliged to address climate change issues and promote sustainable practices. Hopefully, green bonds offer a promising avenue for financing initiatives that align with environmental goals. The data observed in the research confirm the existence of a greenium.

Thus, it is suggested that local authorities may benefit from lower borrowing costs when issuing this kind of securities. The significant implications for local governments arise as not only their financial capacity to invest in sustainable projects is enhanced but also portfolio diversification for investors is encouraged leading to further adoption of green financing strategies. As mentioned before case studies of municipal green bonds illustrate real-world applications and the importance of local authorities in leveraging these financial instruments to foster sustainable urban infrastructure. Thus, the findings confirm the second hypothesis: that local authorities can effectively utilize green bonds as a financial tool to enhance advancement of projects in municipalities. Therefore, hypothesis №2 is accepted.

In summary, the results of this thesis highlight the significant potential of green bonds as a mechanism for driving sustainable development and enhancing local environmental initiatives. The positive outcomes associated with their issuance and utilization underscore the importance of continued investment in green financing solutions to achieve long-term sustainability goals. Turning to implications for sustainable development and insights for policymakers, investors, and stakeholders and the insights derived from this research offer essential direction for decision-makers, investors, and stakeholders, policymakers are encouraged to create supportive regulatory frameworks that facilitate the issuance of green bonds, while investors are urged to recognize the potential of these financial instruments in contributing to sustainable development. Stakeholders, including local authorities and public organizations, should collaborate to identify and implement projects that can be financed through green bonds, ensuring that the benefits of such initiatives are maximized for local communities. More cities, countries, and investors to participate in responsible financing. Increased adoption can lead to systemic shifts in capital allocation toward sustainability, fostering long-term environmental and economic resilience. The findings highlight green bonds as a strategic instrument for funding climate adaptation and mitigation projects, such as renewable energy, carbon reduction, and resilient urban planning. This directly supports global efforts to combat climate change by directing capital toward mindful solutions. The paper provides robust empirical evidence that green bonds are not just a financial instrument but a catalyst for sustainable development. By validating their economic

and environmental benefits, the study encourages broader adoption among governments, investors, and corporations, ultimately contributing to a more sustainable and climate-resilient future.

This research provides valuable insights into the dynamics of green bonds, their role in advancing Sustainable Development Goals, and the existence of a greenium, a premium associated with green bonds compared to traditional ones. The analysis confirms that green bonds tend to have lower yields than conventional bonds, indicating that investors are willing to accept lower returns for environmentally beneficial investments. This reflects the increasing demand for sustainable financial instruments. Moreover, green bonds exhibit a positive correlation with improvements in SDG scores, underscoring their potential as a tool for promoting environmental and social progress. Higher-income nations demonstrate more significant strides toward sustainability. Thus, the analysis reveals a significant positive relationship between the issuance of green bonds and the advancement of sustainability outcomes, supporting the first hypothesis: the issuance of green bonds positively influences the achievement of SDGs while negatively impacts CO₂ emissions, leading to enhanced sustainability progress.

This study provides robust empirical evidence that is consistent with previous studies where investor's preferences for sustainable financial products are statistically significant, as demonstrated through advanced econometric modeling in different academic works and where stock prices increase responding to green bond issuance (Larcker and Watts, 2020; Tang and Zhang, 2020; Zerbib, 2019). The work is also coherent with research that establishes the role of the green factor in the induction of fundamental restriction in fixed income markets, with green bonds exhibiting distinct resilience compared to their brown counterparts, which makes evidential the fact that shareholders are already seeking reimbursement for their financial vulnerability to carbon emission liabilities and that shows premium for green bonds (Baker et al., 2018; Bolton and Kacperczyk, 2021). These results empirically validate the theoretical proposition that environmental externalities play extremely important role in financial asset pricing, particularly through yield channels. The thesis indirectly tries to make theoretical contributions by bridging the gap between neoclassical finance and behavioral economics through its dual examination of revealed and stated preferences. This integrated approach provides new insights into how non-financial motivations interact with traditional return maximization objectives in investment decision making. The ideas can be found in academic literature (Riedle and Smeets, 2017; Flammer, 2020). The study also supports the view that green bond issuance serves as a credible signal of institutional commitment to climate transition, generating both reputational benefits and positive social externalities (Flammer, 2020).

The findings have particular significance for public sector finance, demon-

strating how local governments can utilize sustainable debt instruments to demonstrate leadership in climate finance while potentially benefiting from reduced borrowing costs due to strong investor demand for climate-aligned assets. The research further reinforces studies identifying strong correlations between sustainable financial mechanisms. This work engages with the broader literature on socially responsible investing (SRI) which seeks to balance financial returns with social objectives acknowledging its global growth driven by increasing investor awareness of ESG factors. It also recognizes the persistent research gaps identified in comprehensive literature reviews, particularly regarding corporate social responsibility's impact on shareholder value, the performance of SRI funds, patterns in investor behavior, and the implications for corporate finance and asset pricing. As noted in previous scholarship, evidence remains inconclusive regarding investors' willingness to sacrifice financial returns for ethical objectives (Renneboog et al., 2008).

The findings highlight the importance of green bonds for policymakers, investors, and issuers. Governments can leverage these instruments to finance sustainable projects, while investors can align their portfolios with environmental, social, and governance principles. Municipalities can benefit from the reduced borrowing costs associated with green bonds. Although the models exhibit strong explanatory power, as indicated by high R-squared values and reasonable predictive accuracy, there is potential for further refinement. Future research should address limitations such as data constraints and potential endogeneity by expanding datasets, improving model specifications, and incorporating additional variables like regulatory frameworks and investor behavior. By fostering transparency, enhancing market infrastructure, and encouraging broader participation, green bonds can play a critical role in facilitating the transition to a sustainable, low-carbon economy.

Bibliography

- Auh, J., Choi, J., Deryugina, T., & Park, T. (2022). *Natural Disasters and Municipal Bonds*. (Working Paper No w30280)
- Baker, M., Bergstresser, D., Serafeim, G., & Wurgler, J. (2018). *Financing The Response to Climate Change: The Pricing and Ownership Of U.S Green Bonds*. (Working Paper w25194)
- Baldi, F., & Pandimiglio, A. (2022). The Role of ESG Scoring and Greenwashing Risk in Explaining the Yields of Green Bonds: A Conceptual Framework and an Econometric Analysis. *Global Finance Journal*, 52, 100711. Doi: 10.1016/j.gfj.2022.100711
- Bolton, P., & Kacperczyk, M. (2021). Do Investors Care about Carbon Risk? *Journal Of Financial Economics*, 142(2), 517–549. Doi: 10.1016/J.Jfineco.2021.05.008
- Caramichael, J., & Rapp, A. C. (2024). The Green Corporate Bond Issuance Premium. *Journal Of Banking & Finance*, 162, 107126. Doi: 10.1016/j.jbankfin.2024.107126
- Chang, K., Luo, D., Xing, K., & Mi, B. (2025). The Effectiveness of The Green Bond Instrument on Stimulating Firms' Green Innovation Performance: A Comparative Study Based on Chinese Market. *Pacific-Basin Finance Journal*, 91, 102706. doi: 10.1016/j.pacfin.2025.102706
- Chang, L., Taghizadeh-Hesary, F., Chen, H., & Mohsin, M. (2022). Do Green Bonds Have Environmental Benefits? *Energy Economics*, 115, 106356. Doi: 10.1016/J.Eneco.2022.106356
- City Of Toronto. (2023). *Toronto Issues Sixth Green Bond to Advance Climate Action*. Retrieved From <https://www.toronto.ca/city-government/data-research-maps/research-reports/climate-action/green-bonds/>
- Cousins, J., & Hill, D. (2021). Green Infrastructure, Stormwater, And the Financialization of Municipal Environmental Governance. *Journal Of Environmental Policy & Planning*, 23(5), 581–598. doi: 10.1080/1523908X.2021.1893164
- Dam, L., & Scholtens, B. (2015). Toward A Theory of Responsible Investing: On the Economic Foundations of Corporate Social Responsibility. *Resource And Energy Economics*, 41, 103–121. Doi: 10.1016/J.Reseneeco.2015.04.008
- Del Giudice, A., Rigamonti, S., & Signori, A. (2025). Climate Change Risk and Green Bond Pricing. *Journal Of Empirical Finance*, 82, 101616. Doi: 10.1016/j.jempfin.2025.101616
- Ehlers, T., & Packer, F. (2017, September). *Green Bond Finance and Certification*. BIS Quarterly Review, 89–104.
- El Bannan, M., & Löffler, G. (2024). How Effectively Do Green Bonds Help the Environment? *Journal Of Banking & Finance*, 158, 107051. Doi:10.1016/j.jbankfin.2023.107051

- El Ghouli, S., Guedhami, O., Kwok, C. C. Y., & Mishra, D. R. (2011). Does Corporate Social Responsibility Affect the Cost Of Capital? *Journal of Banking & Finance*, 35(9), 2388–2406. doi: 10.1016/j.jbankfin.2011.02.007
- Euronext. (2025). *Bond instruments*. Retrieved from https://live.euronext.com/en/search_instruments/bond?type=Bond&restMic=&idRest=all (Retrieved February 18, 2025)
- European Commission. (2024). *The European Green Deal*. Retrieved from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
- Feldhütter, P., Halskov, K., & Krebbers, A. (2024). Pricing of sustainability-linked bonds. *Journal of Financial Economics*, 162, 103944. doi: 10.1016/j.jfineco.2024.103944
- Flammer, C. (2020). Green bonds: Effectiveness and implications for public policy. *Environmental and Energy Policy and the Economy*, 1(1), 95–128. doi: 10.1086/710309
- Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, 142(2), 499–516. doi: 10.1016/j.jfineco.2021.01.010
- Goldsmith-Pinkham, P., Gustafson, M. T., Lewis, R. C., & Schwert, M. (2023). Sea-level rise exposure and municipal bond yields. *The Review of Financial Studies*, 36(11), 4588–4635. doi: 10.1093/rfs/hhad044
- Gutsche, G., & Ziegler, A. (2019). Which private investors are willing to pay for sustainable investments? Empirical evidence from stated choice experiments. *Journal of Banking & Finance*, 102, 193–214. doi: 10.1016/j.jbankfin.2019.03.007
- Hachenberg, B., & Schiereck, D. (2018). Are green bonds priced differently from conventional bonds? *Journal of Asset Management*, 19(6), 371–383. doi: 10.1057/s41260-018-0088-5
- Henke, H. (2016). The effect of social screening on bond mutual fund performance. *Journal of Banking & Finance*, 67, 69–84. doi: 10.1016/j.jbankfin.2016.01.010
- Hu, X., Zhu, B., Lin, R., Li, X., Zeng, L., & Zhou, S. (2024). How does greenness translate into greenium? Evidence from China's green bonds. *Energy Economics*, 133, 107511. doi: 10.1016/j.eneco.2024.107511
- Huang, X., Tang, C., Liu, Y., & Ge, P. (2025). Greening or greenwashing? corporate green bonds and stock pricing efficiency in China. *Sustainability Accounting, Management and Policy Journal*, 16(3), 874–913. doi: 10.1108/SAMPJ-05-2024-0287
- International Capital Market Association. (2024). *Sustainable bonds database*. Retrieved from <https://www.icmagroup.org/sustainable-finance/sustainable>

- Larcker, D., & Watts, E. (2020). Where's the greenium? *Journal of Accounting and Economics*, 69(2–3), 101312. doi: 10.1016/j.jacceco.2020.101312
- Lau, C., Padhan, H., Das, A. K., Tiwari, A. K., Gozgor, G., & Jain, P. (2025). The role of green bonds on industrial sustainability for achieving carbon neutrality: Evidence from the artificial neural network method. *Research in International Business and Finance*, 73, 102659. doi: 10.1016/j.ribaf.2024.102659
- Lee, C. C., Wang, F., & Chang, Y. F. (2023). Towards net-zero emissions: Can green bond policy promote green innovation and green space? *Energy Economics*, 121, 106675. doi: 10.1016/j.eneco.2023.106675
- Ma, C., Schoutens, W., Beirlant, J., De Spiegeleer, J., Höcht, S., & Van Kleeck, R. (2020). Are green bonds different from ordinary bonds? A statistical and quantitative point of view (Tech. Rep. No. 394). *National Bank of Belgium*.
- Nykvist, B., & Maltais, A. (2022). Too risky—the role of finance as a driver of sustainability transitions. *Environmental Innovation and Societal Transitions*, 42, 219–231. doi: 10.1016/j.eist.2022.01.001
- Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, 135(2), 468–482. doi: 10.1016/j.jfineco.2019.06.006
- Park, S. K. (2018). Investors as regulators: Green bonds and the governance challenges of the sustainable finance revolution. *Stanford Journal of International Law*, 54(1), 1–48.
- Partridge, C. (2019). *Green municipal bonds and the financing of green infrastructure in the United States* (doctoral dissertation). University College London.
- Partridge, C., & Medda, F. (2020). The evolution of pricing performance of green municipal bonds. *Journal of Sustainable Finance & Investment*, 10(1), 44–64. doi: 10.1080/20430795.2019.1661187
- Pástor, Ľ., Stambaugh, R. F., & Taylor, L. A. (2022). Dissecting green returns *Journal of Financial Economics*, 146(2), 403–424. doi: 10.1016/j.jfineco.2022.07.
- Polbennikov, S., Desclée, A., Dynkin, L., & Maitra, A. (2016). ESG ratings and performance of corporate bonds. *The Journal of Fixed Income*, 26(1), 21–41. doi: 10.3905/jfi.2016.26.1.021
- Pyka, M. (2023). The EU green bond standard: A plausible response to the deficiencies of the EU green bond market? *European Business Organization Law Review*, 24(4), 623–643. doi: 10.1007/s40804-023-00282-6
- Renneboog, L., Horst, J., & Zhang, C. (2008). Socially responsible investments: Institutional aspects, performance, and investor behavior. *Journal of Banking & Finance*, 32(9), 1723–1742. doi: 10.1016/j.jbankfin.2007.12.039

- Rizwan, A., & Fatima, Y. M. (2024). Green bonds as a bridge to the UN sustainable development goals on environment: A climate change empirical investigation. *International Journal of Finance & Economics*, 29(2), 2428–2451. doi: 10.1002/ijfe.2765
- Schoenmaker, D., & Schramade, W. (2018). Principles of sustainable finance. *Oxford University Press*.
- Schultz, P. (2022). The market for new issues of municipal bonds: The roles of transparency and limited access to retail investors. *Journal of Financial Economics*, 106(3), 492–512. doi: 10.1016/j.jfineco.2012.07.004
- Schwab, K. (2021). *Stakeholder capitalism: A global economy that works for progress, people and planet*. John Wiley & Sons.
- Shishlov, I., Morel, R., & Cochran, I. (2016). *Beyond transparency: Unlocking the full potential of green bonds* (Tech. Rep.). Institute for Climate Economics.
- S&P Global. (2025). *U.S. municipal bond indices*. Retrieved from <https://www.spglobal.com/spdji/en/index-family/fixed-income/us-municipal/#indices> (Retrieved February 25, 2025)
- Stelmakh, S., & Sergeeva, A. (2023). The global green bond market and its development prospects. *World Economy and World Finance*, 2(4), 25–30.
- Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds? *Journal of Corporate Finance*, 61, 101427. doi: 10.1016/j.jcorpfin.2019.101427
- The World Bank. (2022). *Sovereign green, social and sustainability bonds: Unlocking the potential for emerging markets and developing economies* (Tech. Rep.). Retrieved from <https://thedocs.worldbank.org/en/doc/4de3839b85c57eb958dd207fad132f8e-0340012022/original/WB-GSS-Bonds-Survey-Report.pdf>
- Tran, N., & Uzmanoglu, C. (2022). Covid-19, lockdowns, and the municipal bond market. *Journal of Banking & Finance*, 143, 106590. doi: 10.1016/j.jbankfin.2022.106590
- Vymyatnina, Y. V., & Chernykh, A. A. (2024). Green bonds in the russian market: Assessing environmental influence on returns. *Russian Journal of Economics*, 10(3), 211–228. doi: 10.32609/j.ruje.10.101234
- World Economic Forum. (2023). *What are municipal green bonds and how are global cities using them to finance green projects?* Retrieved from <https://www.weforum.org/stories/2023/11/heres-how-3-cities-are-using-municipal-green-bonds-to-finance-climate-infrastructure/> (Retrieved November 20, 2024)
- Zamani, M. A. H., & Dessì, S. (2017). *Local governments' approach towards green bond: An opportunity for Italian municipalities to finance green projects in the public real estate sector* (master's thesis). Politecnico di Milano.
- Zerbib, O. D. (2019). The effect of pro-environmental preferences on bond prices: Evidence from green bonds. *Journal of Banking & Finance*, 98, 39–60. doi:10.1016/j.jbankfin.2018.10.012