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Credit Risk Analysis of Green Bonds and Comparison with Conventional Bonds

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Master in
Financial Mathematics

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"Life isn't about how to survive the storm, it is about how to dance in the rain" - *Taylor Swift*

Acknowledgment

This marks a bittersweet moment, the end of my master's degree, and the completion of my academic journey. However, I am happy with the way it all unfolds.

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I dedicate this dissertation to each of you.

Resumo

As obrigações verdes são instrumentos financeiros destinados a angariar capital para projetos ambientalmente sustentáveis. Ao contrário das obrigações convencionais, os recursos das *green bonds* devem ser exclusivamente alocados a iniciativas verdes. À medida que o mercado de obrigações verdes cresce rapidamente, perduram debates sobre o seu desempenho financeiro e credibilidade, especialmente no que se refere ao risco de crédito.

O objetivo desta dissertação é analisar se a emissão de obrigações verdes afeta o risco de crédito de uma empresa. Para tal, foram comparados 94 títulos verdes com 94 títulos convencionais, com características semelhantes, emitidos pelas mesmas empresas. O conjunto de dados, recolhido em junho de 2025, inclui emissões entre 2016 e 2025 com maturidades até 2054. Foi analisado através de um modelo de regressão múltipla cuja variável dependente foi a classificação de crédito (*rating*), tendo-se utilizado seis variáveis independentes das quais quatro *dummy*.

Os resultados não evidenciam qualquer influência estatisticamente significativa da etiqueta verde sobre o *rating*, sugerindo que a emissão de uma obrigação verde não afeta o risco de crédito da empresa.

No entanto, o *rating* foi significativamente influenciado pelas variáveis económicas e estruturais usuais tais como cupão, preço de emissão, setor de atividade, *callable* e país emissor. Estes resultados corroboram a literatura existente, ainda limitada mas crescente, sobre finanças verdes, delineando que as empresas podem recorrer a financiamentos sustentáveis sem consequências adversas inesperadas no *rating*, reforçando ao mesmo tempo a importância de fatores financeiros convencionais no risco de crédito.

Palavras-Chave: Obrigações Verdes, Classificação de Crédito, Regressão Múltipla, Finanças Verdes, Risco de Crédito

Classificação JEL: G24; Q50

Abstract

Green bonds are a financial instrument intended to raise capital towards environmentally sustainable projects. Unlike conventional bonds, green bond proceeds must be exclusively allocated to green initiatives. As the green bond market grows rapidly, debates continue over financial performance and credibility, particularly in relation to credit risk.

The aim of this thesis is to analyse whether the green label affects a company's credit risk. To address this question, 94 green bonds were matched with 94 conventional bonds issued by the same companies with similar characteristics. The dataset, collected in June 2025, included bonds issued between 2016 and 2025 with maturities as late as 2054, and a multivariate regression model was used. The dependent variable was the bond rating, while there were ten independent variables, four of which were dummy. The results show no statistical evidence that the green label has an influence on credit ratings, suggesting that issuing a green bond does not affect a company's credit risk.

Instead, bond ratings were significantly influenced by traditional financial and structural variables, such as coupon, issue price, certain sectors, callable and certain countries of issuance. These findings add to the limited but growing literature on green finance, indicating that firms can pursue sustainable financing without unexpected adverse rating outcomes, while defending the importance of conventional financial conduct in credit risk analysis.

Keywords: Green Bonds, Credit Rating, Multivariate Regression, Green Finance, Credit Risk

JEL Classification Codes: G24; Q50

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Acronyms

ABS: Asset-Backed Securities 11

CBI: Climate Bonds Initiative 8
CBS: Climate Bonds Standard 8
COP21: 21st Conference of the Parties to the UNFCCC 12
CSRC: China Securities Regulatory Commission 9

EIB: European Investment Bank 10
EL: Expected Loss 14
ESG: Environmental, Social and Governance 8
ESMA: European Securities and Market Authority 9
EU: European Union 8
EU GBS: EU Green Bonds Standard 8, 9

G20: 1
GBP: Green Bond Principles 5–10, 21
GHG: Greenhouse Gas 12
GSS+: Green, Social, Sustainability and other Labeled Bonds 11

ICMA: International Capital Market Association 6, 7, 10, 11
IFC: International Finance Corporation 10

LGD: Loss Given Default 14

MDG: Millennium Development Goals 11

NDRC: National Development and Reform Commission 9

PBoC: People's Bank of China 9
PD: Probability of Default 14

SDG: Sustainable Development Goals 11, 12
SRI: Socially Responsible Investors 5
SSR: Regression of square 16
SST: Total Sum of Squares 16

TEG: Technical Expert Group 8, 9

USD: United States of America Dollar 10, 11

CHAPTER 1

Introduction

We are currently living in a global environmental emergency crisis where more frequent and intense extreme weather events occur, such as, rising temperatures, melting ice sheets and the rising of the sea level. The consequences of this are not only environmental, but also economic and social, threatening human health, sustainable development and global stability. This is a serious matter and requires immediate and rapid action.

In recent years, attention has been drawn towards the role of finance in addressing climate change. Achieving a low-carbon and climate-resilient future requires investment in renewable energies, sustainable structures and adaptation measures. Governments cannot bear the financial burden alone and need the help of markets and private investors. The Paris Agreement in 2015 and the 2030 Agenda for Sustainable Development, also in 2015, reflect the growing attention of the financial system towards financing climate mitigation, where capital is allocated towards sustainable projects and away from fossil fuel and carbon-intensive projects. In 2006, Sir Nicholas Stern released the Stern Review on the Economics of Climate [**46**], which is known as the first major attempt to address climate change through an economic lens. Stern assesses a variety of evidence on the impacts of climate change and its economic costs and the urge for action to be taken sooner rather than later, given that the cost for not acting would outweigh the cost of early intervention. This report laid a foundation for today's discussions on climate change, highlighting the need to integrate environmental concerns into economic and financial decision-making.

Within this context, green finance has emerged as a key mechanism to allocate resources for sustainable development, incorporating financial products and services that promote environmental objectives, from bank lending to sustainable investment funds. There is no universally accepted definition of green finance. The Green Finance Study Group G20 describes it as funding investments that promote environmental benefits in the context of sustainable development (G20 2016) [**19**]. Its importance lies in its benefits. Some of them are the promotion of smart cities (He et al. 2020)[**22**], the inclusive economic growth (Wang and Wang 2020)[**52**], the ability to reduce funding for fossil fuel activities and relocating that capital towards green finance projects (McDonnell, 2024)[**32**], to reduce the level of carbon emissions in the short and long term (Li et al. 2021)[**29**], to reduce fossil fuel rents in the long and short term (Zhang and Xi, 2024) [**55**], among others. The green finance market contains a variety of financial instruments and activities to support and raise funds for environmentally beneficial projects. Some of them are green bonds, green bond grant scheme (Chang et al., 2019)[**6**], green loans and green funds (Mahmood et al. 2024) [**30**], green equity and green derivatives (Gilchritst et al. 2021) [**20**].

With the emerging topic of developing a green economic system that supports the reduction of carbon emissions, green bonds have become a prominent focus as a financing instrument. They are defined as bonds whose proceeds are allocated towards environmentally beneficial projects.

A bond is a financial instrument that represents a debt obligation between the borrower (issuer) and the lender (investor or bondholder). They are issued when entities such as corporations, governments, or supranational organisations need to raise capital by borrowing funds from investors. In return, the lender commits to making regular interest payments, based on either a fixed or variable interest rate known as coupon payments, at a predetermined rate during their lifetime. At the end of the bond's term, the issuer pays back the face value to the investor. Details regarding coupon payments and repayment are agreed when issuing the bond and remain unchanged during their lifetime. Some bonds do not have coupon payments, which are the zero-coupon bonds. Bonds are beneficial to both issuers and investors due to the fact that the issuer receives the purchase payment and the proceeds of the bond, which can finance operations or investments. The investor receives a stable return and can diversify its portfolio.

Green bonds follow the same financial structure as conventional bonds but differ in terms of the use of proceeds. In these cases, the proceeds must be allocated towards projects that generate environmental benefits, such as renewable energies, clean transport or sustainable waste management, while non-green bonds do not have this requirement. Green bonds are the bridge between capital markets and climate action.

This thesis will focus on the comparison of the credit risk of green and non-green bonds. This risk comes from the possibility that the issuer may not meet its debt obligation. The aim of this study is to find if the credit risk of a bond is equally affected whether it is green or non green by comparing the credit risk of a green bond with the credit risk of a conventional bond from the same issuer. Additionally, we intend to contribute to the already existing and still limited literature on green matter, especially on the credit risk of green bonds. To do so, we matched 94 green bonds with 94 conventional bonds issued by the same companies that possess similar characteristics. This data was collected using a Bloomberg terminal where, given a selected green bond, a conventional bond with similar maturity, coupon type and day count convention was matched. Our results suggest that there is no relation between the green factor and the rating of the company, i.e., based on our sample, the rating of the green bonds does not appear much different from the rating of the conventional bonds.

By comparing this study with the previous Green Bond literature, we differentiate ourselves from others through our matching method and the use of a multivariate model. Cheng et al. (2023) [**7**] uses a Kealhofer, McQuown and Vasicek (KMV) model to measure the default risk and identify the credit risk, and concludes that this model is a good predictor for corporate credit risk and enterprises issue green bonds with a lower credit risk. On the other hand, Ballester (2024) [**4**] investigates the impact of announcing the issuing of a green bond on a company's credit risk measured through CDS spreads and

finds that this advertising may generate an overall negative impact on the issuer's credit risk. However, companies with activities in the environmental sector that are the most exposed to environmental risks have a positive and significant reduction in credit risk.

The remaining sections of this thesis are organised as follows. Chapter 2 details the context of green bonds, in particular the types of green bonds, market evolution, regulation and credit risk in green bonds. Chapter 3 comprises the Methodology, describing the method used and the regression models applied to compare the credit risk of a green bond with the credit risk of a conventional bond issued by the same company. Chapter 4 details the data collected from Bloomberg and the main descriptive statistics. Chapter 5 sets out the results obtained and their significance. Finally, the conclusions are detailed in Chapter 6 summarising our entire study and providing some recommendations for further research.

For the rest of this thesis, the terms conventional bonds and non-green bonds will be used interchangeably as they both mean the same.

For consistency, tables mentioned in this dissertation starting with a letter and then a number refer to the corresponding tables located in the appendices.

CHAPTER 2

Literature Review

2.1. Green Bonds

Green Bonds are commonly known to be a fixed income security with the purpose of raising capital for environmentally friendly projects. There is no universally accepted definition on what a green bond is, however, various industries and international organisations have proposed different definitions. The Green Bond Principles (GBP) published by the International Capital Market Association (ICMA, 2025) [**26**] define a green bond as "any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects and which are aligned with the four core components of the GBP". Green bonds are attractive to a wide range of institutional and socially responsible investors (SRIs) who seek to strengthen their portfolio with eco-friendly, fixed-income securities. Furthermore, in markets where access to capital is limited, green bonds can provide an alternative source of financing, complementing the limited municipal budget for very expensive infrastructure projects (Tolliver et al., 2020) [**49**]. Importantly, green bonds support the transition to a more sustainable economy. Although they include climate finance, their scope is wider, extending to a range of "other environmental objectives" such as pollution control, water sanitation, or biodiversity protection. According to the Natural Resources Defense Council (2016) [**36**] green bonds and green banks have the potential to help close clean energy financing gaps. Green banks offer several advantages, including more favourable financing conditions for clean energy projects, the ability to combine smaller initiatives into commercially attractive scales, the creation of innovative financial instruments, and the expansion of sustainable capital markets. Although green bonds are primarily useful for providing long-term, affordable funding to refinance projects once they are operational after construction, they can also be used to strengthen a green bank's financial foundation, giving it more funds to lend or invest in clean energy and sustainability projects and to build a portfolio of environmentally friendly assets targeted at institutional investors.

Before detailing the various types of green bonds, it is important to mention that green bonds and conventional bonds have the same issuers; the only difference is that considering the same issuer, the proceeds from the issuance of a green bond are earmarked for environmentally friendly projects (S.Hyun et al., 2019) [**24**]. That being said, bonds are issued by corporations, municipalities, government entities and supranational institutions (Flammer, 2020) [**18**]. Currently, there are four different types of green bonds: conventional bonds invested in green projects, green bonds secured by revenue generated from green projects, bonds that are limited to financing specific environmental projects, and bonds that are backed (securitised) by a pool of green assets (ICMA, 2025) [**26**].

Table 2.1 shows the different types of green bonds and the respective description according to ICMA(2025) [**26**].

TABLE 2.1. Types of Green Bonds. Source: ICMA,2025

Types of Green Bonds	**Description**
Green Use of Proceeds Bond	An unsecured debt obligations with full recourse-to-the-issuer only and aligned with the GBP
Green Revenue Bonds	A non-recourse-to-the-issuer debt obligation aligned with the GBP in which the credit exposure in the bond is to the pledged cash flows of the revenue streams, fees, taxes, etc., and whose use of proceeds go to related or unrelated Green Projects(s)
Green Project Bond	A project bond for a single or multiple Green Project(s) for which the investor has direct exposure to the risk of the project(s) with or without potential recourse to the issuer, and that is aligned with the GBP
Secured Green Bond	A secured bond where the net proceeds will be exclusively applied to finance or refinance either: i. The Green Project(s) securing the specific bond only (a "Secured Green Collateral Bond"); or ii. The Green Project(s) of the issuer, originator, or sponsor, where such Green Projects may or may not be securing the specific bond in whole or in part (a "Secured Green Standard Bond"). A Secured Green Standard Bond may be a specific class or tranche of a larger transaction.

2.2. Regulation

In sustainable finance, regulation refers to the framework, standards, or guidelines that define how green bonds are issued, managed, and reported. These frameworks aim to ensure that capital raised through green bonds is genuinely used for environmentally beneficial projects. In doing so, the risk of greenwashing is reduced and transparency is improved for the investors.

This regulatory step in issuing a bond occurs after an issuer identifies a green project that requires funding and before the bond is issued. Before the bond is made available to the public, the framework is typically verified by an independent third party. The verifier evaluates the bond issuance against the specific framework chosen by the issuer, whether this is ICMA's GBP, or the EU Green Bond Standard, or another recognised standard.

There is no single universally adopted regulation for green bonds. Instead, the variety of overlapping and sometimes complementary frameworks shape the global green bond market. In the following sections, key regulatory approaches will be presented.

Considering that some of the data in this paper involves Chinese bonds, China's regulatory framework is briefly examined.

2.2.1. Green Bond Principles

The Green Bond Principles (GBP) were introduced in 2014 by the International Capital Market Association (ICMA), a global trade association that focuses on promoting the development of international capital and securities markets. GBP have played a fundamental role in the green bond market by establishing voluntary guidelines that emphasise transparency, disclosure, and promote integrity in the development of the green bond market (ICMA,2014)[**25**].

ICMA (2014)[**25**] describes:

> "The Green Bond Principles (GBP) are voluntary process guidelines that recommend transparency and disclosure; and promote integrity in the development of the Green Bond (GB) market by clarifying the issuance process. The transparency and disclosure recommended by the Principles are also intended to provide the informational basis for the market to increase capital allocation to environmentally beneficial purposes without any single authority or gate keeper. The GBP are intended for broad use by the market. They provide definitions of the recognized types of GBs. They give issuers guidance on the key components involved in launching a credible GB, and specifically with respect to use of proceeds; process for project evaluation and selection; management of proceeds; and reporting. They also include information on the availability and type of third party assurance to evaluate the environmental impact of their related green investments and projects."

The GBP are structured around four main components: use of proceeds; process for project evaluation and selection; management of proceeds and reporting.

The use of proceeds specifies the eligible green project categories, such as renewable energy; energy efficient (including efficient buildings); pollution prevention and control; environmentally sustainable management of living natural resources and land use; terrestrial and aquatic biodiversity; clean transportation; sustainable water and wastewater management; climate change adaptation; circular economy adapted products; production technologies and processes and green buildings (ICMA,2025)[**26**]. The project evaluation and selection process outlines the internal procedures used to identify, assess, and approve eligible green projects. According to the management of proceeds, it recommends being as transparent as possible for the tracking and reporting of how the funds are being allocated. Finally, reporting encourages issuers to provide annual reports regarding

how funding is being used, amounts invested, environmental impacts, and progress of the funded project.

Although widely adopted, the main criticism that GBP faces revolves around being voluntary and general. The lack of mandatory verification and detailed criteria may allow for greenwashing.

2.2.2. Climate Bonds Standards

The international non-profit Climate Bonds Initiative (CBI) drafted in 2012 the Climate Bonds Standard (CBS) to provide a more rigorous and science-based framework for green bonds. It includes a formal certification scheme aimed at ensuring that investments align with the Paris Agreement's goal of limiting global temperature increase to 1.5 ° C. (CBI,2024) [**10**]

CBS's key features include two separate issuance requirements for continued certification, a pre-issuance for issuers who want a certification ahead of issuance and post-issuance, for issuers seeking continued certification ahead of issuance. A certifiable taxonomy with rigorous sector-specific eligibility criteria; a strong emphasis on climate mitigation and resilience (in contrast to GBP's broader green focus) and, finally, a mandatory third-party verification through CBI certification, which enhances their credibility. These characteristics make CBS a more robust framework compared to GBP, particularly in trying to minimise the risk of greenwashing and ensure environmental integrity. Some limitations of this framework are the certification costs that may deter some issuers, making this less adopted compared to GBP or the sectoral rigidity, where the taxonomy may exclude beneficial projects that do not meet strict climate criteria (ICMA,2025) [**10**].

2.2.3. EU Green Bond Standard

The EU Green Bond Standard (EU GBS) is a voluntary but legally binding framework created by the European Commission as part of its Sustainable Finance Action Plan. It aims to strengthen investor trust, reduce greenwashing and harmonise green bond practices across the EU member states by aligning with the EU Taxonomy. In 2018, the European Commission established the Technical Expert Group (TEG) to developed four key tools, including the EU GBS. The legislation was officially published in 2023 [**15**]. According to the European Commission (2019) [**12**]:

> "The TEG has been working on recommendations for the European Commission on the definition of minimum standards for the methodology of the 'EU Climate Transition' and 'EU Paris-aligned' benchmarks, that are aligned with the objectives of the Paris Agreement and addressing the risk of greenwashing. It has also worked on disclosure requirements in relation to Environmental, Social and Governance (ESG) factors in the benchmark statement and the benchmark methodology for all types of benchmarks (except interest rate and foreign exchange benchmarks) including the standard format to be used to report such elements."

The EU GBS is built around four key pillars: EU taxonomy alignment, green bond framework, reporting requirements and external review. The EU taxonomy alignment says that green projects must contribute to at least one of the six [1] environmental objectives while doing no significant harm to the others, meeting social safeguards and technical screening criteria. As per the Green Bond Framework, issuers must disclose details on the use of proceeds, strategy and processes. For reporting, report periodically the use of proceeds and environmental impacts, if possible, supported by quantitative data. (European Union, 2020) [**14**].

Finally, an external review is necessary to ensure compliance and to ensure accurate reporting of the use of proceeds. TEG has recommended that the European Securities and Market Authority (ESMA) serves as the competent authority responsible for supervising and accrediting these external reviews [**15**].

Although legally robust and science-aligned, EU GBS face some limitations. It is considered to be expensive, complex, narrow, and not widely available to non-EU issuers. Additionally, the EU taxonomy excludes many transition technologies and sectors that are still necessary for decarbonisation. External reviews and EU templates can also be expensive and complex, discouraging small issuers.

2.2.4. China's Green Bond Principles

China is one of the largest green bond markets globally and has developed its own domestic regulatory frameworks. In July 2019, the China Green Bond Principles were issued by the China Green Bond Standard Committee regulated by the People's Bank of China (PBoC), National Development and Reform Commission (NDRC) and China Securities Regulatory Commission (CSRC). This multi-agency approach has led to inconsistencies in standards and definitions with efforts being made to harmonise Chinese regulations and align with the international regulations, to move towards a unification. The key characteristics of China GBP[**8**] include the mandatory full allocation of proceeds to green projects and the annual reporting on both allocation and impacts. It requires that projects follow China's Green Bond Endorsed Project Catalogue (2021 Edition)[**40**], which defines eligible projects with recent updates excluding fossil fuelled related projects. Regarding temporary unallocated proceeds, it is recommended that they be invested in China government bonds, policy bank bonds and local government bonds. If the unallocated proceeds exceed 12 months without being invested, the green bond designation may be at risk. It is also required that the projects do not violate any laws or regulations. Finally, an external review is encouraged, not mandatory.

A controversy that evolved around this taxonomy was the fact that just a few years ago there was a sector called clean coal. Some challenges faced by this framework compared

[1]The six core environmental objectives are: climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems.

to EU standards are the lack of mandatory external review and less standardised reporting. Recent developments include China issuing green sovereign bonds internationally, denoting a greater alignment with global markets.

The regulatory framework for green bonds reveals a tension between flexibility and rigour. ICMA's GBP provides a more flexible, widely accepted baseline, nonetheless its voluntary nature and general guidelines expose issuers to greenwashing. In contrast, the Climate Bonds Standards and the EU Green Bond Standard offer a stricter science-based framework that emphasizes transparency and credibility at higher costs. China's framework reflects an evolving effort to reconcile national priorities with international standards and shows progress particularly through the exclusion of fossil fuels and alignment initiatives; however, it lacks verification and consistency.

The existence of multiple frameworks allows market diversity, but it also creates fragmentation. With the growth of the green bond market, regulatory convergence will be crucial to support investor trust and sustainable finance outcomes globally.

2.3. Market Evolution

This section will start by summarising the evolution of the green bond market with a focus on the year 2024 as well as giving an overlook between 2007 and 2024.

In 2007, the first ever green bond was issued by the European Investment Bank (EIB)(Flammer,2020) [**18**] and was named as "Climate Awareness Bond", worth approximately USD 1 billion (Banga, 2019) [**5**] to finance renewable energy and energy efficiency projects (European Investment Bank, 2024)[**13**]. After that, in 2008, the World Bank issued its first green bond, following EIB's lead, to focus on climate change mitigation and adaptation projects (The World Bank,2015) [**48**]. The market has grown exponentially since 2014, the key catalyst being the introduction of the Green Bonds Principles (GBP) by the International Capital Market Association (ICMA) in January 2014. These Principles are the basis for the many existing green labels (ICMA,2014)[**25**]. Since then, the market has expanded dramatically. Table 2.2 gives an overview of some of the most important events in the evolution of the green bond market.

Table 2.2. Market Evolution. Source: CBI; Baker and McKenzie LLP [**9**][**3**]

Year	**Achievement**
2007	First Green Bond/Climate Awareness issued by European Bank and World Bank
December 2010	Climate Bond Initiative launched the Climate Bond Standard and Certification Scheme
March 2013	International Finance Corporation (IFC) sold the first benchmark green bond with the amount USD 1 million
June 2013	First Municipal green bond issued by Massachusetts

Year	Achievement
October 2013	Gothenburg in Sweden put the first city green bond on the market
November 2013	SolarCity (now Tesla Energy) was the earliest company in issuing solar asset-backed security (ABS)
January 2014	ICMA publishes the ICMA Green Bond Principles
November 2014	Swedish real estate company issued first corporate green bond
September 2015	UN Sustainable Development Goals and 2030 Agenda for Sustainable Development
December 2015	Adoption of the Paris Agreement
2016	Entered in force the Paris Agreement on Climate Change - ratified by 170 countries
2018	International Capital Market Association (ICMA) updated and revised its Green Bond Principles
2019	Netherlands becomes the largest certified sovereign
2019	Green Bond Market hits USD 257.7 billion in total green bond issuance
2024	CBI has recorded cumulative volume of USD 6.9tn of green, social, sustainability, and sustainability linked (GSS+) debt in alignment with its screening methodologies (aligned)
2025	Climate Bonds Initiative reports USD 5.9tn in cumulative aligned GSS+ debt by end of Q1 2025

Two important marks on the market evolution are next described.

2.3.1. 2030 Agenda

In September 2015, the United Nations gathered a summit in New York to establish goals and targets for the next 15 years that the member states should implement in their countries, leading to the adoption of the 2030 Agenda for Sustainable Development [**50**]. This plan of action outlines 17 Sustainable Development Goals (SDGs) and 169 targets designed to address various social, economic and environmental challenges by 2030. The agenda is structured around five central themes, often referred as the "5 Ps": People, Planet, Prosperity, Peace and Partnership. It is important to refer that the SDGs are build on the Millennium Development Goals (MDGs), which were adopted in 2000 for their achievement by 2015 and all goals not achieved remain targets to be met. Due to this framework, green bonds emerged, once again as a crucial financial instrument to support projects that directly contribute to the achievement of the SDGs, particularly

focused on climate action and sustainable development. Green bonds accumulate capital for climate-related initiatives, allowing investments that align with the goals of the 2030 Agenda. Of the 17 goals, seven of them (SDG 7,9,11,12,13,14,15) are considered directly linked to the use of green financing, while three others (SDG 3,6,8) are indirectly related but have co-benefits. Table B.1 summarises the specific SDGs connected to Green Bonds and explains their relevance.

2.3.2. Paris Agreement

In December 2015, more than 196 negotiating parties, according to France Diplomatie, gathered in Paris for the United Nations Climate Change Conference, also known as COP21. The intention was to discuss strategies to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable, low-carbon future. It was the first time that a universal agreement was reached in the global fight against climate change, the well-known Paris Agreement emerged from this conference. Its central aim is to strengthen the global response to the threat of climate change in the context of sustainable development and efforts to eradicate poverty. This includes keeping the global temperature rise this century well below 2 °C, the preindustrial level, and ideally limiting the increase to 1.5 °C. It also aims to lower greenhouse gas (GHG) emissions without threatening food production and make finance flows consistent with a path towards low GHG emissions and resilient development to climate change (United Nations, 2015) [**51**].

The adoption of this agreement marked a pivotal moment in global flight against climate change. An important response was the increased seriousness and growth of green bonds as a sustainable finance instrument, as previously mentioned as a mechanism that funds projects that support renewable energy, energy efficiency and other environmentally beneficial initiatives outlined in the Paris Agreement.

2.4. Benefits and Limitations

In the following section, the benefits and limitations of issuing green bonds for both issuers and investors will be described.

Issuers

One of the benefits of issuing a green bond is that the portfolio will be more diverse when compared to conventional bonds, thus obtaining a positive reputation. Issuers will potentially gain new clients or customers that are attracted by the knowledge that the issuer is interested in green bonds and helping fight climate change. Other benefits with positive impacts may be achieved, but there has not yet been sufficient time or research to demonstrate significant results, making it unclear whether the issue of green bonds is the correct way to address climate change.

In terms of limitations, issuers face several challenges. First, the benefits of issuing a bond remain unclear, there are high costs involved regardless of if there is a greenium (Bachelet et al., 2019) [**2**]. Additional deterrents include difficulties in verifying the actual environmental impact of financed projects and the overall complexity of the issuance

process. The question of whether an issuer benefits from a greenium is an ongoing inconclusive situation in the literature. Some authors identify significant price differences between green and conventional bonds (Hu 2022, Nanayakkara and Colombage 2019) [**23**] [**35**]. Partridge and Medda (2020)[**39**] found a positive premium on the secondary market but no conclusive evidence on the primary market. Okafor et al. (2024)[**38**] found a positive premium among government and corporate issuers. Fatica and Panzica (2019) [**16**] found that it depends on the type of issuer. Hachenberg and Schiereck (2018) [**21**] conclude that there exists a modest greenium and others report negative greenium (Sheng et al., 2021; Ivashkovskaya and Mikhaylova, 2020; Zerbib, 2018)[**43**][**27**][**54**]. A further challenge arises from the significant transformation required for projects and institutions toward sustainability. A significant monetary commitment is required in renewable energy, emissions reduction and clear production processes. Many firms may struggle to implement these actions and support a genuine green transformation. Finally, the uncertainty about financial and environmental benefits emphasises the need to establish specialised teams that dedicate resources to the development, monitoring, and continuous review of the green bond framework.

Investors

Investors want their money to be invested in environmentally friendly projects. The main reason may be the knowledge that their money is being put to good use and helping the future. There are still things to do, for example, in defining a clear and universal definition of green bonds, and then the real benefits that investors gain may be shown. Also, with the lack of definition, many may issue a bond and call it green.

Apart from this last situation, called the risk of greenwashing, which arises from the lack of consistent definitions, standards, and framework and verification, there are some other limitations. Investors face uncertainty about whether a bond genuinely funds environmentally sustainable projects. This ambiguity can affect their credibility and reputation if projects are later perceived as lacking in greenness. Another limitation is the difficulty and cost of assessing the actual environmental impacts of projects. Measurement of outcomes requires reliable data and normalised reporting. This is limited due to the early stages of the green market. The unavailability of transparent and comparable data makes it difficult for investors to assess performance and align their investments with long-term sustainability goals. Furthermore, there is an ongoing debate about financial exchange. Some investors worry that prioritising environmental objectives may come at the expense of yield or risk adjusted return. Others point to mixed evidence in the literature. Sartzetakis (2021) [**42**] argues that green bonds have yet to reach their full potential as an effective instrument for climate change mitigation, while multiple authors emphasise the importance of defining a clear and unique definition of green bonds (Tao, 2015; Shishlov, 2016) [**47**] [**44**]. Finally, the lack of a global regulatory framework and the different taxonomies create additional uncertainty.

2.5. Credit Risk

Credit risk refers to the likelihood that an issuer will fail to meet its contractual obligations, such as repaying a loan or making interest payments. This failure can lead to financial losses for the lender and, in severe cases, may result in financial distress, even bankruptcy. It is quantified using the probability metrics of default (PD), loss given default (LGD) and expected loss (EL). The traditional ways to measure the credit risk include structural models, such as Merton's model (1974) [**33**], which determines the probability of a company defaulting on its debt obligation by analysing the relationship between the company's asset value, its liabilities and the time until maturity. There are also reduced-form models that focus on a statistical estimation of default probabilities, rather than trying to explain it through the underlying asset value of a firm (the theoretical value of the company based on its assets and future cash flows and what a company's real worth is separated from the market price or the price of its derivatives). Credit risk is evaluated and communicated to investors and stakeholders through credit rating agencies.

These agencies play a crucial role in the financial market by providing independent assessments of a company's creditworthiness. Ratings offer an independent evaluation of the likelihood that a borrower will meet their debt obligations in full and on time. Moody's, Standard & Poor's (S&P) and Fitch Ratings are some of the widely known credit rating agencies. They all utilise insights derived from credit risk models, along with quantitative factors, and assign credit ratings that reflect the likelihood of default by the issuer. For instance, Moody's [**34**] uses a letter grade system ranging from Aaa to C, while S&P [**45**] and Fitch [**17**] use a similar scale, ranging from AAA to D. Usually, the higher on the scale, the less credit risk, and the lower on the scale, the riskier. It is important to note that credit ratings are not perfect. Agencies base their estimation on available information and forecasting models, which means that they cannot guarantee complete accuracy. For example, these agencies were unable to anticipate the 2008 global financial crisis, highlighting the limitations of the system in predicting defaults or systemic risks.

Although conventional bonds have a well-established credit risk assessment framework, green bonds introduce unique considerations, and since they are designed to finance environmentally sustainable projects, their credit risk can differ from conventional bonds. Such risks can arise from the project itself, as the proceeds earmarked for specific environmental projects can introduce asset-level risks distinct from the issuer's creditworthiness. The success of the project can also play a decisive impact on the bond's performance and, therefore, the rating. Another risk is the regulatory advantages that green bonds benefit from, such as tax benefits or government guarantees. These can improve their credit quality compared to conventional bonds. Last but not least, the growing demand for sustainable investments has attracted a unique investor base, which can influence the pricing and, therefore, the risk. Some studies suggest that investors in the Asia-Pacific region are willing to accept lower yields in exchange for investing in environmentally sustainable assets (P. Wongaree et al.,2025) [**53**].

CHAPTER 3

Methodology

3.1. Objectives of the Study

The goal of this study is to compare the credit risk, in particular the credit rating, of a green bond with that of a similar conventional bond issued by the same company. Bond rating drivers will be analysed and measured. Conventional bonds were matched with a green bond in terms of type of maturity, sector, type of coupon, coupon frequency and day count convention.

3.2. Data and Sample Selection

To address the objective of this study, green bonds were collected from different countries and sectors and then matched with bonds with apparently similar characteristics except for the "Green" label. In this sample, bonds were issued from both corporations and government. There were no restrictions on the year of issuance of the bonds. However, efforts were made to ensure similar maturities for both green and conventional bonds. To evaluate credit risk, the variable rating was chosen as the dependent variable. The green label is another characteristic of interest, making it an additional variable to be considered and closely observed in relation to the others.

3.3. Dummy Variables

Dummy variables are categorical variables that only take two values, 0 or 1, to represent absence or presence. This is widely used in regression models to incorporate categorical data that cannot be directly computed. For example, the characteristic Green is a dummy variable, taking 1 if green and 0 otherwise, as shown in the function:

$$f(x) = \begin{cases} 1 & \text{if } x \text{ is Green} \\ 0 & \text{otherwise} \end{cases}$$

3.4. Multivariate Regression Model

The model selected for this analysis was the Multivariate Regression Model, due to its simplicity and ease of use, as well as the ability to analyse the relationship between multiple independent variables and a single dependent variable, allowing to comprehend the relationship between variables and understand the factors that influence the outcome of the rating. The goal is to understand whether there exists a linear relationship between one or more independent variables and one dependent variable. The equation of a multivariate regression model is given by:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \cdots + \beta_k X_{ki} + \epsilon_i \tag{3.1}$$

Where:

- Y_i is the dependent variable
- $X_1, X_2, X_3, \ldots, X_k$ are the independent variables
- $\beta_1, \beta_2, \beta_3, \ldots, \beta_k$ are the regression coefficients
- β_0 is the Y intercept
- β_i is the slope of Y with variable X_i, holding all variables X_j, with $i \neq j$, constant
- ϵ_i is the random error term in Y for observation i

The term linear comes from the fact that the mean is a linear function of the unknown parameters β_1, β_2, β_3, ..., β_k (Johnson and Wichern 2007)[**28**].

3.4.1. Least Squares Estimation

The least squares method estimates the regression parameters β by finding the values of the coefficients b that minimise the sum of squared differences between the observed and the predicted values. The function is given by: (Johnson and Wichern 2007)[**28**]

$$S(b) = \sum_{j=1}^{n} (Y_i - b_0 - b_1 X_{j1} - b_2 X_{j2} - \cdots - b_r X_{jr})^2 \tag{3.2}$$

where

- Y_i is the observed response for the i-th observation
- $X_{j1}, X_{j2}, \ldots, X_{jr}$ are the predictor variables
- $b_0, b_1, b_2, \ldots, b_r$ are the regression coefficients

The values of b that minimise $S(b)$ are called the least squares estimation of the regression parameters β.

3.4.2. Coefficients of multivariate determination

The multivariate determination coefficient (R^2) indicates the portion of variance in a dependent variable that can be explained by the independent variables. It shows how well the model fits the data. This coefficient is determined by the formula (Rawlings et al., 1998)([**41**]:

$$R^2 = \frac{\text{Regression sum of the squares (SSR)}}{\text{Total sum of squares (SST)}} \tag{3.3}$$

where:

- SSR is the variation explained by the regression model;
- SST is the total variation in the dependent variable, representing the error if the average value were used as the independent variable;

The adjusted coefficient determination is given by the formula (Rawlings et al., 1998) [**41**]:

$$R^2_{adj} = 1 - \frac{(1 - R^2)(n - 1)}{n - p'} \tag{3.4}$$

where:

- n is the total number of data in the regression;
- p' is the number of parameters to be estimated and $p' = p + 1$ with p being the number of independent variables in the regression model.

The adjusted coefficient of determination R^2_{adj} corrects the standard coefficient of determination R^2 for the number of independent variables in a new regression model, providing an accurate assessment of the ideal model. It decreases if a new variable is added, and it does not sufficiently improve the predictive power of the model. It is usually used when comparing models with different number of independent variables.

3.5. Variance Inflation Factor (VIF)

The Variance Inflation Factor is a test that detects multicollinearity among independent variables (Marquardt, 1970; O'Brien, 2007) [**31**] [**37**]. High values of VIF indicate the existence of multicollinearity between variables, which may affect the interpretation of coefficients and may indicate that a variable's variance is significantly inflated due to its relationship with other independent variables. It is suggested to try and remove the variable with the highest VIF to check if there is any difference in coefficient (R^2). The formula for computing the VIF is given by:

$$VIF_k = \frac{1}{1 - R^2_k} \tag{3.5}$$

If VIF equals one, there is no sign of multicollinearity.

3.6. Regression Variables

In this section, the independent variable, rating, and all the independent variables such as coupon, issue price, amount issued, sector, yield at issue, 90-day volatility, callable, maturity, country and green will be described and how the independent variables are related to the credit rating.

Rating

Rating is the dependent variable in the multivariate regression model and is aimed at being predicted by several independent variables, as described. However, the main goal is to understand whether the green dummy variable has any influence on the rating. Will it be a risk for a company to issue a green bond? This variable is categorical, however, due to all other variables being in numerical scale, the rating was assigned using an ordinal scale in ascending order (see Table C.1). A reduction in the value of the rating actually means a move up the scale and, therefore, a better credit assessment (for example, if it reduces from 5 to 4 indicates a change from A+ to AA-). This variable is expressed in a numerical scale in the regression model.

Coupon

This first independent variable refers to the interest payment that the bondholder receives from the issuer, typically expressed as a percentage of the bond's face value. It is paid at regular intervals, usually annually or semi-annually, until the bond matures.

For this thesis, it was ensured that the coupon had an annual frequency. The coupon represents the income the investor earns from holding the bond and is critical when assessing the attractiveness of a bond. It also reflects the risk associated with the bond: Higher coupon rates suggest a higher risk, as issuers may need to be compensated for taking additional risks. As mentioned above, this variable is expressed in the regression model as a percentage.

Issue Price

This is the price at which a bond is initially sold to investors at the time of issuance. The issue price may affect the bond's yield and, consequently, influence investors' demand. Bonds issued at a discount typically exhibit higher yields, which may also have implications on their credit rating. This variable is expressed in numerical values.

Amount Issued

The amount issued denotes the total nominal value of a bond made available to investors at the time of issuance. It reflects the size of the bond offering and provides an indication of the issuer's financing needs. A larger issuance may suggest a stronger credit profile, which can lead to a higher rating. The relationship between this variable and the rating allows an assessment of how the dynamics of the market influence the credit evaluation.

Sector

This thesis collected bonds from different sectors such as Financials, Government, Utilities, Consumer Discretionary, Communications, Materials, Industrials and Technology. Different sectors tend to attract different types of investors and economic conditions that can impact credit ratings. Some sectors are more stable than others. Comparing the sector variable with the rating can help identify some sector-specific trends that can influence credit ratings. This variable is a dummy variable, so it will be expressed as a categorical value.

Yield at Issue

The yield at issue is the rate that investors are promised or expect when acquiring the bond. Reflects the attractiveness and risk of the bond at the time of issuance. A higher yield may indicate a higher perceived risk, which could correlate with a lower rating. It is expressed as a percentage in the model.

90-day volatility

This variable measures the price volatility of the bond over the past 90 days. Volatility is usually an indicator of the risk associated with the bond. Higher volatility may suggest greater uncertainty or risk, which can negatively impact credit ratings. It is expressed as a percentage in the model.

Callable

A callable bond is a bond that can be redeemed by the issuer before its maturity date, usually at a specified call price. Callable bonds typically offer higher coupon rates to compensate for the risk of uncertainty of early redemption. This is a dummy variable, taking 1 when it is callable and 0 when it is not. When it is held to maturity, this means

that it offers predictable cash flows and overall some stability, which can bring less credit risk. This type of variable is expressed as categorical in the model.

Maturity

The variable maturity refers to the time until a bond's face value is repaid and interest payments cease. Longer maturity generally carry greater interest rate risk, denoting that they are more sensitive to fluctuation in market interest rate, which can influence credit ratings. Bonds with longer maturity may be rated lower due to uncertainty. The variable is expressed in years in the regression model.

Country

The variable country indicates which country is the issuer of the bonds. In this thesis data were collected from more than fifteen countries, namely: Australia, Britain, Canada, France, Spain, South Korea, Belgium, USA, Japan. The remaining six countries are grouped under the label 'Other' because they each issued only one green bond. It was important to use this variable because some countries have a higher risk due to their economic stability and regulatory environments that can significantly affect the credit rating. Bonds issued in stable countries may receive a higher rating. This variable is a dummy variable, so it is expressed as categorical.

Green

Finally, the most important variable in this study is the green variable, used to determine the impact of investing in green bonds over conventional bonds. It is expressed as a dummy variable, receiving a value of 1 if the bond is green or 0 if it is not, which means that it is a conventional bond.

Table 3.1 summarises the description of each variable, the name of the variable, the type and the date of extraction.

TABLE 3.1. Description of each variable in the regression model. Source: Own representation

Name of the Variables	**Type of Variable**	**Variable**	**Date of Extraction**
Rating	Numeric	Dependent	June 2025
Coupon	Numeric	Independent	June 2025
Issue Price	Numeric	Independent	June 2025
Amount Issued	Numeric	Independent	June 2025
Sector	Categorical	Dummy	June 2025
Yield at Issue	Numeric	Independent	June 2025
90D Volatility	Numeric	Independent	June 2025
Callable	Categorical	Dummy	June 2025
Maturity	Numeric	Independent	June 2025
Country	Categorical	Dummy	June 2025

Name of the Variables	Type of Variable	Variable	Date of Extraction
Green	Categorical	Dummy	June 2025

3.7. Hypothesis

It will be considered:

H_0: The issuing of a green bond does not have a significant impact on a company's credit risk.

H_1: There is a significant impact on the company's credit risk.

CHAPTER 4

Data

4.1. Data Collection

All data used in the empirical part of this thesis were collected from the Bloomberg Terminal, specifically through the fixed-income search section. The main reason for the use of Bloomberg is its extensive and comprehensive data coverage, including bond characteristics, credit ratings and market analysis. In Bloomberg, bonds can be identified as "Green Bond" through the use of the proceeds field. A bond receives this label either when the investor self-labels his bond as "green" or when it is recognised as an environmental sustainability-orientated bond issued with clear statements about the commitment towards projects and activities mentioned in the Green Bond Principles categories. Bloomberg also requires issuers to indicate alignment with GBP as a condition for classification. However, it is important to note that Bloomberg does not impose additional requirements for a bond to be listed as green in their database. Specifically, issuers are not required to provide impact reporting, obtain a third-party verification or specify project selection and proceeds management criteria beyond the GBP alignment.

Due to restrictions on the Bloomberg Terminal available at the faculty premises, we were unable to download the data in bulk, and as a result, we had to manually extract the necessary information for this research. The data collection period ranged from February to June 2025.

The dataset comprises a total of 188 bonds, consisting of 94 green bonds and the matching 94 conventional (non-green) bonds, each pair issued by the same company. The bonds were issued between 2016 and 2025, with maturities as late as 2054. This pairing ensures comparability between green and non-green instruments while controlling firm-specific characteristics. Green bonds were selected first, using a set of Bloomberg filters to ensure consistency in data availability. Some of the filters used were the Green Instruments Indicator to mark the "green", a fixed and annual coupon structure and the day count convention restricted to ACT/ACT. Key characteristics such as credit rating, coupon rate, amount issued, issue price, yield at issuance, date issuance and maturity were mandatory. The importance of having a fixed coupon is to facilitate computations and reduce uncertainty (Ehlers & Packer, 2017)[**11**]. After selecting the green bonds, we matched a corresponding conventional bond from the same company. The same criteria were applied, with the sole exception that the Green Instrument Indicator was required to be off. To ensure comparability, conventional bonds were matched primarily on the basis of maturity date. When the match was not available, the bond with the closest maturity was selected.

4.2. Descriptive Statistics and Balance overall

After establishing our dataset, the main statistics of the variables will be analysed. Pie charts, histograms, and graphs are shown to better understand and visualise some of the variables. Every figure was a result of using Python and its tools.

We start by showing the summary of the descriptive statistics of green bonds, table 4.1a and then conventional bonds, table 4.1b.

TABLE 4.1. Summary of the descriptive statistics. Source: Own representation

	Coupon	Issue Price	Rating	Amt Issued (in million)	Yield at Issue	90D volatility	Callable	Maturity
mean	2.5947	99.6417	6.0319	0.8405	2.6463	3.9433	0.3936	8.3381
median	3.0875	99.6760	6.5000	0.6000	3.1060	3.5720	0.0000	7.0000
std	1.5575	0.4207	3.1399	1.1140	1.5613	2.8976	0.4912	4.5670
min	0.0100	98.2920	1.0000	0.0010	-0.1900	0.1160	0.0000	3.0000
max	5.6250	102.0210	19.0000	9.1340	5.7700	14.3430	1.0000	30.0000

(A) Green Bond Summary

	Coupon	Issue Price	Rating	Amt Issued (in million)	Yield at Issue	90D volatility	Callable	Maturity
mean	2.0608	99.6227	5.9574	1.3578	2.1069	3.6393	0.4043	9.2590
median	1.5960	99.7645	6.0000	0.7175	1.6480	2.9895	0.0000	9.0900
std	1.6089	0.5253	3.2393	3.6837	1.6164	2.6172	0.4934	4.3200
min	0.0030	97.8840	1.0000	0.0015	-0.2670	0.0000	0.0000	3.0000
max	102.1000	19.0000	30.0000	7.2640	7.2640	1.0000	1.0000	30.0000

(B) Conventional Bonds Summary

A quick scan of both tables shows that green bonds have a higher mean coupon than conventional bonds, reflecting that green bonds are generally issued with higher coupons. This is usually due to being a new market and wanting to attract new investors by offering slightly higher coupon rates. Conventional bonds are already more familiar and can raise capital with lower coupons. The issue prices are very similar, both are around par (100), since bonds are usually priced near face value at issuance. This suggests that this is not a distinguishing factor between the two types of bonds. In terms of rating, it shows very similar means, indicating that green and conventional bonds are issued with similar risk profile. The amount issued shows that conventional bonds tend to have larger issuance sizes, which is expected since conventional bonds dominate the market and can attract larger investors. The yield at issue tends to be higher for green bonds, consistent with the coupon, to compensate the issuers for the lower demand. The 90-day volatility is slightly higher in the case of green bonds, which is consistent with smaller issue sizes, higher uncertainty, and less market depth reinforcing the price/yield variation. The callable feature is not a distinguishing factor between types of bonds as they are almost the same. Finally, the maturity is slightly longer in conventional bonds, reflecting investor comfort and knowledge of the market, therefore, issuing longer term bonds.

Figure 4.1 shows the distribution of bonds across the various sectors, which is the same for both types of bonds.

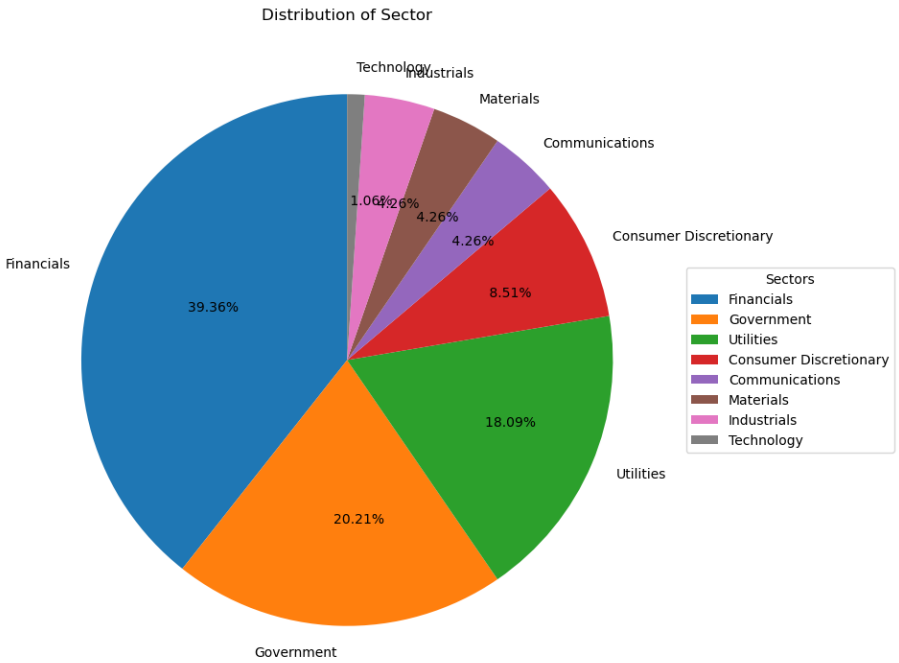


FIGURE 4.1. Distribution Sector. Source: Own representation

The sectors with the most issued bonds are the *Financials* with 39.36% followed by *Government* with 20.21%. The sector with fewer issued bonds is *Technology* with 1.06% Figure 4.2 shows the difference in maturity between green and conventional bonds.

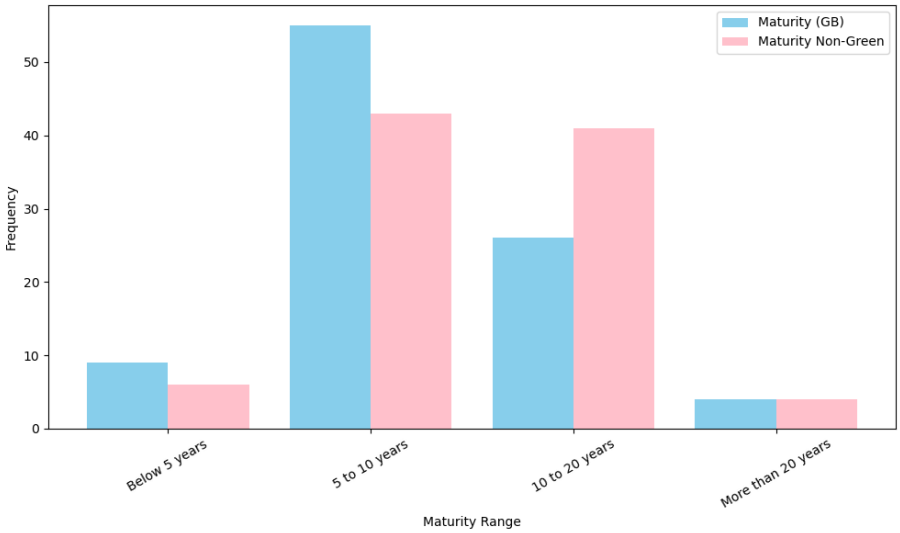


FIGURE 4.2. Maturity Range. Source: Own representation

In general, most bonds are issued with a maturity between 5 and 10 years. However, in the case of conventional bonds, there is almost the same amount of bonds issued with a maturity of 5 to 10 years as there is for 10 to 20 years. For green bonds, the difference between the group of the most issued bonds and the second most issued bonds is almost half the same amount. Most issued bonds are between 5 and 10 years, and the second

most issued bonds between 10 and 20 years. Pie charts for each type of bond are available in D.1 and D.2.

Figure 4.3 displays the difference in the yield range.

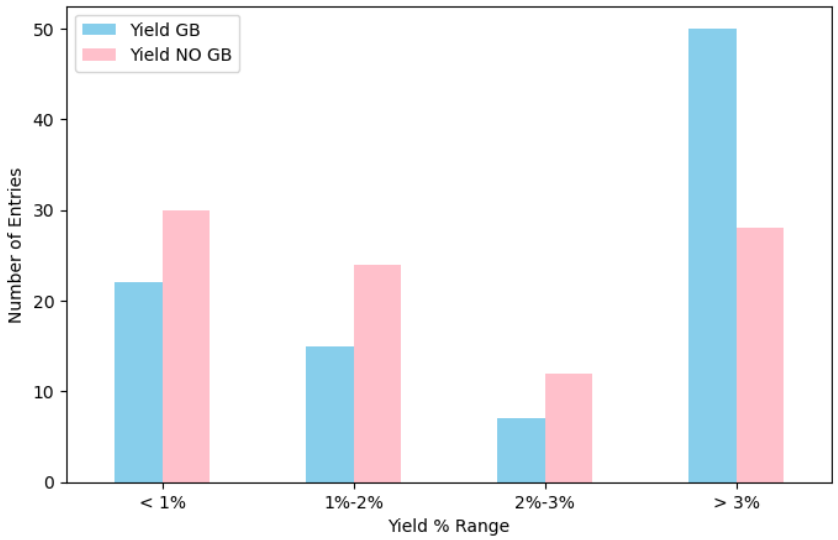


FIGURE 4.3. Range of Yields. Source: Own representation

On a first note, the green bond yields are higher than conventional bonds. Whereas most of the issued bonds have yields greater than 3%, conventional bonds are mostly issued with yields below 1%. This difference may not only be attributed to the green label, but rather differences in the characteristics of the bonds or the timing of issuance. Conventional bonds may have been issued in a period with low interest rates.

As for the variable coupon, figure 4.4 shows the difference between each type of bond.

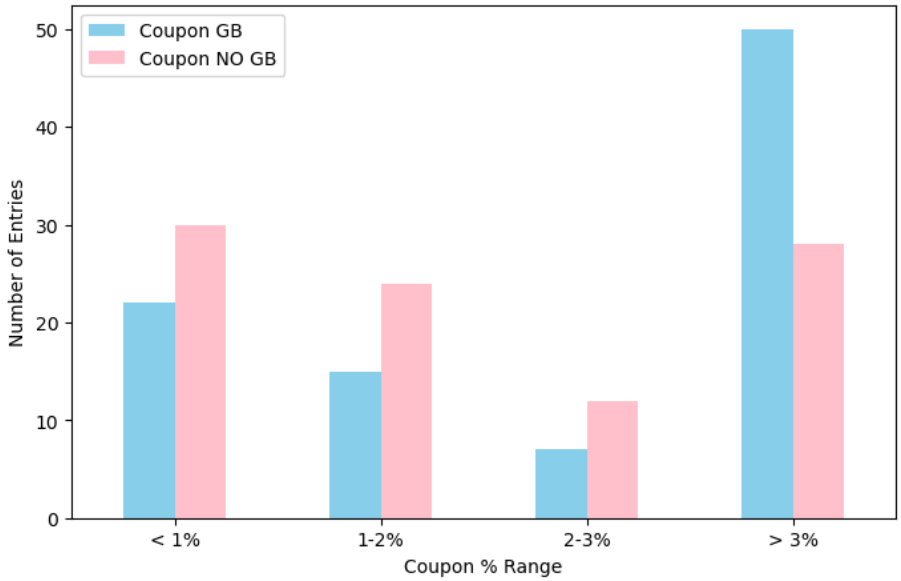


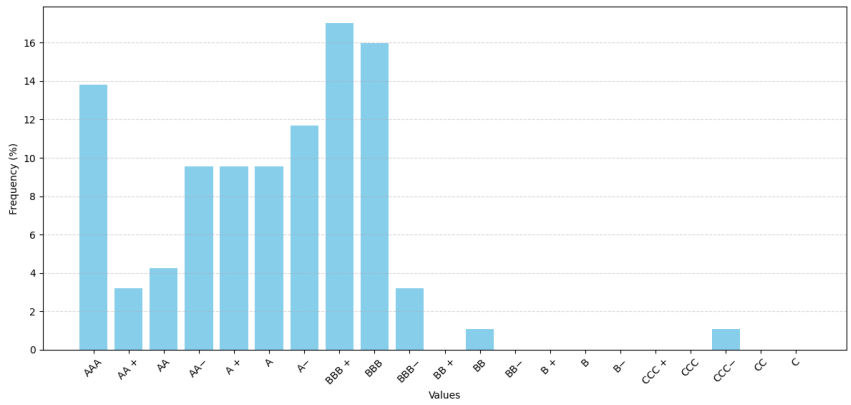
FIGURE 4.4. Coupon Comparison. Source: Own representation

Whereas green bonds have a higher number of bonds issued with a coupon rate of more than 3%, conventional bonds have a higher number of bonds issued with less than

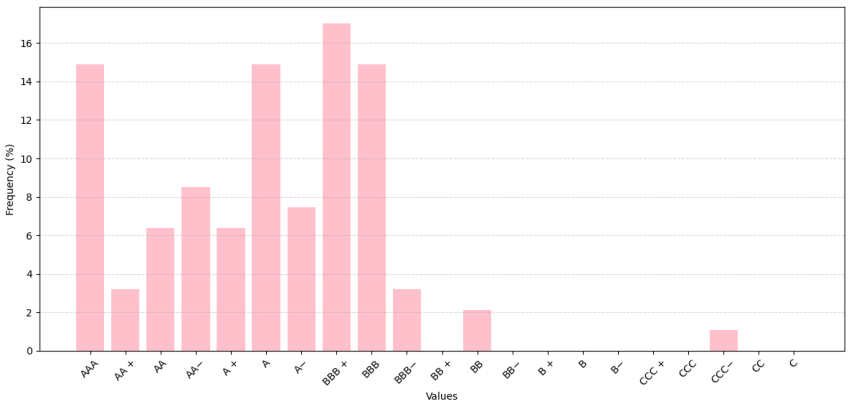
1%. This difference reflects market conditions and does not directly indicate an increased risk of default by the issuer.

Comparing figures 4.3 and 4.4 we may conclude that the higher the coupon, the higher the yield at issue.

FIGURE 4.5. Frequency Distribution Green and Conventional Bonds. Source: Own representation.



(A) Frequency Distribution for Green Bond. Source: Own representation



(B) Frequency Distribution for Conventional Bonds. Source: Own representation

Regarding the frequency of ratings, Figure 4.5a shows that the ratings BBB+ and BBB are the most common ratings for green bonds, followed by AAA. In contrast, Figure 4.5b indicates that conventional bonds are most commonly rated BBB+, BBB, A and then AAA.

To complete this section, we present the scatter plot of the ratings of green bonds and conventional bonds. The correlation between the rating of green and conventional bonds is 0.919, which indicates a very strong positive association. Green bonds appear to carry the same credit risk as conventional bonds with minor deviations. Figure 4.6 shows this relationship.

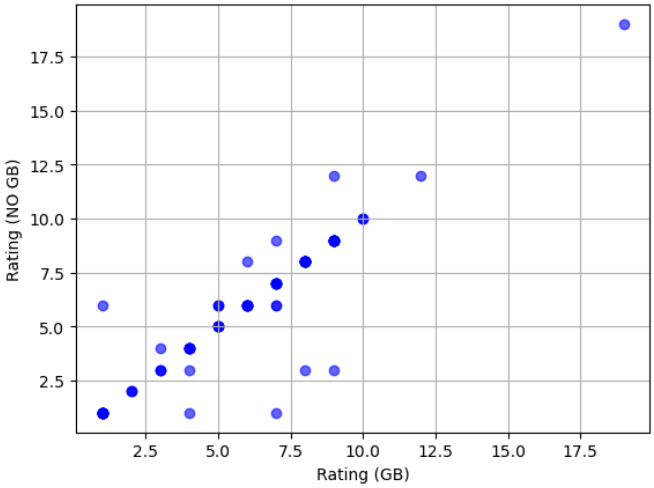


FIGURE 4.6. Scatter plot of ratings. Source: Own representation

To finalise, Figure 4.7 presents the box plot and the violin plot of the ratings.

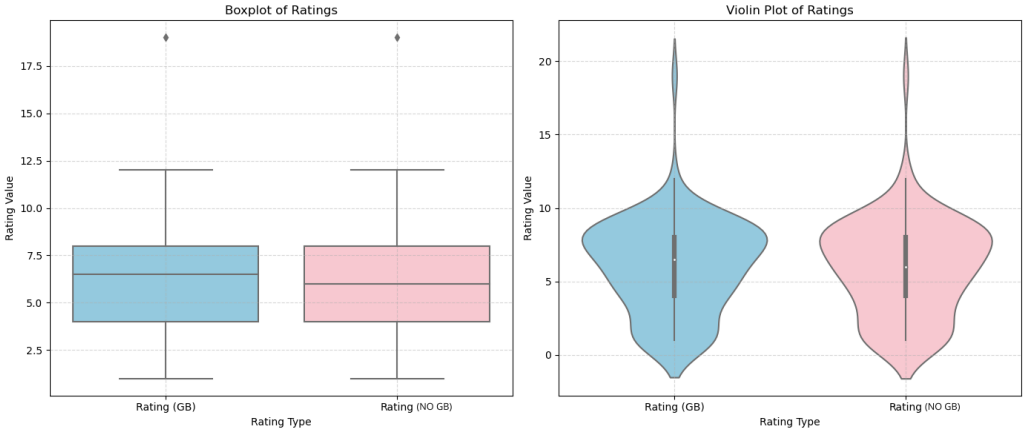


FIGURE 4.7. Box plot and Violin plot of Ratings. Source: Own representation

The Box-and-Whisker plot gives a closer look at the distribution of the values of the dependent variable. Both green and conventional bonds exhibit similar median ratings; the interquartile ranges are also comparable, indicating a similar dispersion. As for outliers, each type of bond has one outlier, representing a bond with an unusually high rating, which is noticeable in both boxes.

In terms of the violin plot, it provides a richer visualisation of the density, which reinforces the similarity in the overall distribution. The longer tails reflect the existence of bonds with very high ratings.

CHAPTER 5

Results and Discussion

In this chapter, the results of the multivariate regression model will be presented and analysed. The confidence level used in this thesis is 95%. Although the variables have already been introduced in the previous chapter, the dummy variables require further specification. For the dummy variable sector, eight sectors are considered. Seven are represented by dummy variables, with the sector *Communications* serving as a reference category (taking the value 0). For the dummy country, *Australia* was chosen as the reference category (value 0). For the callable variable, being callable takes 1 and at maturity 0. Finally, the green variable takes 1 if the bond is a green bond and 0 if it is a conventional bond.

The results of the multivariate regression statistics are presented in Table 5.1. Figure E.1 presents the results of the OLS regression, coefficients, standard error for each variable, test t and the p-values.

TABLE 5.1. Regression Statistics. Source: Own representation

R Squared	0.663
Adj. R Squared	0.599
F- statistic	10.31
Prob (F-statistic)	$3.68e^{24}$
Log-Likelihood	-381.52
AIC	825.0
BIC	925.4

Equation (5.1) presents the full model:

$$\begin{aligned} Y_i = {} & 37.6141 - 3.0843X_{1i} - 0.3678X_{2i} - 5.937 \times 10^{-8}X_{3i} \\ & + 3.3375X_{4i} - 0.0489X_{5i} - 0.0277X_{6i} - 0.0814X_{7i} \\ & + 2.6483X_{8i} + 1.4114X_{9i} + 0.6664X_{10i} + 0.3512X_{11i} \\ & + 0.1541X_{12i} - 4.5809X_{13i} + 1.4190X_{14i} + 2.9404X_{15i} \\ & + 1.3954X_{16i} + 3.0860X_{17i} + 5.1660X_{18i} + 0.3877X_{19i} \\ & + 2.0116X_{20i} + 1.9602X_{21i} + 2.6742X_{22i} + 3.1927X_{23i} \\ & + 3.3283X_{24i} + 0.0425X_{25i} + 2.4413X_{26i} - 0.9296X_{27i} \\ & + 0.3332X_{28i} + 4.3464X_{29i} + 2.7487X_{30i}, \end{aligned} \tag{5.1}$$

where:

- Y_i: predicted rating of bond i
- X_{1i}: coupon of bond i
- X_{2i}: issue price of bond i
- X_{3i}: amount issued of bond i
- X_{4i}: yield at issue of bond i
- X_{5i}: 90-day volatility of bond i
- X_{6i}: maturity of bond i
- X_{7i}: dummy variable green representing the absence or presence of the characteristic green
- X_{8i},X_{9i}, ...X_{14i}: dummy variable sector, representing the absence or presence of sector Consumer Discretionary, Financials, Government, Industrials, Materials, Technology, Utilities, respectively
- X_{15i}: dummy variable callable, representing the absence or presence of a bond i being callable
- X_{16i},X_{17i}, ..., X_{30i}: dummy variable country, representing the absence or presence of country Austria, Belgium, Britain, Canada, France, Germany, Italy, Japan, Netherlands, Norway, Other, SNAT, South Korea, Spain and US, respectively

Taking the p-values of the independent variables and the level of significance of five percent, the only significant variables are the sectors *Consumer Discretionary* and *Technology*, the countries Belgium, Britain, Italy, Japan, Netherlands, Spain and US and Callable.
The R-squared (R^2) of this multivariate regression model is 0.663 which means that the model can explain 66.3% of the variance of the rating. Since its adjusted R^2 is lower than R^2, it suggests that some predictors may not add much explanatory power. The overall model is statistically significant, as indicated by the F-statistic ($F = 10.72$, $p < 0.05$). This means that the chosen independent variables may not fully explain the variable rating.
Let us interpret some variables of the model.

- The intercept estimates the rating to be 37.6141 units, in the absence of any influence from the other variables. Since our scale only ranges from 1 (AAA) to 21 (C), this value is outside the meaningful range of ratings. The intercept here is not directly interpretable in terms of a real rating category, but is necessary for the regression equation to properly describe the relationship between the independent variables and the rating;
- All the variables of bond characteristics (coupon, issue price, amount issued, yield at issue, 90-day volatility, maturity and green) have mixed effects. All variables have negative coefficients except for the yield at issue. That is, if there is an increase in the value of the yield, keeping all other variables constant, the numerical value of rating increases, but in fact it means that the rating downgrades

(see Table C.1); The coupon and issue price having negative coefficients: if they increase by one unit, the numerical value of rating will decrease, but in reality the rating will increase, keeping all other variables constant. For the green variable, the negative coefficient indicates almost no effect on the rating. The amount issued, 90-day volatility and maturity have negative coefficients as well but are insignificant due to being so close to zero;

- The sector dummies have all positive coefficients, except for sector *Technology* which means that these sectors are related to higher ratings when compared to the reference sector *Communications*;
- Callable bonds have a positive coefficient, which means that they are associated with higher ratings;
- As for the dummy countries, they are mostly positive except for one, $SNAT$. The positive coefficients indicated that the countries are associated with higher ratings when compared to the omitted country *Australia*;
- For any variable not significant at a 95% confidence level, there is no statistical evidence to conclude that it impacts the credit rating.

Because the results were not as expected, we wanted to detect if there was multicollinearity among the independent variables, and so the VIF test was performed. Results are presented in Table F.1.

After eliminating the variable with the largest VIF, the yield at issue, a new VIF was calculated to detect if there's still any multicollinearity. The final results are presented in Table F.2. Given that all VIF are less than ten, we can conclude that there are no signs of multicollinearity.

The new regression statistics without the variable yield at issue are presented in Table 5.2. Figure E.2 shows the OLS regression results for the model without the yield at issue variable with the coefficients, standard error, t-test and the p-values.

TABLE 5.2. Regression Statistics - without yield at issue. Source: Own representation

R Squared	0.663
Adj. R Squared	0.601
F- statistic	10.72
Prob (F-statistic)	$1.18e^{24}$
Log-Likelihood	-381.60
AIC	823.2
BIC	920.3

The new regression model is given in equation (5.2).

$$
\begin{aligned}
Y_i = {} & 74.8251 + 0.2649X_{1i} - 0.7395X_{2i} - 6.148 \times 10^{-8}X_{3i} \\
& - 0.0553X_{5i} - 0.0355X_{6i} - 0.0699X_{7i} + 2.6945X_{8i} \\
& + 1.4110X_{9i} + 0.6622X_{10i} + 0.3545X_{11i} + 0.1880X_{12i} \\
& - 4.5840X_{13i} + 1.4261X_{14i} + 2.9490X_{15i} + 1.4641X_{16i} \\
& + 3.2221X_{17i} + 5.2039X_{18i} + 0.4521X_{19i} + 2.0301X_{20i} \\
& + 1.9975X_{21i} + 2.7071X_{22i} + 3.2262X_{23i} + 3.3285X_{24i} \\
& + 0.0818X_{25i} + 2.4822X_{26i} - 0.9022X_{27i} + 0.3792X_{28i} \\
& + 4.3676X_{29i} + 2.7504X_{30i}
\end{aligned} \tag{5.2}
$$

The level of significance is once again five percent. The variables coupon, issue price, the sectors *Consumer Discretionary* and *Technology*, Callable and countries Belgium, Britain, Italy, Japan, Netherlands, Spain and US, are the only significant variables. The R^2 of this multivariate regression model is 0.663, the same as in the previous model. The only difference in the statistical regression between the two regressions is the decrease in the adjusted R-squared by 0.002, which means that the model fits slightly worse without the yield at issue.

The final model with only the significant variables is given by:

$$
\begin{aligned}
Y_i = {} & 74.8251 + 0.2649X_{1i} - 0.7395X_{2i} + 2.6945X_{8i} \\
& - 4.5840X_{13i} + 2.9490X_{15i} + 3.2221X_{17i} + 5.2039X_{18i} \\
& + 2.7071X_{22i} + 3.2262X_{23i} + 3.3285X_{24i} + 4.3676X_{29i} + 2.7504X_{30i}
\end{aligned} \tag{5.3}
$$

To evaluate the prediction accuracy, the RMSE (Root Mean Square Error) was calculated. The RMSE measures the difference between the predicted values and the actual observed values of both regressions. Table 5.3, shows the results of the two regressions.

Table 5.3. RMSE. Source: Own representation

RMSE first regression	RMSE second regression
1.8412	1.8420

Table shows 5.3 that there was an increase of 0.0008 in the difference between the predicted and actual values. This can also mean that the model predictions have become slightly less accurate, and the new regression model makes a slightly larger error when predicting ratings.

5.1. Significance of the Overall Multivariate Regression Model

A multivariate regression model with conventional and green bonds was built to test whether the issue of a green bond affects the credit risk, while controlling for other variables. The results show that the model is able to explain approximately 60% of the variation in credit ratings. Several variables are statistically significant including coupon rate, issue price, callable, sectors *Technology* and *Consumer Discretionary* and countries Belgium, Britain, Italy, Japan, Netherlands, Spain and US. These findings suggest that structural bond features and issuer characteristics are important determinants of the credit risk. In contrast, the green dummy variable is not statistically significant at the 5% level, indicating that the issuance of green bonds does not have an impact on credit risk. This means that the null hypothesis (H_0) cannot be rejected, there is no evidence that issuing green bonds may impact a company's credit risk. The variance influence test (VIF) initially revealed very high multicollinearity between the coupon rate and the yield at issue (both above 9000). To address this, the variable yield at issue was removed. This substantially reduced all VIF to below 10, indicating that there are no more issues with multicollinearity. According to the regression statistics, there was a slight increase in the adjusted R^2 (from 0.599 to 0.601) and a slight increase on the RMSE (1.8412 to 1.8420), meaning that the model remains unchanged. This suggests that the yield at issue did not add unique descriptive capacity beyond the other variables and its removal improved the coefficient without sacrificing the predictive accuracy. Overall, there is no evidence on green bond issuance that influences credit risk, supporting the conclusions that credit risk is primarily driven by bond design, sector and country specific factors rather than the green label.

5.2. Individual Multivariate Regressions

To further explore the impact of the green label on credit risk, we separated the previously studied multivariate regression model into two regressions, one with just green bonds and the other with only conventional bonds. This approach allows for a comparison of whether the determinants of credit risk differ between green and conventional bonds. By examining individual regressions, it is possible to assess whether the effects observed in the combined regression are present for each bond type or whether distinct patterns emerge, providing additional information on the influence of the green label on credit risk. It is important to note that there will be one fewer variable, since the green variable will be excluded.

5.2.1. Multivariate Regression for Green Bonds

Regression statistics are presented in Table 5.4. And Figure E.3 shows the OLS regression results for this model with only green bonds.

TABLE 5.4. Regression Statistics Green Bonds. Source: Own representation

R Squared	0.627
Adj. R Squared	0.458
F- statistic	3.705
Prob (F-statistic)	$6.42e^{-06}$
Log-Likelihood	-194.12
AIC	448.2
BIC	524.5

The regression equation is given by:

$$\begin{aligned} Y_i = &-154.4581 - 15.8292X_{1i} + 1.5576X_{2i} - 3.135 \times 10^{-7}X_{3i} \\ &+ 16.0091X_{4i} - 0.1189X_{5i} + 0.0331X_{6i} + 3.1294X_{8i} + 1.9880X_{9i} \\ &+ 1.4190X_{10i} + 1.1223X_{11i} + 0.7844X_{12i} - 3.6575X_{13i} \\ &+ 2.4185X_{14i} + 2.6336X_{15i} + 0.2253X_{16i} + 2.2403X_{17i} \\ &+ 4.3161X_{18i} - 0.2678X_{19i} + 1.0871X_{20i} + 1.2366X_{21i} \\ &+ 2.2828X_{22i} + 1.8306X_{23i} + 2.2743X_{24i} - 0.8678X_{25i} \\ &+ 1.3037X_{26i} - 2.3133X_{27i} - 1.0024X_{28i} + 3.3249X_{29i} \\ &+ 2.2709X_{30i} \end{aligned} \tag{5.4}$$

The p-values of the independent variables are used to assess the statistical significance. Since the level of significance is five percent, the only significant variables are Callable and the country Britain. There are fewer significant variables than the ones in the overall model. The adjusted R^2 of this multivariate model is 0.627, which means that 62.7% of the variation in the rating is explained by this model. It is already a worse percentage of the variation compared to the overall model, which was 66.3%. This means that the predictors of this model fit the green bond sample worse than the combined regression model. In other words, the factors included in the regression may have a weaker or less consistent relationship with the credit ratings for green bonds than for the entire dataset. As for the interpretation of the coefficients of the model:

- The intercept estimates the rating to be 154.4581 units, in the absence of the influence from the other variables, contrary to the overall model in equation (5.2), this is a negative coefficient. It is meaningless giving that the rating ranges between 1 and 21.
- The bond characteristics variables, coupon and 90-day volatility are negative, and, hence, the increase of these variables results in a lower numerical value of the rating, which in fact means an increase in the rating (see Table C.1). The amount issued is almost zero, which implies minor impacts. The issue price and

the maturity have positive coefficients, and, hence, an increase in these variables results in an increase of the rating. The maturity coefficient is also zero, practically without impact.

- The sector dummies have all positive coefficients except for *Technology*, the same as in the overall model. The impact is mostly positive, showing stronger sector differentiation in this model.
- The callable feature still has a positive coefficient.
- The effects of the dummy country have different magnitudes. There are some countries with high positive coefficients such as Britain, Germany, Spain and US, slightly positive with Austria, Belgium or negative such as Norway.

We used the VIF test to detect whether there was multicollinearity among the independent variables. Results are presented in Table F.3.

Considering that there are VIF greater than 10, there are signs of multicollinearity. We chose to eliminate the variable with the largest value of the VIF, in this case, the coupon. Table F.4 shows the recalculation of the VIF, without the previously eliminated variable.

Now all VIF values are less than ten and we can conclude that there are no longer signs of multicollinearity. Equation (5.4) presents the regression model without the variable coupon, and the regression statistics without this variable are presented in Table 5.5. Figure E.4 contains the results of this new OLS regression.

TABLE 5.5. Regression Statistics Green Bonds without the coupon variable. Source: Own representation

R Squared	0.621
Adj. R Squared	0.457
F- statistic	3.800
Prob (F-statistic)	$4.69e^{-06}$
Log-Likelihood	-194.86
AIC	447.7
BIC	521.5

The new regression model without the coupon variable is:

$$\begin{aligned} Y_i = {} & 23.6603 - 0.2230X_{2i} - 3.450 \times 10^{-7}X_{3i} \\ & + 0.2234X_{4i} - 0.1233X_{5i} + 0.0014X_{6i} + 3.2911X_{8i} + 1.9815X_{9i} \\ & + 1.4350X_{10i} + 1.0538X_{11i} + 0.9499X_{12i} - 3.7354X_{13i} \\ & + 2.3471X_{14i} + 2.6166X_{15i} + 0.8371X_{16i} + 2.9356X_{17i} \\ & + 4.6696X_{18i} - 0.0054X_{19i} + 1.4095X_{20i} + 1.5316X_{21i} \\ & + 2.5734X_{22i} + 2.0775X_{23i} + 2.5423X_{24i} - 0.4245X_{25i} \\ & + 1.7166X_{26i} - 1.8968X_{27i} - 0.6484X_{28i} + 3.5348X_{29i} \\ & + 2.4284X_{30i} \end{aligned} \tag{5.5}$$

The p-values of the independent variables show their significance. Since the level of significance is five percent, the variables Callable and Country Britain are the only significant variables, as in Equation (5.4). The R^2 is 0.621, that is, 62.1% of the variance of the rating variable is predicted from the independent variables. It is slightly lower than the previous model with the coupon variable shown in Table 5.4, meaning that the coupon variable contributed to some explanatory factors. The only difference between the coefficients of this equation and Equation (5.4) is that the intercept is positive in this new model and that the coefficient of the issue price is now negative, which means that an increase of the issue price results in an increase in the rating. All other coefficients remain, with the same signal.

The final model, the one with only the significant variables, is given by Equation (5.6), and the only significant variables being Callable and the country of issuance, Britain:

$$Y_i = 2.6166X_{15i} + 4.6696X_{18i} \tag{5.6}$$

5.2.2. Multivariate Regression for Conventional Bonds

Regression statistics for the model with only conventional bonds are presented in Table 5.6. Figure E.5 shows the OLS results.

TABLE 5.6. Regression Statistics Conventional Bonds. Source: Own representation

R Squared	0.738
Adj. R Squared	0.619
F- statistic	6.218
Prob (F-statistic)	$6.22e^{-10}$
Log-Likelihood	-180.40
AIC	420.8
BIC	497.1

The regression equation is given by:

$$\begin{aligned} Y_i = {} & 183.1424 + 8.8536X_{1i} - 1.8235X_{2i} - 6.071 \times 10^{-8}X_{3i} \\ & - 8.4942X_{4i} + 0.0002X_{5i} - 0.1027X_{6i} + 2.2280X_{8i} + 0.7463X_{9i} \\ & + 0.1947X_{10i} - 0.4502X_{11i} - 0.3830X_{12i} - 5.1682X_{13i} \\ & + 0.6946X_{14i} + 3.3561X_{15i} + 2.2108X_{16i} + 4.9290X_{17i} \\ & + 5.9423X_{18i} + 1.0413X_{19i} + 2.6252X_{20i} + 2.8588X_{21i} \\ & + 2.9362X_{22i} + 4.3192X_{23i} + 4.2373X_{24i} + 0.5873X_{25i} \\ & + 3.4027X_{26i} - 0.6404X_{27i} + 1.3959X_{28i} + 5.2687X_{29i} \\ & + 3.1807X_{30i} \end{aligned} \tag{5.7}$$

Given that the p-values show the significance of the independent variables and given that their significance level is five percent, the variables Callable, countries Belgium,

Britain, Japan, Netherlands and Spain are significant variables. Because this model does not have the green indicator, we cannot test the null hypothesis; we can only say that the significant variables are statistically associated with the variable rating. The R^2 of this multivariate regression model is 0.738, meaning that 73.8% of the rating variance is explained by the model. This is the highest coefficient obtained considering all models. Notably, the sign of certain coefficients differs between the green bond model and the conventional bond model. For instance, the coupon coefficient in equation (5.5) is negative and in this model is positive, meaning that this variable increases the rating in this model and in the green model decreases the rating, holding all other independent variables constant. This change in the coefficient signal is also the case for issue price, yield at issue, 90-day volatility, maturity, sectors *Industrials* and *Materials*, and countries Canada, Netherlands and South Korea. This suggests that these variables differ across bond types, which could reflect how the green bonds and conventional bonds markets operate. Nevertheless, this change may also arise from sample composition effects or multicollinearity.

We used the VIF test to detect if there was any indication of multicollinearity among the independent variables. Results of this test are presented in Table F.5.

The occurrence of a VIF greater than 10 indicates the presence of multicollinearity. We chose to eliminate the variable with the largest value of VIF, in this case is the yield at issue. We retook the test without the eliminated variable to study if there were still signs of multicollinearity. Table F.6 presents the results.

Now, all VIF values are less than ten, allowing us to conclude that there are no longer signs of multicollinearity. Equation (5.8) exhibits a regression model similar to equation (5.7) but without the variable yield at issue. The regression statistics of this new model are presented in Table 5.7, and Figure E.6 shows the results of this new OLS regression model.

TABLE 5.7. Regression Statistics Conventional Bonds without the yield at issue variable. Source: Own representation based on python output

R Squared	0.736
Adj. R Squared	0.623
F- statistic	6.485
Prob (F-statistic)	$2.84e^{-10}$
Log-Likelihood	-180.69
AIC	419.4
BIC	493.1

Finally, the equation for this new model is given by:

$$
\begin{aligned}
Y_i = {} & 88.8157 + 0.3311X_{1i} - 0.8828X_{2i} - 5.545 \times 10^{-8}X_{3i} \\
& + 0.0235X_{5i} - 0.0748X_{6i} + 2.0842X_{8i} + 0.7340X_{9i} + 0.1770X_{10i} \\
& - 0.4799X_{11i} - 0.4676X_{12i} - 5.1641X_{13i} + 0.6601X_{14i} \\
& + 3.2755X_{15i} + 2.1889X_{16i} + 4.5304X_{17i} + 5.8751X_{18i} \\
& + 0.8789X_{19i} + 2.6726X_{20i} + 2.8440X_{21i} + 2.9131X_{22i} \\
& + 4.2656X_{23i} + 4.3336X_{24i} + 0.6269X_{25i} + 3.4223X_{26i} \\
& - 0.5566X_{27i} + 1.3649X_{28i} + 5.2713X_{29i} + 3.2493X_{30i}
\end{aligned} \tag{5.8}
$$

Given that the p-values show the significance of the independent variables and given that the significance level is five percent, the variables Coupon, Callable and countries Belgium, Britain, Japan, Netherlands and Spain are the only significant variables. They are the only variables that show that there is a significant impact on the company's credit risk when issuing a bond. The R^2 of this regression is 0.736, a little less than the regression of conventional bonds with all variables. The adjusted R^2 increases by 0.004, indicating that the removal of the variable made the model slightly more efficient despite the decrease in the explanatory power, explained by the decrease in R^2.

It is of interest to note that the coupon variable becomes significant in the new model without the yield at issue, suggesting that it absorbs the variation previously explained by the yield at issue. Given that this model does not include the green indicator, we cannot reject the null hypothesis: it only means that the coupon is statistically associated with the rating variable.

The final model with no signs of multicollinearity is given by equation (5.9) with only significant variables:

$$
\begin{aligned}
Y_i = {} & 88.8157 + 0.3311X_{1i} + 3.2755X_{15i} + 4.5304X_{17i} + 5.8751X_{18i} \\
& + 4.2656X_{23i} + 4.3336X_{24i} + 5.2713X_{29i}
\end{aligned} \tag{5.9}
$$

5.2.3. Significance of the only green and only conventional models

The green regression model is able to explain approximately 62.7% of the variation in the bond rating, which is slightly lower than the overall model. This suggests that green bonds contain meaningful information about the dependent variable rating, and conventional bonds contribute to additional information regarding the overall model. The only significant variables are Callable and the country Britain. Other variables, including the green bond indicator, which is constant here, are not relevant in this subset. This limited number of significant variables indicates that the factors driving credit ratings in green bonds may differ from the factors of the overall market or that the sample size has reduced statistical power. The VIF test revealed a very high multicollinearity between the Coupon and the Yield at Issue (greater than 10,000). Removing the coupon variable

reduced all VIF values below 10, solving the multicollinearity problem. The coefficient R^2 decreased vaguely, indicating that the coupon added a small amount of explanatory power, but at the cost of losing the reliability of the coefficient estimates. This exchange improves the interpretability and robustness of the model. Altogether, this green model indicates that a bond being Callable and being issued from Britain influences the rating, while other factors are substantially insignificant. This suggests that within the green bond only sample, credit ratings are mostly driven by structural bond features rather than pricing or sector factors.

The model with conventional bonds has the highest explanatory power among all models, with a R^2 of 0.738. This indicates that conventional bond ratings are more predictable based on the chosen independent variables for this model. The significant variables include Coupon, Callable and countries Belgium, Britain, Japan, Netherlands and Spain. Compared to the only green bond model, more variables are statistically significant, which can mean that credit ratings in conventional bonds are influenced by a wider set of factors. Notably, several coefficients can have different signs between the green bond and conventional bond models. This is the case of the Coupon which is negative in the green model and positive in the conventional model, meaning that for green bonds, higher coupons reduce the ratings while for conventional bonds, higher coupons increase the ratings, holding other variables constant. Similar differences are observed for issue price, yield at issue, maturity and some sectors and countries. These differences reflect structural market differences, sample composition effects or residual multicollinearity. The VIF test showed high multicollinearity between yield at issue and coupon (values higher than 10,000). After removing the yield at issue, all the VIF values were below 10, and the new coefficient R^2 was 0.736.

Overall, this model showed that credit ratings are explained by structural, pricing and country characteristics. The variable Coupon becomes significant when the yield at issue is removed, absorbing the variation that was previously captured by the yield at issue.

CHAPTER 6

Conclusions

Corporations and governments often issue bonds to raise capital, as bonds allow them to raise money to fund projects from investors without giving up ownership or control. The only difference between green and conventional (non-green) bonds is that green bonds use their proceeds exclusively for environmentally sustainable projects, with the goal of promoting the transition towards a more sustainable and carbon-free world. With climate change and sustainability gaining more attention, the insistence for financial solutions is increasing, as is the green bond market.

This dissertation aims to examine whether the green label has an impact on a company's credit risk. To assess this, a matched sample of 94 green bonds and 94 conventional bonds from the same issuers was analysed using a multivariate regression model. The results indicate that the green label does not have a statistically significant effect on credit ratings, suggesting that issuing a green bond does not affect a company's credit risk. Instead, other factors, such as coupon, issue price, sector, country of issuance and a bond being callable, were found to play a more considerable role in determinate the rating.

The main contribution of this study is to provide empirical evidence in an area where academic research is still in its early stages. When showing that the green label does not influence credit risk, this analysis helps to understand an aspect of the green bond market, contributing to the ongoing debates about the costs, benefits and credibility of sustainable finance instruments. It also highlights the importance of regulatory frameworks and standardised definitions in order to ensure that green bonds achieve their full potential on environmental objectives rather than being subjected to greenwashing. However, according to Asgari (2019) [**1**], there is still a small risk that green bonds will become a "passing fad", as they carry the same credit rating and interest rate as conventional bonds but with lower liquidity. To reduce this risk, market regulations should be created by establishing a clean and unique definition of green bonds to ensure transparency and this requires external mandatory verification to guarantee that the goals of the green bonds are met.

This study has some limitations. The relatively small sample size and the still emerging nature of the green bond market mean that results presented here may not hold for a long time, particularly as new policies, initiatives and regulations are introduced. In addition, filtering criteria may have restricted the sample, limiting the universality of the finding. However, all filters used were justified.

For future research, we advise exploring long-term environmental benefits, the development of homogeneous global certification standards to reduce fragmentation and specific region or sector challenges and opportunities for market growth. Expanding the literature on green bonds and other green finance instruments will also be beneficial in

influencing policy design, strengthening market credibility, and guiding investors towards truly sustainable practices.

The necessity for sustainable finance continues to grow, understanding the actual purpose and effectiveness of green bonds will be important in ensuring that capital markets contribute meaningfully to the global transition to a low-carbon economy.

References

Asgari,N. (2019, July 3). "World's top pension fund warns against risk of green-bond "fad." "Financial Times. https://www.ft.com/content/f844f1c2-998e-11e9-8cfb-30c211dcd229(Accessed in September 2025)

Bachelet, M. J., Becchetti, L., & Manfredonia, S. (2019). "The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification."Sustainability, 11(4), 1098. https://doi.org/10.3390/su11041098

Baker McKenzie . (2019). "Critical challenges facing the green bond market "(M. Doran & J. Tanner, Eds.) [Review of Critical challenges facing the green bond market]. https://www.bakermckenzie.com/-/media/files/insight/publications/2019/09/iflr--green-bonds-%28002%29.pdf (Accessed in March 2025)

Ballester, L., González-Urteaga, A., & Shen, L. (2024). "Green bond issuance and credit Risk: International evidence. "Journal of International Financial Markets, Institutions & Money, 102013–102013. https://doi.org/10.1016/j.intfin.2024.102013

Banga, J. (2018). The green bond market: a potential source of climate finance for developing countries. Journal of Sustainable Finance & Investment, 9(1), 17–32. https://doi.org/10.1080/20430795.2018.1498617

Chang, Y. (2019, January 17). "Green Finance in Singapore: Barriers and Solutions. Papers.ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3326287

Cheng, C., Wen, X., & Xu, K. (2023). "Research on the Impact of Green Bonds on Credit Risk of Manufacturing Enterprises. "Journal of Risk Analysis and Crisis Response, 13(3). https://doi.org/10.54560/jracr.v13i3.382

China Green Bond Standard Committee . (2022). "China Green Bond Principles "[Review of China Green Bond Principles]. https://www.nafmii.org.cn/ggtz/gg/202207/P020220801631427094313.pdf (Accessed in March 2025)

Climate Bonds. (2024). "Climate Bonds Initiative. "Climate Bonds Initiative. https://www.climatebonds.net/

Climate Bonds Initiative (2025). "Climate Bonds Standard "(v.4.3) https://www.climatebonds.net/files/documents/CBI_Standard_V4.3_FINAL_2025-08-20-102147_gbqn.pdf (Accessed September 2025)

Ehlers, T., & Frank, P. (2017)."Green Bond Finance and Certification."Ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3042378

European Commission (2025) "Technical expert group on sustainable finance (TEG)."https://finance.ec.europa.eu/publications/technical-expert-group-sustainable-finance-teg_en

European Investment Bank. (2024, July 3)."Climate and Sustainability Awareness Bonds "[Review of Climate and Sustainability Awareness Bonds]. https://www.eib.org/en/investor-relations/sustainable-finance/index

European Union. (2020). “EU Regulation - EU - 2020/852 - EN - Eur-Lex. (2020). ”Europa.eu. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R0852

European Union. (2023). “EU Regulation - EU - 2023/2631 - EN - EUR-Lex. (2023). ”Europa.eu. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32023R2631

Fatica, S., Panzica, R., & Rancan, M. (2021). “The pricing of green bonds: Are financial institutions special? ”Journal of Financial Stability, 54(100873), 100873. https://doi.org/10.1016/j.jfs.2021.100873

Fitch Ratings. (2024). “Rating Definitions. ”Fitch Ratings. https://www.fitchratings.com/products/rating-definitions (Accessed March 2025)

Flammer, C. (2020). “Green Bonds: Effectiveness and Implications for Public Policy. ”Environmental and Energy Policy and the Economy, 1(1), 95–128. https://doi.org/10.1086/706794

G20 (2016). “Green Finance Synthesis Report ”G20 Green Finance Study Group GrDRAFT-VERSION 6 Vers G20 Green Finance Synthesis Report 2 Contents. https://g20sfwg.org/wp-content/uploads/2021/07/2016_Synthesis_Report_Full_EN.pdf (Accessed in September 2025)

Gilchrist, D., Yu, J., & Zhong, R. (2021). “The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans. ”Sustainability, 13(2), 478.

Hachenberg, B., & Schiereck, D. (2018).“Are Green Bonds Priced Differently from Conventional bonds?”Journal of Asset Management, 19(6), 371–383. https://doi.org/10.1057/s41260-018-0088-5

He, Z., Liu, Z., Wu, H., Gu, X., Zhao, Y., & Yue, X. (2020). “Research on the Impact of Green Finance and Fintech in Smart City.”Complexity, 2020, 1–10. https://doi.org/10.1155/2020/6673386

Hu, X., Zhong, A., & Cao, Y. (2022).“Greenium in the Chinese corporate bond market. ”Emerging Markets Review, 53, 100946. https://doi.org/10.1016/j.ememar.2022.100946

Hyun, S., Park, D., & Tian, S. (2019). “Differences Between Green Bonds Versus Conventional Bonds.”https://doi.org/10.1007/978-981-10-8710-3_34-1

International Capital Market Association (2014) “The Green Bond Principles.”https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/Green-Bond-Principles---Brochure-2014.pdf (Accessed in June 2025)

International Capital Market Association (2025) “Green Bond Principles Voluntary Process Guidelines for Issuing Green Bonds Principles.”(June 2025) https://www.icmagroup.org/assets/documents/Sustainable-finance/2025-updates/Green-Bond-Principles-GBP-June-2025.pdf (Accessed in July 2025)

Ivashkovskaya, I., & Mikhaylova, A. (2020, April 13).“Do Investors Pay Yield Premiums on Green Bonds?”Ssrn.com. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3752102

Johnson, R.A. and Wichern, D.W. (2007) “Applied Multivariate Statistical Analysis.”6th Edition, Pearson Prentice Hall, Upper Saddle River. pp.361,364

Li, Z.-Z., Li, R. Y. M., Malik, M. Y., Murshed, M., Khan, Z., & Umar, M. (2021). “Determinants of Carbon Emission in China: How Good is Green Investment?”Sustainable Production and Consumption, 27, 392–401. https://doi.org/10.1016/j.spc.2020.11.008

Mahmood, F., Younes Ben Zaied, & Abedin, M. Z. (2024). “Role of green finance instruments in shaping economic cycles. ”Technological Forecasting and Social Change, 209, 123792–123792. https://doi.org/10.1016/j.techfore.2024.123792

Marquardt, D. W. (1970).“Generalized Inverses, Ridge Regression, Biased Linear Estimation, and Nonlinear Estimation. ”Technometrics, 12(3), 591. https://doi.org/10.2307/1267205

McDonnell, C. (2024). “Pension funds and fossil fuel phase-out: historical developments and limitations of pension climate strategies. ”International Environmental Agreements/International Environmental Agreements (Print). https://doi.org/10.1007/s10784-024-09626-0

Merton, R. C. (1974). “On the Pricing of Corporate Debt: the Risk Structure of Interest Rates.”The Journal of Finance, 29(2), 449–470.

Moody’s. (2025). “Rating scale and definitions.”https://www.moodys.com/sites/products/ProductAttachments/AP075378_1_1408_KI.pdf (Accessed in March 2025)

Nanayakkara, M., & Colombage, S. (2019). “Do investors in Green Bond market pay a premium? Global evidence. ”Applied Economics, 51(40), 4425–4437. https://doi.org/10.1080/00036846.2019.1591611

Natural Resources Defense Council. (2016). “Clean Energy Finance Outlook: Opportunities for Green Banks and Green Bonds in Chile.”Natural Resources Defense Council.

O’Brien, R. M. (2007).“A caution regarding rules of thumb for variance inflation factors.”Quality & Quantity, 41(5), 673–690. https://doi.org/10.1007/s11135-006-9018-6

Okafor, A., Adusei, M., & Edo, O. C. (2024). “Effects of the utilization of green bonds proceeds on green bond premium. ”Journal of Cleaner Production, 469, 143131. https://doi.org/10.1016/j.jclepro.2024.143131

Partridge, C., & Medda, F. R. (2019).“The evolution of pricing performance of green municipal bonds.”Journal of Sustainable Finance & Investment, 10(1), 1–21. https://doi.org/10.1080/20430795.2019.1661187

People’s Bank of China, National Development and Reform Commission, & China Securities Regulatory Commission. (2021). “Green Bond Endorsed Projects Catalogue (2021 Edition) ”[Review of Green Bond Endorsed Projects Catalogue (2021 Edition)]. http://www.pbc.gov.cn/goutongjiaoliu/113456/113469/4342400/2021091617180089879.pdf (Accessed in March 2025)

Rawlings, J. O., Pantula, S. G., & Dickey, D. A. (1998). “Applied Regression Analysis. ”https://doi.org/10.1007/b98890 pp. 8-9, 15, 220, 222-223

Sartzetakis, E. S. (2020). “Green bonds as an instrument to finance low carbon transition. ”Economic Change and Restructuring, 54. https://doi.org/10.1007/s10644-020-09266-9

Sheng, Q., Zheng, X., & Zhong, N. (2021).“Financing for sustainability: Empirical analysis of green bond premium and issuer heterogeneity.”Natural Hazards. https://doi.org/10.1007/s11069-021-04540-z

Shishlov, I., Morel, R., & Cochran, I. (2016). “Beyond transparency: unlocking the full potential of green bonds.”https://www.i4ce.org/wp-content/uploads/2016/06/Executive-summary_Beyond-transparency-unlocking-the-full-potential-of-green-bonds.pdf

Standard & Poor’s Global. (2025). “Understanding Credit Ratings.”S&P Global. https://www.spglobal.com/ratings/en/credit-ratings/about/understanding-credit-ratings (Accessed March 2025)

Stern, N. H. (2006) “The Economics of Climate Change: The Stern Review. ”Cambridge University Press. pp.xv-xx

Tao, J. Y. (2015), “Utilising Green Bonds for Financing Renewable Energy Projects in Developing Asian Countries ”, in Kimura, S., Y. Chang and Y. Li (eds.), Financing Renewable Energy Development in East Asia Summit Countries. ERIA Research Project Report 2014-27, Jakarta: ERIA, pp.343-381

The World Bank. (2015). "Annual Report 2015."World Bank. https://www.worldbank.org/en/about/annual-report-2015(Accessed in August 2025)

Tolliver, C., Keeley, A. R., & Managi, S. (2020). "Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability."Journal of Cleaner Production, 244, 118643. https://doi.org/10.1016/j.jclepro.2019.118643

United Nations. (2015). "Transforming our world: The 2030 agenda for sustainable development."United Nations. https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (Accessed in June 2025)

United Nations Framework Convention on Climate Change. (2015)."Paris Agreement. "United Nations. https://unfccc.int/sites/default/files/english_paris_agreement.pdf (Accessed in June 2025)

Wang, X., & Wang, S. (2020). "The impact of green finance on inclusive economic growth—empirical analysis based on spatial panel. "Open Journal of Business and Management, 08(05), 2093–2112. https://doi.org/10.4236/ojbm.2020.85128

Wongaree, P., Chiyachantana, C. N., Ding, D. K., Prasarnphanich, P., & Siwasarit, W. (2025). "The pricing of green bonds and the determinants of the green bond premium in the Asia-Pacific and European markets."Journal of Open Innovation: Technology, Market, and Complexity, 11(2), 100546. https://doi.org/10.1016/j.joitmc.2025.100546

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

Zhang, X., & Xi, Y. (2024)."Green finance, private investments and fossil fuels rents."Resources Policy, 99, 105415. https://doi.org/10.1016/j.resourpol.2024.105415

APPENDIX A

Glossary

ACT/ACT Convention

Or, Actual/Actual is a financial day count convention used to calculate the amount of interest paid over a specific period. It is the devision of the actual number of days in the interest period by the actual number of days in the year (365 when a common year or 366 when a leap year).

Creditworthiness

Measures the probability that a company will default on their own debt obligations based on previous financials, current performance, and assessments by lenders or credit rating agencies.

EU Taxonomy

The EU Taxonomy is a classification system that establishes which economic activities are environmentally sustainable activities.

Greenium

Term combining green and premium, referring to the yield discount observed in green bonds relative to conventional bonds.

Greenwashing

Greenwashing is when a bond is issued as environmental project, yet it does not follow concrete measures as one.

Securitised

Also known as green securitisation. It is the financial mechanism for transforming environmental projects into financial products.

SRIs

SRIs refer to socially responsible investors. They are investors who allocate capital towards projects that follow the ESG criteria.

Sustainable Finance

Investment and financing decisions that take into account not only traditional financial criteria, but also environmental, social and governance consideration. It aims to a long-term sustainable commitment while addressing climate change, inequality and social cohesion.

Sustainable Finance Action Plan

Created by the European Commission. Is a plan to direct finance to specific needs from the European economy to benefit the environment and the social. It is a step towards achieving the Paris Agreement and the EU's agenda for sustainable development.

APPENDIX B

SDGs and Their Relation to Green Bonds

TABLE B.1. SDGs and Their Relation to Green Bonds. Source: SDGs and author

#	**Social Development Goals**	**Description**	**How they relate to Green Bonds**
SDG 3	Good Health and Well-Being	Ensure healthy lives and promote well-being for all at all ages	Indirect benefit through improved environmental quality and reduced pollution, contributing to better public health outcomes
SDG 6	Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all	Indirect benefits through investments in water efficiency and pollution control, enhancing water security and sanitation
SDG 7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all	Financing renewable energy projects, such as solar, wind, and hydropower
SDG 8	Decent Work and Economic Growth	Promote sustained inclusive and sustainable economic growth, full and productive employment and decent work for all	Indirect benefits through the creation of green jobs and sustainable economic activities
SDG 9	Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation	Supporting sustainable and climate-resilient infrastructure
SDG 11	Sustainable Cities and Communities	Make Cities and human settlements inclusive, safe, resilient and sustainable	Funding green buildings, clean transportation and urban resilience projects

#	**Social Development Goals**	**Description**	**How they relate to Green Bonds**
SDG 12	Resposible Consumption and Production	Ensure sustainable consumption and production patterns	Promoting resource efficient and circular economy activities
SDG 13	Climate Action	Take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy	Central to the green bond agenda, focusing on emission reduction and climate adaptation
SDG 14	Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	(in case of blue bonds [1]) financing ocean conservation and marine protection initiatives
SDG 15	Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss	Supporting reforestation, biodiversity conservation and sustainable land use.

Source: UN 2030 Agenda

[1]Blue bonds are a specific category of bonds in which capital is raised to fund investments in healthy oceans and the blue economy, aligned with the UN Sustainable Development Goal number 14 (Life below Water). They are similar to green bonds, except that they specifically focus on marine and ocean-related initiatives.

APPENDIX C

Rating scale and numerical scale

TABLE C.1. Rating scales on a numerical. Source: Own representation

S&P Values	**Fitch Values**	**Moody's Values**	**Assigned Numbers**
AAA	AAA	Aaa	1
AA+	AA+	Aa1	2
AA	AA	Aa2	3
AA-	AA-	Aa3	4
A+	A+	A1	5
A	A	A2	6
A-	A-	A3	7
BBB+	BBB +	Baa1	8
BBB	BBB	Baa2	9
BBB-	BBB-	Baa3	10
BB+	BB+	Ba1	11
BB	BB	Ba2	12
BB-	BB-	Ba3	13
B+	B+	B1	14
B	B	B2	15
B-	B-	B3	16
CCC+	CCC+	Caa1	17
CCC	CCC	Caa2	18
CCC-	CCC-	Caa3	19
CC	CC	Ca	20
C	C	C	21
D	D	-	22

APPENDIX D

Pie Chart Maturities

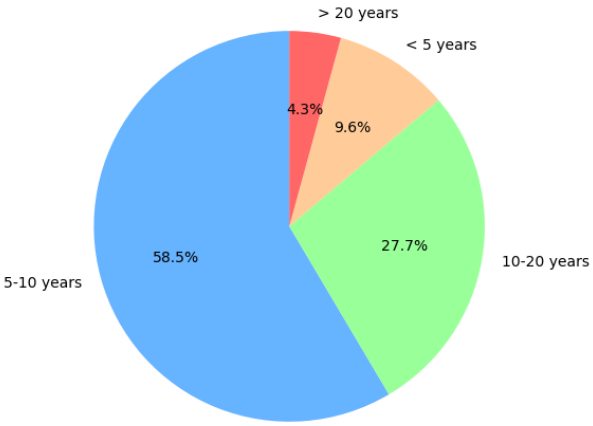


FIGURE D.1. Maturity Distribution of Green Bonds. Source: Own representation

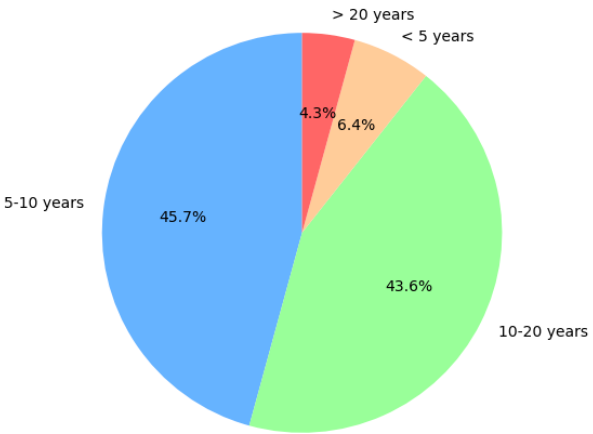


FIGURE D.2. Maturity Distribution Conventional Bonds. Source: Own representation

APPENDIX E

OLS Regression Results

Regression Results:

OLS Regression Results

Dep. Variable:	rating	R-squared:	0.663
Model:	OLS	Adj. R-squared:	0.599
Method:	Least Squares	F-statistic:	10.31
Date:	Thu, 21 Aug 2025	Prob (F-statistic):	3.68e-24
Time:	16:36:22	Log-Likelihood:	-381.52
No. Observations:	188	AIC:	825.0
Df Residuals:	157	BIC:	925.4
Df Model:	30		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	37.6141	104.647	0.359	0.720	-169.083	244.311
coupon	-3.0843	8.832	-0.349	0.727	-20.529	14.360
issue_price	-0.3678	1.045	-0.352	0.725	-2.433	1.697
amt_issued	-5.937e-08	5.98e-08	-0.992	0.323	-1.78e-07	5.88e-08
yield_at_issue	3.3375	8.800	0.379	0.705	-14.044	20.719
90d_volatility	-0.0489	0.107	-0.459	0.647	-0.260	0.162
maturity	-0.0277	0.065	-0.429	0.668	-0.155	0.100
green	-0.0814	0.308	-0.264	0.792	-0.689	0.527
sector_Consumer Discretionary	2.6483	1.074	2.465	0.015	0.527	4.770
sector_Financials	1.4114	0.915	1.543	0.125	-0.395	3.218
sector_Government	0.6664	1.003	0.665	0.507	-1.314	2.647
sector_Industrials	0.3512	1.107	0.317	0.752	-1.836	2.539
sector_Materials	0.1541	1.114	0.138	0.890	-2.045	2.354
sector_Technology	-4.5809	1.848	-2.479	0.014	-8.231	-0.931
sector_Utilities	1.4190	0.885	1.604	0.111	-0.328	3.166
callable_1	2.9404	0.544	5.404	0.000	1.866	4.015
country_Austria	1.3954	1.415	0.986	0.326	-1.400	4.190
country_Belgium	3.0860	1.556	1.984	0.049	0.013	6.159
country_Britain	5.1660	1.243	4.157	0.000	2.711	7.621
country_Canada	0.3877	1.334	0.291	0.772	-2.248	3.024
country_France	2.0116	1.198	1.679	0.095	-0.355	4.378
country_Germany	1.9602	1.232	1.591	0.114	-0.473	4.394
country_Italy	2.6742	1.213	2.205	0.029	0.279	5.070
country_Japan	3.1927	1.194	2.675	0.008	0.835	5.550
country_Netherlands	3.3283	1.264	2.633	0.009	0.832	5.825
country_Norway	0.0425	1.267	0.034	0.973	-2.461	2.546
country_Other	2.4413	1.275	1.915	0.057	-0.076	4.959
country_SNAT	-0.9296	1.569	-0.593	0.554	-4.028	2.169
country_South Korea	0.3332	1.555	0.214	0.831	-2.739	3.405
country_Spain	4.3464	1.208	3.598	0.000	1.961	6.732
country_US	2.7487	1.377	1.996	0.048	0.028	5.469

Omnibus:	18.225	Durbin-Watson:	2.086
Prob(Omnibus):	0.000	Jarque-Bera (JB):	38.276
Skew:	0.433	Prob(JB):	4.88e-09
Kurtosis:	5.034	Cond. No.	2.10e+09

FIGURE E.1. Regression Results. Source: Own representation

Reduced Regression Results (without yield_at_issue):

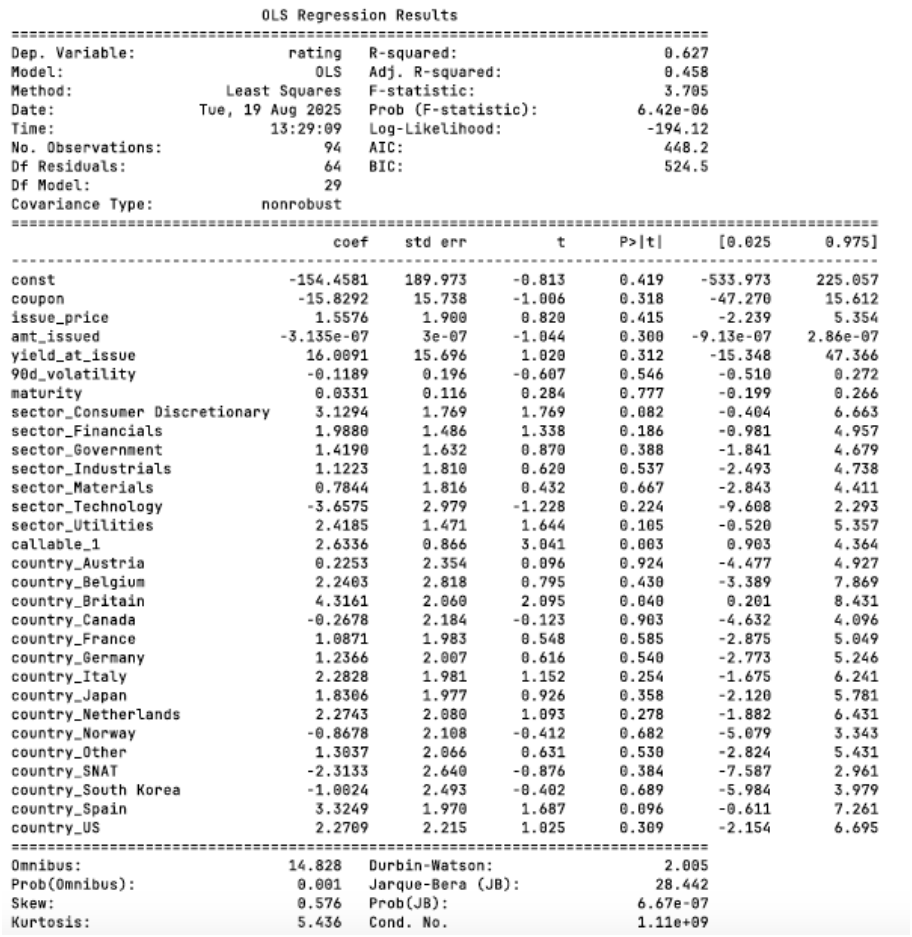
OLS Regression Results

Dep. Variable:	rating	R-squared:	0.663
Model:	OLS	Adj. R-squared:	0.601
Method:	Least Squares	F-statistic:	10.72
Date:	Thu, 21 Aug 2025	Prob (F-statistic):	1.18e-24
Time:	16:36:22	Log-Likelihood:	-381.60
No. Observations:	188	AIC:	823.2
Df Residuals:	158	BIC:	928.3
Df Model:	29		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	74.8251	36.288	2.062	0.041	3.153	146.497
coupon	0.2649	0.110	2.410	0.017	0.048	0.482
issue_price	-0.7395	0.363	-2.035	0.043	-1.457	-0.022
amt_issued	-6.148e-08	5.94e-08	-1.035	0.302	-1.79e-07	5.59e-08
90d_volatility	-0.0553	0.105	-0.526	0.600	-0.263	0.152
maturity	-0.0355	0.061	-0.582	0.562	-0.156	0.085
green	-0.0699	0.305	-0.229	0.819	-0.673	0.533
sector_Consumer Discretionary	2.6945	1.064	2.532	0.012	0.592	4.797
sector_Financials	1.4110	0.912	1.547	0.124	-0.391	3.213
sector_Government	0.6622	1.000	0.662	0.509	-1.313	2.637
sector_Industrials	0.3545	1.104	0.321	0.749	-1.827	2.536
sector_Materials	0.1880	1.107	0.170	0.865	-1.998	2.374
sector_Technology	-4.5840	1.843	-2.487	0.014	-8.224	-0.944
sector_Utilities	1.4261	0.882	1.617	0.108	-0.316	3.168
callable_1	2.9490	0.542	5.439	0.000	1.878	4.020
country_Austria	1.4641	1.400	1.046	0.297	-1.300	4.228
country_Belgium	3.2221	1.510	2.134	0.034	0.240	6.204
country_Britain	5.2039	1.235	4.212	0.000	2.764	7.644
country_Canada	0.4521	1.320	0.342	0.732	-2.155	3.059
country_France	2.0301	1.194	1.700	0.091	-0.328	4.388
country_Germany	1.9975	1.225	1.631	0.105	-0.421	4.416
country_Italy	2.7071	1.206	2.244	0.026	0.324	5.090
country_Norway	0.0818	1.260	0.065	0.948	-2.406	2.570
country_Other	2.4822	1.267	1.960	0.052	-0.020	4.984
country_SNAT	-0.9022	1.563	-0.577	0.565	-3.989	2.184
country_South Korea	0.3792	1.546	0.245	0.807	-2.675	3.433
country_Spain	4.3676	1.203	3.630	0.000	1.991	6.744
country_US	2.7504	1.374	2.002	0.047	0.037	5.463

Omnibus:	18.319	Durbin-Watson:	2.084
Prob(Omnibus):	0.000	Jarque-Bera (JB):	38.546
Skew:	0.434	Prob(JB):	4.26e-09
Kurtosis:	5.041	Cond. No.	7.26e+08

FIGURE E.2. Regression Results without yield at issue. Source: Onwn representation



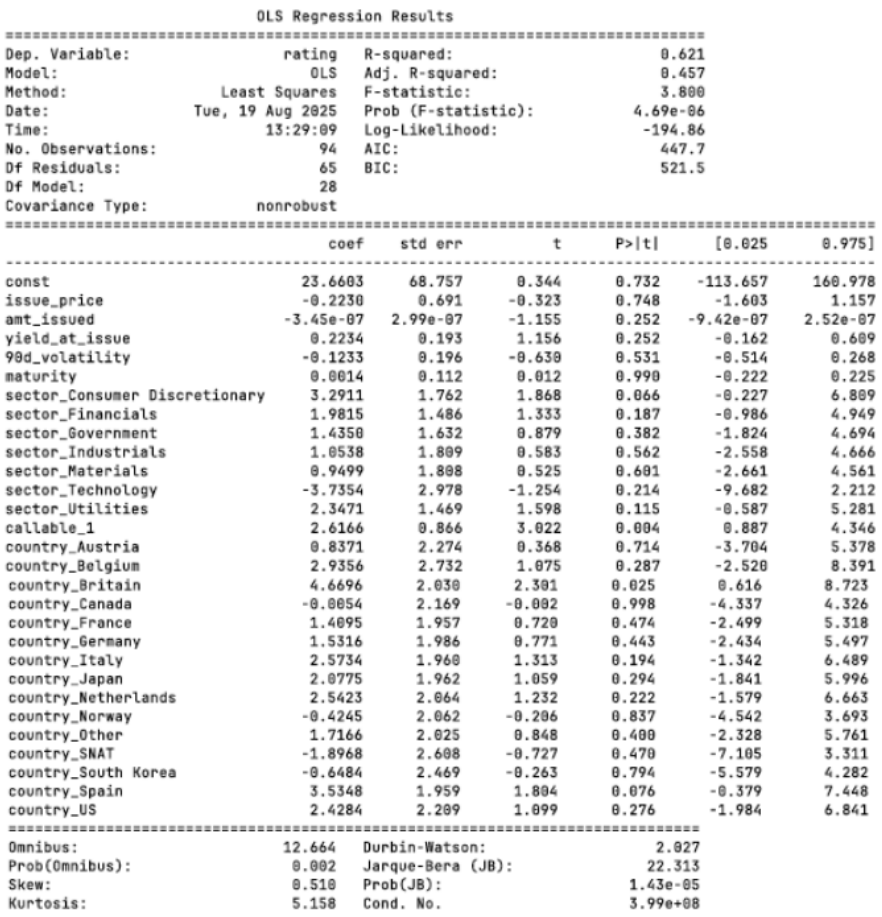
OLS Regression Results

Dep. Variable:	rating	R-squared:	0.627
Model:	OLS	Adj. R-squared:	0.458
Method:	Least Squares	F-statistic:	3.705
Date:	Tue, 19 Aug 2025	Prob (F-statistic):	6.42e-06
Time:	13:29:09	Log-Likelihood:	-194.12
No. Observations:	94	AIC:	448.2
Df Residuals:	64	BIC:	524.5
Df Model:	29		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-154.4581	189.973	-0.813	0.419	-533.973	225.057
coupon	-15.8292	15.738	-1.006	0.318	-47.270	15.612
issue_price	1.5576	1.900	0.820	0.415	-2.239	5.354
amt_issued	-3.135e-07	3e-07	-1.044	0.300	-9.13e-07	2.86e-07
yield_at_issue	16.0091	15.696	1.020	0.312	-15.348	47.366
90d_volatility	-0.1189	0.196	-0.607	0.546	-0.510	0.272
maturity	0.0331	0.116	0.284	0.777	-0.199	0.266
sector_Consumer Discretionary	3.1294	1.769	1.769	0.082	-0.404	6.663
sector_Financials	1.9880	1.486	1.338	0.186	-0.981	4.957
sector_Government	1.4190	1.632	0.870	0.388	-1.841	4.679
sector_Industrials	1.1223	1.810	0.620	0.537	-2.493	4.738
sector_Materials	0.7844	1.816	0.432	0.667	-2.843	4.411
sector_Technology	-3.6575	2.979	-1.228	0.224	-9.608	2.293
sector_Utilities	2.4185	1.471	1.644	0.105	-0.520	5.357
callable_1	2.6336	0.866	3.041	0.003	0.903	4.364
country_Austria	0.2253	2.354	0.096	0.924	-4.477	4.927
country_Belgium	2.2403	2.818	0.795	0.430	-3.389	7.869
country_Britain	4.3161	2.060	2.095	0.040	0.201	8.431
country_Canada	-0.2678	2.184	-0.123	0.903	-4.632	4.096
country_France	1.0871	1.983	0.548	0.585	-2.875	5.049
country_Germany	1.2366	2.007	0.616	0.540	-2.773	5.246
country_Italy	2.2828	1.981	1.152	0.254	-1.675	6.241
country_Japan	1.8306	1.977	0.926	0.358	-2.120	5.781
country_Netherlands	2.2743	2.080	1.093	0.278	-1.882	6.431
country_Norway	-0.8678	2.108	-0.412	0.682	-5.079	3.343
country_Other	1.3037	2.066	0.631	0.530	-2.824	5.431
country_SNAT	-2.3133	2.640	-0.876	0.384	-7.587	2.961
country_South Korea	-1.0024	2.493	-0.402	0.689	-5.984	3.979
country_Spain	3.3249	1.970	1.687	0.096	-0.611	7.261
country_US	2.2709	2.215	1.025	0.309	-2.154	6.695

Omnibus:	14.828	Durbin-Watson:	2.005
Prob(Omnibus):	0.001	Jarque-Bera (JB):	28.442
Skew:	0.576	Prob(JB):	6.67e-07
Kurtosis:	5.436	Cond. No.	1.11e+09

FIGURE E.3. Regression Results - Green Bonds Only. Source: Own representation



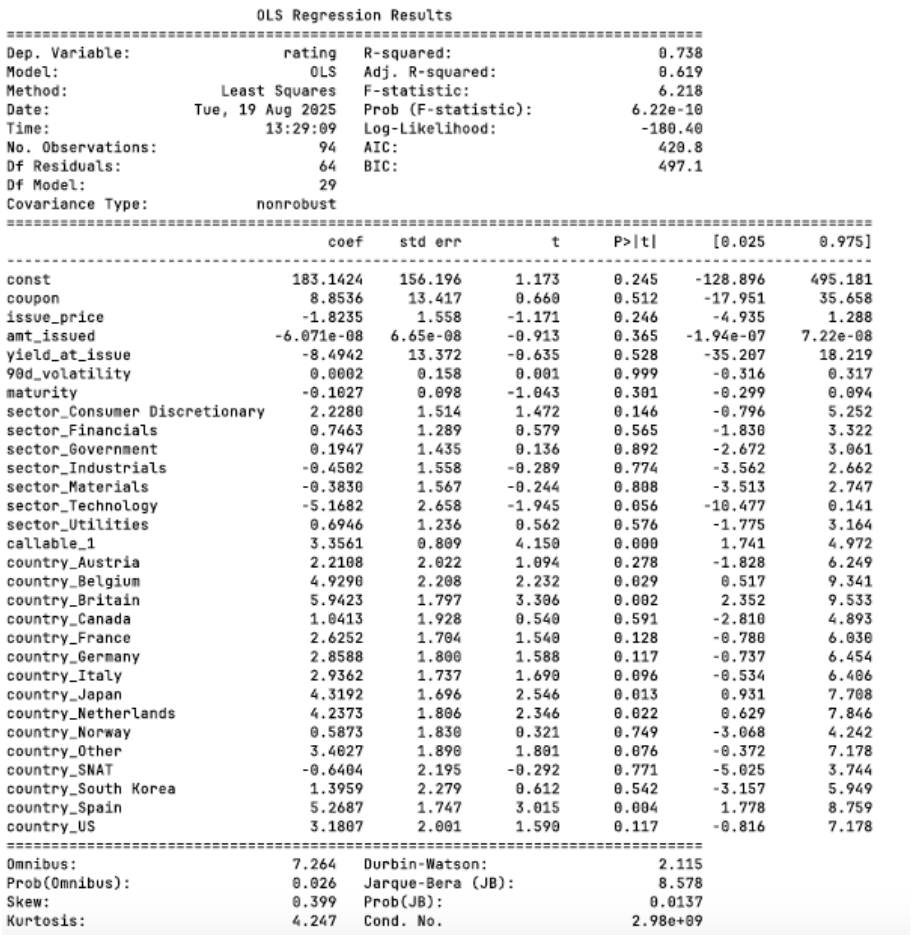
OLS Regression Results

Dep. Variable:	rating	R-squared:	0.621
Model:	OLS	Adj. R-squared:	0.457
Method:	Least Squares	F-statistic:	3.800
Date:	Tue, 19 Aug 2025	Prob (F-statistic):	4.69e-06
Time:	13:29:09	Log-Likelihood:	-194.86
No. Observations:	94	AIC:	447.7
Df Residuals:	65	BIC:	521.5
Df Model:	28		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	23.6603	68.757	0.344	0.732	-113.657	160.978
issue_price	-0.2230	0.691	-0.323	0.748	-1.603	1.157
amt_issued	-3.45e-07	2.99e-07	-1.155	0.252	-9.42e-07	2.52e-07
yield_at_issue	0.2234	0.193	1.156	0.252	-0.162	0.609
90d_volatility	-0.1233	0.196	-0.630	0.531	-0.514	0.268
maturity	0.0014	0.112	0.012	0.990	-0.222	0.225
sector_Consumer Discretionary	3.2911	1.762	1.868	0.066	-0.227	6.809
sector_Financials	1.9815	1.486	1.333	0.187	-0.986	4.949
sector_Government	1.4350	1.632	0.879	0.382	-1.824	4.694
sector_Industrials	1.0538	1.809	0.583	0.562	-2.558	4.666
sector_Materials	0.9499	1.808	0.525	0.601	-2.661	4.561
sector_Technology	-3.7354	2.978	-1.254	0.214	-9.682	2.212
sector_Utilities	2.3471	1.469	1.598	0.115	-0.587	5.281
callable_1	2.6166	0.866	3.022	0.004	0.887	4.346
country_Austria	0.8371	2.274	0.368	0.714	-3.704	5.378
country_Belgium	2.9356	2.732	1.075	0.287	-2.520	8.391
country_Britain	4.6696	2.030	2.301	0.025	0.616	8.723
country_Canada	-0.0054	2.169	-0.002	0.998	-4.337	4.326
country_France	1.4095	1.957	0.720	0.474	-2.499	5.318
country_Germany	1.5316	1.986	0.771	0.443	-2.434	5.497
country_Italy	2.5734	1.960	1.313	0.194	-1.342	6.489
country_Japan	2.0775	1.962	1.059	0.294	-1.841	5.996
country_Netherlands	2.5423	2.064	1.232	0.222	-1.579	6.663
country_Norway	-0.4245	2.062	-0.206	0.837	-4.542	3.693
country_Other	1.7166	2.025	0.848	0.400	-2.328	5.761
country_SNAT	-1.8968	2.608	-0.727	0.470	-7.105	3.311
country_South Korea	-0.6484	2.469	-0.263	0.794	-5.579	4.282
country_Spain	3.5348	1.959	1.804	0.076	-0.379	7.448
country_US	2.4284	2.209	1.099	0.276	-1.984	6.841

Omnibus:	12.664	Durbin-Watson:	2.027
Prob(Omnibus):	0.002	Jarque-Bera (JB):	22.313
Skew:	0.518	Prob(JB):	1.43e-05
Kurtosis:	5.158	Cond. No.	3.99e+08

FIGURE E.4. Regression Results - Green Bonds Only, without coupon. Source: Own representation



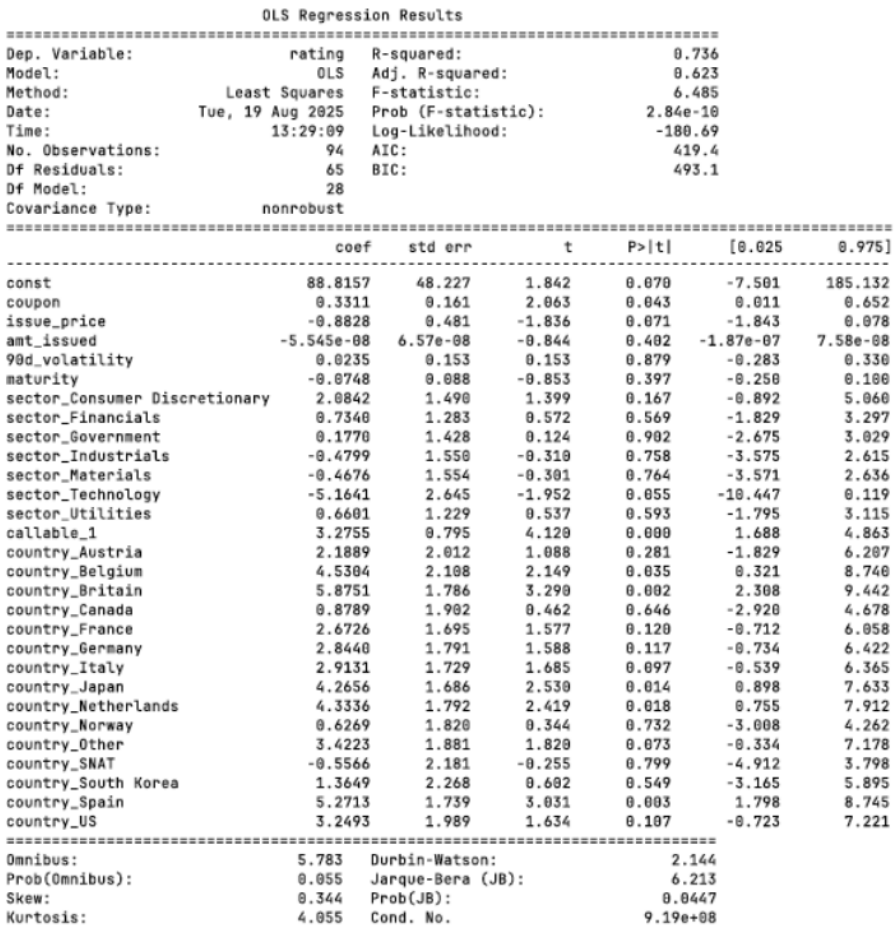
OLS Regression Results

Dep. Variable:	rating	R-squared:	0.738
Model:	OLS	Adj. R-squared:	0.619
Method:	Least Squares	F-statistic:	6.218
Date:	Tue, 19 Aug 2025	Prob (F-statistic):	6.22e-10
Time:	13:29:09	Log-Likelihood:	-180.40
No. Observations:	94	AIC:	420.8
Df Residuals:	64	BIC:	497.1
Df Model:	29		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	183.1424	156.196	1.173	0.245	-128.896	495.181
coupon	8.8536	13.417	0.660	0.512	-17.951	35.658
issue_price	-1.8235	1.558	-1.171	0.246	-4.935	1.288
amt_issued	-6.071e-08	6.65e-08	-0.913	0.365	-1.94e-07	7.22e-08
yield_at_issue	-8.4942	13.372	-0.635	0.528	-35.207	18.219
90d_volatility	0.0002	0.158	0.001	0.999	-0.316	0.317
maturity	-0.1027	0.098	-1.043	0.301	-0.299	0.094
sector_Consumer Discretionary	2.2280	1.514	1.472	0.146	-0.796	5.252
sector_Financials	0.7463	1.289	0.579	0.565	-1.830	3.322
sector_Government	0.1947	1.435	0.136	0.892	-2.672	3.061
sector_Industrials	-0.4502	1.558	-0.289	0.774	-3.562	2.662
sector_Materials	-0.3830	1.567	-0.244	0.808	-3.513	2.747
sector_Technology	-5.1682	2.658	-1.945	0.056	-10.477	0.141
sector_Utilities	0.6946	1.236	0.562	0.576	-1.775	3.164
callable_1	3.3561	0.809	4.150	0.000	1.741	4.972
country_Austria	2.2108	2.022	1.094	0.278	-1.828	6.249
country_Belgium	4.9290	2.208	2.232	0.029	0.517	9.341
country_Britain	5.9423	1.797	3.306	0.002	2.352	9.533
country_Canada	1.0413	1.928	0.540	0.591	-2.810	4.893
country_France	2.6252	1.704	1.540	0.128	-0.780	6.030
country_Germany	2.8588	1.800	1.588	0.117	-0.737	6.454
country_Italy	2.9362	1.737	1.690	0.096	-0.534	6.406
country_Japan	4.3192	1.696	2.546	0.013	0.931	7.708
country_Netherlands	4.2373	1.806	2.346	0.022	0.629	7.846
country_Norway	0.5873	1.830	0.321	0.749	-3.068	4.242
country_Other	3.4027	1.898	1.801	0.076	-0.372	7.178
country_SNAT	-0.6404	2.195	-0.292	0.771	-5.025	3.744
country_South Korea	1.3959	2.279	0.612	0.542	-3.157	5.949
country_Spain	5.2687	1.747	3.015	0.004	1.778	8.759
country_US	3.1807	2.001	1.590	0.117	-0.816	7.178

Omnibus:	7.264	Durbin-Watson:	2.115
Prob(Omnibus):	0.026	Jarque-Bera (JB):	8.578
Skew:	0.399	Prob(JB):	0.0137
Kurtosis:	4.247	Cond. No.	2.98e+09

FIGURE E.5. Regression Results - Conventional Bonds Only. Source: Own representation



OLS Regression Results

Dep. Variable:	rating	R-squared:	0.736
Model:	OLS	Adj. R-squared:	0.623
Method:	Least Squares	F-statistic:	6.485
Date:	Tue, 19 Aug 2025	Prob (F-statistic):	2.84e-10
Time:	13:29:09	Log-Likelihood:	-180.69
No. Observations:	94	AIC:	419.4
Df Residuals:	65	BIC:	493.1
Df Model:	28		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	88.8157	48.227	1.842	0.070	-7.501	185.132
coupon	0.3311	0.161	2.063	0.043	0.011	0.652
issue_price	-0.8828	0.481	-1.836	0.071	-1.843	0.078
amt_issued	-5.545e-08	6.57e-08	-0.844	0.402	-1.87e-07	7.58e-08
90d_volatility	0.0235	0.153	0.153	0.879	-0.283	0.330
maturity	-0.0748	0.088	-0.853	0.397	-0.250	0.100
sector_Consumer Discretionary	2.0842	1.490	1.399	0.167	-0.892	5.060
sector_Financials	0.7340	1.283	0.572	0.569	-1.829	3.297
sector_Government	0.1770	1.428	0.124	0.902	-2.675	3.029
sector_Industrials	-0.4799	1.550	-0.310	0.758	-3.575	2.615
sector_Materials	-0.4676	1.554	-0.301	0.764	-3.571	2.636
sector_Technology	-5.1641	2.645	-1.952	0.055	-10.447	0.119
sector_Utilities	0.6601	1.229	0.537	0.593	-1.795	3.115
callable_1	3.2755	0.795	4.120	0.000	1.688	4.863
country_Austria	2.1889	2.012	1.088	0.281	-1.829	6.207
country_Belgium	4.5304	2.108	2.149	0.035	0.321	8.740
country_Britain	5.8751	1.786	3.290	0.002	2.308	9.442
country_Canada	0.8789	1.902	0.462	0.646	-2.920	4.678
country_France	2.6726	1.695	1.577	0.120	-0.712	6.058
country_Germany	2.8440	1.791	1.588	0.117	-0.734	6.422
country_Italy	2.9131	1.729	1.685	0.097	-0.539	6.365
country_Japan	4.2656	1.686	2.530	0.014	0.898	7.633
country_Netherlands	4.3336	1.792	2.419	0.018	0.755	7.912
country_Norway	0.6269	1.820	0.344	0.732	-3.008	4.262
country_Other	3.4223	1.881	1.820	0.073	-0.334	7.178
country_SNAT	-0.5566	2.181	-0.255	0.799	-4.912	3.798
country_South Korea	1.3649	2.268	0.602	0.549	-3.165	5.895
country_Spain	5.2713	1.739	3.031	0.003	1.798	8.745
country_US	3.2493	1.989	1.634	0.107	-0.723	7.221

Omnibus:	5.783	Durbin-Watson:	2.144
Prob(Omnibus):	0.055	Jarque-Bera (JB):	6.213
Skew:	0.344	Prob(JB):	0.0447
Kurtosis:	4.055	Cond. No.	9.19e+08

FIGURE E.6. Regression Results - Conventional Bonds Only, without yield at issue. Source: Own representation

APPENDIX F

VIF Results

TABLE F.1. First VIF Results - Overall Sample. Source: Own representation

Feature	**VIF**
Constant	507173.06
Coupon	9218.01
Issue Price	11.35
Amount Issued	1.23
Yield at Issue	9221.37
90-day volatility	3.99
Maturity	3.81
Green	1.10
Sector Consumer Discretionary	4.16
Sector Financials	9.25
Sector Government	7.51
Sector Industrials	2.31
Sector Materials	2.34
Sector Technology	1.66
Sector Utilities	5.37
Callable	3.29
Country Austria	2.87
Country Belgium	2.33
Country Britain	5.57
Country Canada	3.36
Country France	6.32
Country Germany	6.09
Country Italy	5.90
Country Japan	5.14
Country Netherlands	5.76
Country Norway	4.45
Country Other	5.86

Feature	VIF
Country SNAT	2.37
Country South Korea	2.33
Country Spain	5.26
Country US	4.42

TABLE F.2. Second VIF Results - Overall Sample. Source: Own representation

Feature	VIF
Constant	61318.52
Coupon	1.44
Issue Price	1.38
Amount Issued	1.22
90-day volatility	3.89
Maturity	3.42
Green	1.09
Sector Consumer Discretionary	4.11
Sector Financials	9.25
Sector Government	7.51
Sector Industrials	2.31
Sector Materials	2.32
Sector Technology	1.66
Sector Utilities	5.37
Callable	3.28
Country Austria	2.82
Country Belgium	2.21
Country Britain	5.53
Country Canada	3.31
Country France	6.31
Country Germany	6.05
Country Italy	5.87
Country Japan	5.11
Country Netherlands	5.76
Country Norway	4.42
Country Other	5.82

Feature	VIF
Country SNAT	2.37
Country South Korea	2.32
Country Spain	5.25
Country US	4.42

TABLE F.3. First VIF Results - Green Only. Source: Own representation

Feature	VIF
Constant	634310.82
Coupon	10533.23
Issue Price	11.29
Amount Issued	1.95
Yield at Issue	10525.45
90-day volatility	5.60
Maturity	4.90
Sector Consumer Discretionary	4.28
Sector Financials	9.26
Sector Government	7.55
Sector Industrials	2.35
Sector Materials	2.36
Sector Technology	1.64
Sector Utilities	5.63
Callable	3.15
Country Austria	3.00
Country Belgium	2.91
Country Britain	5.81
Country Canada	3.42
Country France	6.57
Country Germany	6.13
Country Italy	5.97
Country Japan	5.35
Country Netherlands	5.92
Country Norway	4.67
Country Other	5.84

Feature	VIF
Country SNAT	2.55
Country South Korea	2.28
Country Spain	5.31
Country US	4.34

TABLE F.4. Second VIF results - Green Only. Source: Own representation

Feature	VIF
Constant	83075.93
Issue Price	1.49
Amount Issued	1.92
Yield at Issue	1.59
90-day volatility	5.60
Maturity	4.54
Sector Consumer Discretionary	4.25
Sector Financials	9.26
Sector Government	7.55
Sector Industrials	2.34
Sector Materials	2.34
Sector Technology	1.64
Sector Utilities	5.62
Callable	3.15
Country Austria	2.81
Country Belgium	2.73
Country Britain	5.64
Country Canada	3.37
Country France	6.40
Country Germany	6.00
Country Italy	5.85
Country Japan	5.27
Country Netherlands	5.83
Country Norway	4.46
Country Other	5.61
Country SNAT	2.49

Feature	VIF
Country South Korea	2.23
Country Spain	5.25
Country US	4.32

TABLE F.5. First VIF results - Conventional only. Source: Own representation

Feature	VIF
Constant	574190.72
Issue Price	15.44
Amount Issued	1.40
Yield at Issue	10888.17
90-day volatility	4.00
Maturity	4.23
Sector Consumer Discretionary	4.20
Sector Financials	9.34
Sector Government	7.82
Sector Industrials	2.33
Sector Materials	2.35
Sector Technology	1.75
Sector Utilities	5.33
Callable	3.71
Country Austria	2.97
Country Belgium	2.39
Country Britain	5.92
Country Canada	3.56
Country France	6.50
Country Germany	6.60
Country Italy	6.15
Country Japan	5.27
Country Netherlands	5.98
Country Norway	4.71
Country Other	6.54
Country SNAT	2.36
Country South Korea	2.55

Feature	VIF
Country Spain	5.59
Country US	4.75

TABLE F.6. Second VIF results - Conventional only. Source: Own representation

Feature	VIF
Constant	55246.18
Issue Price	1.49
Amount Issued	1.38
90-day volatility	3.79
Maturity	3.39
Sector Consumer Discretionary	4.11
Sector Financials	9.34
Sector Government	7.81
Sector Industrials	2.32
Sector Materials	2.34
Sector Technology	1.75
Sector Utilities	5.32
Callable	3.62
Country Austria	2.97
Country Belgium	2.20
Country Britain	5.90
Country Canada	3.50
Country France	6.49
Country Germany	6.60
Country Italy	6.14
Country Japan	5.26
Country Netherlands	5.94
Country Norway	4.70
Country Other	6.54
Country SNAT	2.35
Country South Korea	2.54
Country Spain	5.59

Feature	VIF
Country US	4.73