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The market of Green Bonds

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Contents

INTRODUCTION

Green finance and sustainable finance are topics *du jour*, even though sustainable development issue is not a new topic.

The first conference on the environment was, in 1972, the United Nations Conference on the Human Environment in Stockholm. It is considered the starting point in the sustainable development journey. The term *sustainable development* was defined in the report "*Our Common Future*", known also as "Brundtland Report", as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Since then, a series of initiatives, conferences and action plans have followed. The Paris Agreement and the Agenda 2030 for Sustainable Development represented a significant turning point, with ambitious but necessary goals set.

The European Union committed to becoming the first climate-neutral economy by 2050. To achieve these ambitious goals huge investments are needed both from the public and private sectors. The role of sustainable finance is thus crucial.

Within sustainable finance green finance, which takes into consideration environmentally friendly investments, is growing fast and has led to the emergence of new financial instruments. Among the new financial product, Green Bonds (GBs) are the most widespread. Green bonds are fixed-income securities whose purpose, unlike traditional fixed-income bonds, is to support specific projects with a positive environmental benefit

This study aims to investigate these new financial instruments in different ways. The manuscript is divided into three Chapters.

Chapter 1 analyses the regulation evolution and describes the principles that guide the issuance of green bonds.

Chapter 2 empirically studies the main features of the GBs.

Chapter 3 investigate the existence of the so-called *greenium,* namely whether GBs are issued with a less yield to maturity compared to traditional bonds.

CHAPTER 1

The evolution of the Green Bond market

1.1 Introduction

This chapter describes the regulatory evolution that has fostered the widespread of green finance. Starting from the Stockholm Conference in 1972, the main milestones are retraced. The Paris Agreement and the Agenda 2030 represented a significant turning point. Within sustainable finance, green finance has assumed an increasingly prominent role. In the last decade, green investments have grown exponentially. Green bonds (GBs) are the most widespread green instruments and the focus of this contribution.
The definition of green bonds and the features that make these securities different from other instruments will be deeply analysed.

1.2 The journey towards sustainable development goals and the Agenda 2030.

Green and sustainable finance are very topical nowadays, even though the attention towards sustainability started a long time ago. In 1972, during the United Nations Conference on the Human Environment in Stockholm, the environment became an important issue, for the first time. The conference involved 113 countries which adopted the Stockholm Declaration and Action Plan for the Human Environment (United Nations 1972). The Declaration contains 26 common principles "to inspire and guide the peoples of the world in the preservation and enhancement of the human environment[1]". The document also includes an action plan with 109 recommendations with the aim to monitor, evaluate, and manage environmental issues.

In 1987, Gro Harlem Brundtland, President of the World Commission on Environment and Development (WCED), present the report "*Our Common Future*", also called "Brundtland Report" (Brundtland *et al.* 1987). The report introduces the concept of

[1] Declaration and Action Plan for the Human Environmental, Chapter 1, page 3.

"sustainable development" defined as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs[2]". The report highlighted the importance of environmental protection including, among others, the Inter-Generational Equity.

1992 was another important year for sustainable development. The United Nations Conference on Environmental and Development (UNCED), also known as the "Earth Summit, took place in Rio de Janeiro. Twenty years after the conference in Stockholm, the summit involved people of different backgrounds, such as political leaders and scientists, from 179 countries.

Based on the previously traced path, the increasingly important issues of sustainability are addressed at the Summit. The main result of the "Earth Summit" was *Agenda 21*, defined by the United Nations as "a daring program of action calling for new strategies to invest in the future to achieve overall sustainable development in the 21st century. Its recommendations ranged from new methods of education to new ways of preserving natural resources and new ways of participating in a sustainable economy."

The United Nations Framework Convention on Climate Change (UNFCC) was another important step which lays the foundations for "Kyoto Protocol", adopted in 1997 and entered into force in 2005. The protocol aims to reduce global emissions from the period 2008-2015 of an average of 5 per cent, through the commitment of the main industrialized countries to undertake appropriate actions.

In 2002, during the World Summit on Sustainable Development (WSSD) in Johannesburg, delegates from all over the world faced a situation that had not improved. However, it emerged that, although the Agenda 21 was a reliable and high-quality document giving guidance for implementing sustainable development, its practical implementation fell far short of what was needed and agreed upon in Rio ten years before (Hens 2005).

The Summit brought together tens of thousands of participants, including heads of State and Government, national delegates, leaders from non-governmental organizations (NGOs), businesses and other major groups in order to implement effective strategies and new action plans. The Johannesburg Declaration on Sustainable Development was

[2] (Brundtland *et al.* 1987), Chapter 2: Towards Sustainable Development

adopted. Once again, it is a set of activities and measures that would have to be taken with respect to the environment. The Declaration encouraged, among others, the need to diversify the energy supply and the need to invest in renewable energy sources. This encouragement, after more than 20 years, is more and more relevant.

The European Commission is very active on the issue of sustainability, in particular regarding the Corporate Social Responsibility (CSR). In 2001 the Commission presented a Green Paper *"Promoting a European Framework for Corporate Social Responsibility*", with the aim to start a debate about CSR and building a partnership to create a European framework for the promotion of CSR[3]. In 2011 the Commission published "*A renewed EU Strategy 2011-14 for Corporate Social Responsibility",* extending the EU strategy for CSR promoting transparency and non-financial reporting.

Twenty years after the "Earth Summit" the United Nations Conference was organized again in Rio de Janeiro. Known as Rio+20, the UN Conference on Sustainable Development launched a process to develop the Sustainable Development Goals (SDGs). Inspired by Millennium Development Goals (MDGs), SDGs were officially adopted in 2015 when 193 Member Countries of the United Nations approved the UN Agenda 2030 for Sustainable Development.

SDGs are a set of 17 global goals with the aim to promote social, economic, and environmental sustainability (see Figure 1).

In December 2015 in Paris, at the UN Change Conference (COP 21), The Paris Agreement was adopted by 196 members. It is a legally-binding international treaty on climate change that introduces very challenging aims. Indeed, the overarching goal is to hold *"the increase in the global average temperature to well below 2°C above pre-industrial* levels" and pursue efforts "*to limit the temperature increase to 1.5°C above pre-industrial levels.[4]"*

European Union and its member states have signed and ratified the Paris Agreement. EU committed to becoming the first climate-neutral economy by 2050.

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[3] European Commission, 2022 "Corporate Social Responsibility: A business contribution to Sustainable Development"

[4] United Nation Climate Change (UNFCC) "The Paris Agreement: What is the Paris Agreement? Available at: https://unfccc.int/process-and-meetings/the-paris-agreement. Accessed June 2023.

The commitment and ambition of the EU led to the *EU Green Deal*, a strategy which encompasses several policies and measures to achieve the climate-neutral aim.
EU introduced, in 2020, a taxonomy to create a common and clear language[5]. The taxonomy provides several definitions and defines the criteria for environmentally and sustainable economic activities.

Figure 1. Sustainable Development Goals (SDGs)

The attainment of these challenging goals requires significant investments due to the inherent complexities involved. In anticipation of the Conference of the Parties (COP 27) under the United Nations Framework Convention on Climate Change, which took place from 6 to 18 November 2022 in Sharm el-Sheikh, Egypt, the EU has allocated €23.04 billion in climate finance. This financial allocation reflects the EU's proactive approach to

[5] REGULATION (EU) 2020/852 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 June 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088.

supporting climate-related initiatives and signifies its commitment to addressing the global challenge of climate change.

Achievement of sustainability goals requires the adaptation of the current regulatory system. On January 2023, the Corporate Sustainability Reporting Directive (CSRD) entered into force. The directive represents the replacement of the NFRD (Non-financial reporting directive). The CSRD requires all large companies and all listed companies[6] to disclose information regarding their perspective on the risks and opportunities stemming from social and environmental issues. New rules will be included in the 2025, for the 2024 financial year. Companies subject to the CSRD will have to report information according to European Sustainability Reporting Standards (ESRS).

In this framework, it emerges that sustainability objectives require a major effort on the part of all market players. Huge investments are needed, both from the public and private sectors, to achieve the commitments undertaken. The financial sector, therefore, plays a key role by mobilizing funds, directing investments, and supporting environmentally friendly initiatives.

1.3 Sustainable and Green Finance

The European Commission defines sustainable finance as "*the process of taking **environmental, social and governance (ESG) considerations** into account when making investment decisions in the financial sector, leading to more long-term investments in sustainable economic activities and projects*".

[6] Micro-enterprises are excluded. DIRECTIVE (EU) 2022/2464 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, art. 21: "Considering the growing relevance of sustainability-related risks and taking into account that small and medium- sized undertakings whose securities are admitted to trading on a regulated market in the Union comprise a significant proportion of all undertakings whose securities are admitted to trading on a regulated market in the Union, in order to ensure investor protection, it is appropriate to require that also small and medium-sized undertakings, except micro undertakings, whose securities are admitted to trading on a regulated market in the Union disclose information on sustainability matters. The introduction of such a requirement will help to ensure that financial market participants can include smaller undertakings whose securities are admitted to trading on a regulated market in the Union in investment portfolios, on the basis that they report the sustainability information that financial market participants need."

Environmental, Social and Governance are the three pillars used to evaluate a company's impact in terms of sustainability:

- *Environmental (E):* refers to environmental issues and may be related to climate policies, energy use, greenhouse gas emission or pollution;
- *Social (S):* refers to the social issues and can be related to the employees' safety and health, or unethical behaviour with internal and external stakeholders;
- *Governance (G):* refers to the governance factors of decision-making and can be related to the distribution of rights and responsibilities in the board directors, or the compensations.

The output of the evaluation process is the ESG rating, a measure which is, as the credit risk rating, very simple to interpret. The ESG rating is the result of each pillar score (see Figure 2 for an example of the ESG rating framework). Given the absence of a unified methodology, the correlation between ESG ratings from different providers can vary significantly (Berg 2022). This divergence in ratings underscores the challenges associated with comparability and standardization in the ESG rating landscape (OECD 2022). This is a crucial aspect, considering that financial instruments incorporating environmental, social and governance aspects are increasing exponentially.

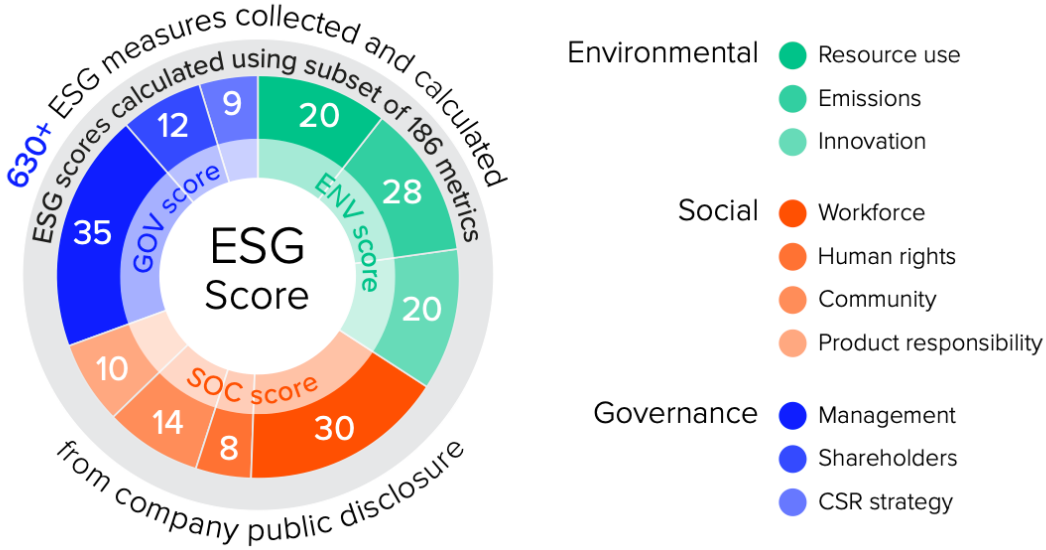


Figure 2 Thomson Refinitiv captures and calculates over 630 company-level ESG measures, of which a subset of 186 of the most comparable and material per industry. These are grouped into 10 categories that reformulate the three pillar scores and the final ESG score, which is a reflection of the company's ESG performance, commitment and effectiveness based on publicly-reported information. The category scores are rolled up into three pillar scores – environmental, social and corporate governance. The ESG pillar score is a relative sum of the category weights, which vary by industry for the environmental and social categories. For the governance, the weights remain the same across all industries.

Within sustainable finance, it falls the so-called Green Finance, which include financial products with a positive environmental impact. Greening finance[7] and green financing are driving the green transformation of the financial system (Spinaci 2021).

New green financial instruments are boosting green financing. Green bonds are the most popular and widespread, accompanied by sustainability bonds, sustainability-linked bonds, green loans, and sustainability-linked loans (See Box 1).

This study focuses on green bonds, which will be deeply analysed in the manuscript.

Box 1

Green financing financial instruments:

Green bonds are any type of bond instrument committed to financing environmental or climate projects that invest in any of these areas: renewable energy, energy efficiency, pollution prevention and control, biodiversity, clean transportation, sustainable water management, climate change adaptation, eco-efficient products, production technologies and processes.

Sustainability bonds are any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance a combination of both Green and Social Projects. Sustainability Bonds are aligned with the four core components of both the Green Bond Principles (GBP) and Social Bonds

[7] *Greening finance* is short for "greening the financial system" and refers to all the actions that can promote climate and environmental considerations into the financial system, identifying and managing climate and environmental risks. *Green financing* refers to the mobilisation of private financial capital in green investments.

Principle (SBP) with the former being especially relevant to underlying Green Projects and the latter to underlying Social Projects

Sustainability-linked bonds are any type of bond instrument for which the financial and/or structural characteristics can vary depending on whether the issuer achieves predefined Sustainability/ESG objectives. In that sense, issuers are thereby committing explicitly (including in the bond documentation) to future improvements in sustainability outcome(s) within a predefined timeline. SLBs are a forward-looking performance-based instrument.

Green loans are any type of loan instrument made available exclusively to finance or re-finance, in whole or in part, new and/or existing eligible Green Projects. Green loans must align with the four core components of the Green Loan Principles (GLP), as set out below. Green loans should not be considered interchangeable with loans that are not aligned with the four core components of the GLP.

Sustainability-linked loans are any types of loan instruments and/or contingent facilities (such as bonding lines, guarantee lines or letters of credit) which incentivise the borrower's achievement of ambitious, predetermined sustainability performance objectives.

1.4 Green Bond: *Definition e market size*

The International Capital Market Association (ICMA 2021) defines Green Bonds (GB) as *"any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects".*

Green bonds are fixed-income securities that enable issuers to finance environmentally sustainable initiatives. The main difference with ordinary bonds is the support of projects with positive environmental impacts.

Green bonds are a relatively new instrument. The Climate Bond Initiative (CBI), an international organisation working to mobilise global capital for climate change, estimates that the cumulative GB Issuance is US$ 2.334 trillion.

Since 2014 GBs have increased rapidly (see Figure 2) even though the first green bond was issued in 2007. The growth of green bonds has led to an increasing weight of these new instruments in the global markets. Their increasingly significant weight can also be seen in the birth of many green indexes, such as S&P Green Bond Index or Bloomberg Barclays MSCI Global Green Bond Index.

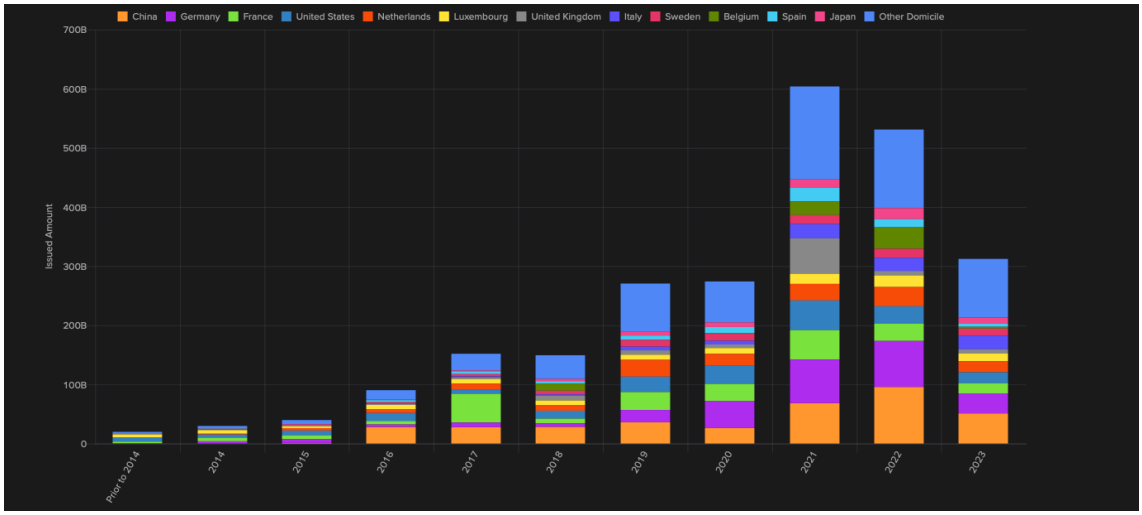


Figure 3.
Issued amount ($US billion) over the years. Source: Refinitiv-Eikon, Green Bond Guide.

The first bond labelled as green was the "climate awareness bond" issued by the European Investment Bank (EIB). However, the turning point for the GBs market was the introduction in 2014 of the Green Bond Principles (GBP) by the International Capital Market Association. The principles are a collection of voluntary frameworks with the stated mission and vision of promoting the role that global debt capital markets can play in financing progress towards environmental and social sustainability (ICMA 2021). They

define the best practices that should guide green bond issuance and provide recommendations to promote transparency and disclosure. The GBP divided green bonds into 4 categories[8]:

- ***Standard Green Use of Proceeds Bond***: it is unsecured security with full recourse-to-the-issuer only and aligned with the GBP.

- ***Green Revenue Bond***: 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 Project(s).
- ***Standard Green Use of Proceeds Bond***: it is unsecured security with full recourse-to-the-issuer only and aligned with the GBP.

- ***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:

    - *The Green Project(s)* securing the specific bond only (a "Secured Green Collateral Bond"); or
    - 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.

[8] See Green Bond Principles, Appendix I (Last update June 2022).

1.5. Green Bond Principles: the four core components

The ICMA identifies four components to be aligned with the Green Bond Principles: 1) Use of Proceeds, 2) Process for Project and Process for Project Evaluation and Selection, 3) Management of Proceeds, and 4) Reporting.

1.5.1 Use of proceeds

The use of proceeds can be considered the component that makes green bonds unique. As mentioned above, issuers must finance projects with a positive environmental impact. The use of proceeds should be clearly described in the official documentation of the bond. In defining the eligible Green Projects, the ICMA opted for broad and open categories. The eligible green projects are included in the following categories:

- *Renewable energy*
- *Energy efficiency*
- *Pollution prevention and control*
- *Environmentally sustainable management of living natural resources and land use*
- *Terrestrial and aquatic biodiversity conservation*
- *Clean transportation*
- *Sustainable water and wastewater management*
- *Climate change adaptation*
- *Circular economy-adapted products, production technologies and processes and/or certified eco-efficient products*
- *Green buildings*

As of today, the most common green projects are related to the clean transportation category, followed by energy efficiency. More details will be provided in Chapter 2.

1.5.2 Process for Project and Process for Project Evaluation and Selection

Issuers should clearly communicate to investors the environmental and sustainability goals of the eligible green project. Issuers should explain how they determine the eligibility of the project and the strategies to manage the potential risks. GBP encourage the communication of all the relevant information in a transparent way.

1.5.3. Management of Proceeds

The net proceeds of the Green Bond, or an amount equal to these net proceeds, should be credited to a sub-account, moved to a sub-portfolio, or otherwise tracked by the issuer in an appropriate manner, and attested by the issuer in a formal internal process linked to the issuer's lending and investment operations for eligible Green Projects.
During the life of the bonds, issuers have to track and eventually adjust net proceeds. Again, the GBP encourage high transparency and suggest the use of an external auditor, or another third party to verify and manage the allocation of funds.

1.5.4. Reporting

Issuers should make, and keep, readily available up-to-date information on the use of proceeds to be renewed annually until full allocation, and on a timely basis in case of material developments. The annual report should include a list of the projects to which Green Bond proceeds have been allocated, as well as a brief description of the projects, the amounts allocated, and their expected impact.
The GBP recommend the use of qualitative and quantitative indicators, with a transparent disclosure about the methodology to calculate the indicators. Issuers are encouraged to follow the Harmonized Framework for Impact Reporting[9].

[9] A green bond framework is a document created by the issuer that clearly articulates the company's proposed use of proceeds for the bond. See Handbook Harmonised Framework for Impact Reporting, June 2023.

1.6 External Reviews and Certification

The four main Green Bond Corporate Principles do not include an external certification even if it is strongly encouraged by the ICMA.

The issuance of green bonds may represent an instrument of "greenwashing[10]" (Flammer 2021). With the aim to reduce this risk, in 2012 the Climate Bonds Standard and Certification Scheme was lunched by the Climate Bond Initiative. It is a voluntary labelling scheme for investments – and now entities – that addresses the challenge of climate change and is consistent with the goals of the Paris Climate Agreement (Climate Bond Standard 2023).

Several different types of certifications have arisen, all with the aim to verify whether the use of proceeds is related to environmentally friendly investments.

The European Commission proposed the EU green bond standard (EU TEG 2019), based on the EU sustainable finance taxonomy (EU TEG 2019b). Ehlsers *et al*. (2020) state that the EU standard entails detailed eligibility criteria for green projects and calls for official authorisation and supervision of third-party reviewers. Indeed, to improve credibility and transparency, issuers can ask for a third-party opinion. Various specialized agencies provide third-party opinions on green bonds, improving the trust in the entire system.

The Climate Bond Initiative website shows 67 approved verifiers under the Climate Bonds Standard.

[10] Cambridge Dictionary defines greenwashing as a behaviour or activities that make people believe that a company is doing more to protect the environment than what is actually doing.

CHAPTER 2

2.1 Introduction

This chapter describes all the features of green bonds. The exponential growth both in terms of the issuance number and total amount issued, allows an in-depth analysis of this recent instrument. In order to have an overview of the green bonds and issuers' characteristics we focus on the main features of fixed-income securities, introducing the ones that make green bonds unique.

Inspired by Fabozzi (2007), the analysis will consider the following characteristics:

a) Maturity (with a focus on perpetual bonds),
b) Pair value and price at issuance,
c) Coupon rate
d) Embedded options
e) Sectors
f) Use of proceeds
g) Currency

After a theoretical recall of the various terms, each characteristic will be analysed with specific reference to green bonds.

The analysis is conducted using data from the Refinitiv-Eikon database from 2007 to the 14 June 2023.

2.2 Maturity

Maturity is one of the bonds' essential features and it is defined as ex-ante.

It is useful to highlight that the term "maturity" is commonly used to refer to the term to maturity (or time to maturity), namely the number of years the debt is outstanding or the number of years remaining prior to the principal payment, that change during the instrument's life. It is possible to find just the term "maturity" also referring to the maturity date which is the date when the principal will be repaid, and the debt expires.

Green bonds, such as traditional bonds, may have several maturities. Based on their maturity, it is common to divide bonds into three categories:

a) Short-term bonds: maturity between 1 and 5 years;
b) Medium-term bonds: maturity between 5 and 12 years;
c) Long-term bonds: maturity of more than 12 years.

Fabozzi (2007) highlighted three reasons that make term to maturity important:

1) Term to maturity indicates the time period over which the bondholder can expect to receive interest payments and the number of years before the principal will be paid in full;
2) The bond yield depends on the term to maturity.
3) The bond price will fluctuate over its life as interest rates in the market change. The bond's price volatility is a function of its maturity (among other variables).

The overall range of maturities in the green bond markets it is very large. The mean value, evaluated at the issuance moment, is 7.9 years while the median value is 5 years.

Table 2.1 summarises maturity about short, medium and long-term maturity.

Table2. 1.
Maturity of the Green Bonds

Maturity	Obs	Mean	Median	Min	Max
Short-term	2,921	2.880	3.003	0.082	4.997
Medium-term	4,592	6.938	6.010	5.000	11.989
Long-term	854	30.591	18.037	12.003	1,000.663
Total	8,367	7.935	5.005	0.082	1,000.663

It is interesting to investigate the extreme values of the distribution, especially the right longer maturities.

Focusing on the short-term, it is possible to identify 203 green bonds with a maturity of less than 1 year, which represented about 7% of the short-term bonds and 2.5% of the total sample. The bond with the shortest maturity, just one month, is a Zero-Coupon Bond issued in June 2021 by *CPI Ronghe Financial Leasing Co Ltd*, a Chinese company.

Focusing on the long-term period, it is common to refer to 30 years as the longest maturity, even though were issued 50 and 100-year bonds. However, within the green bonds' universe, we can find bonds with a maturity of 1,000 years. The first bond with this maturity was issued

by *Orsted A/S*, a Denmark-based energy company, in 2017. Subsequently, *European Energy A/S* and *NkT A/S*, as well as *Orsted* itself, issued 1,000-year green bonds. The last one was issued on 9 January 2023 and will expire on January 9, 3022.

A millennium is a very long time period for bonds, and they call to mind *perpetual bond*s, namely bonds without maturity. *Perpetual bonds,* which ended on the sidelines for several years, have recently returned to a matter of discussion, especially during the Covid-19 pandemic. Giavazzi and Tabellini (2020) have proposed to finance the UE Recovery Fund (RF) by issuing *perpetual Eurobonds* guaranteed and supported by the ECB. Similarly, in April 2020, George Soros, whose words always arouse the interest of numerous stakeholders, argued that *perpetual bonds* should have been the priority for the European Council[11]. According to this current of thought, during the EU in April 2020, the Spain Governament proposed to finance the RF with no maturity debt raising up to 1.5 trillion euros[12].

Institutions and governments have adopted different solutions to deal with the pandemic crisis. However, these proposals have aroused important debate among academics, professionals and policymakers.

The interest in green perpetual bonds involves also the green market, even though we observe limited phenomenon.

Before analysing the features of these instruments labelled as green, it is important to highlight the main reasons for financing through instruments with no maturity and their embedded risks.

2.2.1 Perpetual green bond

The most important advantage of issuing perpetual bonds is the lack of repayment of principal. This feature makes *perpetual bonds,* sometimes called *perps,* more similar to stocks. However, issuers are obligated to pay, theoretically forever, coupon rates which is the reason why they are classified as bonds. Table 2.3 provide an example of perpetual green bond.

Investors may be willing to forego the principal for the exchange of interest coupon rate higher than comparable bonds with defined maturities.

[11] See https://www.project-syndicate.org/commentary/finance-european-union-recovery-with-perpetual-bonds-by-george-soros-2020-04?barrier=accesspaylog.

[12] See https://www.reuters.com/article/us-health-coronavirus-spain-breakingview-idUSKBN2231TC.

The lack of maturity also allows issuers to eliminate the refinancing risk. However, perpetual bonds embed a high potential interest rate risk. Bonds with high *duration* are extremely sensitive to interest rate changes and long-term instruments' prices and returns are more volatile than short-term ones.

Observing the perpetual bond market, it is possible to notice how the absence of maturity is often a theoretical feature. Thus, perpetual bonds often include a call provision that allows issuers to redeem the bonds. It is set a first call date, typically after a few years, when borrowers can call the entire issuance or part of it at the *call price (*or *redemption price).*

The option to redeem beforehand is not exclusive to perpetual bonds, even though is more common for long-term maturity. Callable bonds give a great advantage to issuers and, conversely, a great disadvantage to investors. Indeed, if interest rates decrease, borrowers can exercise the option, thus refinancing at the new and more convenient market conditions. To enjoy this benefit, issuers must compensate borrowers with a high coupon rate. ,

It is common for issuers to "*call the bond*", especially in the banking sector.

For this reason, perps are often described as bonds without maturity just from a theoretical perspective. Failure to exercise the right could also be considered a signal of lack of capital and liquidity.

Perpetual bonds are thus risky instruments. These risks can be underestimated during economic and financial stability periods but can explode in the event of negative shocks.

According to the DataStream database, on 14 June 2023, the number of perpetual bonds labelled green is 111, representing 1,31% of the green bonds universe[13]. It is a limited amount compared with the non-green bonds. Nevertheless, since 2016 the number of green perps increase, reaching a peak in 2021 (see Table 2.2).

This limited number of perps labelled green is not surprising, considering that the issuers' motivation to prefer this specific financial instrument may be weak. The lack of maturity may be considered a signal of the commitment toward environmental initiatives with a long-term view, which could increase the reputation and attract investors that are sensitive to environmental issues. Notwithstanding, the long-term perspective may be questioned by the

[13] According to Refinitiv-Eikon, in May 2023 the total number of perpetual bonds is 16,999, of which about 80% are callable. Issuers are mainly banks and other financials which overall cover 71% of the total issuance.

right to call the bond, especially considering that all the existing perpetual bonds are callable at the time of our data extraction.

Table 2.2
Perpetual green bonds

Year	Number of issuance	Average amount issued (Mln $)
2016	4	386
2017	4	284
2018	6	269
2019	7	275
2020	16	224
2021	42	260
2022	23	291
2023*	9	355

In addition, it is important to highlight that, for a bond without maturity, the management of the use of proceeds could be extremely complex, due to the difficulty of planning, at the issuance time, some future choices to achieve the environmental goals. It would be required to adjust environmental and sustainable goals over time. From the issuers' perspective, this means higher costs for both pre-issuance and post-issuance. What is more, for certified green bonds, the verification of compliance with certifications, especially in the post-issuance phase, may be based on variables with a higher level of uncertainty, with higher “green default”.
In the banking system, issuances of perpetual bonds, in particular AT1, may be related to the evolution of the regulation. Indeed, Tier 1 Capital CET1 instruments are perpetual[14] and are used by banks to strengthen their capital ratios.
Appendix 1 provides more details about the role of perpetual bonds within the regulation system.
To conclude, it is important to highlight that the maturity, contractually defined ex-ante, could be changed if bonds embed options that give the issuer, or more rarely the investor, the right to take actions that may change the initial features of the contract

[14] Capital Requirements Regulation (CRR) , Part two, title I, Chapter 2, Section 1, Article 28.

Table 2.3

Example of Perpetual green bond

Banco Bilbao Vizcaya Argentaria, S.A.
Series 10 €1,000,000,000 Non-Step-Up Non-Cumulative Contingent Convertible Perpetual Preferred Tier 1 Green Securities

Issuer: Banco Bilbao Vizcaya Argentaria (BBVA),

***Country of Issue*:** Spain

***Issuer Sector*:** Banking

ISIN: ES0813211028

Issue Date: 15 July 2020

Maturity Date: Perpetual

Issue Price: 100

Reset Date: The first call date is 15 January 2026, each fifth year thereafter.

Optional Redemption: All, and not some only, of the Preferred Securities may be redeemed at the option of the Bank, subject to the prior consent of the Regulator (if required, and otherwise in accordance with Applicable Banking Regulations then in force), at any time on or after the First Reset Date at the Redemption Price.

Rating: Ba2 (Moody's) / BB (Fitch)

Amount outstanding: €1,000,000,000.

Coupon: 6,00%, paid quarterly.

Pair Value: 200,000,000

Green Bond: Yes

ESG Bond: Yes, Self-Labeled Green Bond

Source: Refinitiv-Eikon. Accessed 17 May 2023, 4.30 pm.

2.3 Par Value and issue price

The bond's **par value** is the amount that the issuer promises to repay the bondholders at the maturity date. The par value could be also called face value, principal value, redemption value, maturity value or nominal value. Bonds, green and non-green, may have any par value. Table 2.4 summarises the par value of the sample.

Table 2.4
Summary statistic of Pair Value in USD of the green bond universe.
The variable has been winsorized at 2% and 99% level.

	obs	mean	median	min	max
Par Value	8,006	4,246,173	1,000	100	100,000,000

The par value is used to calculate the coupon payment, namely the periodic payment that the borrower must pay to the lender during the financial instrument's life.
In the market bond prices are typically expressed as a percentage of the pair value.[15]
Bonds issue prices can be:

- **At a pair:** the price coincides with the nominal value (=100);
- **At a premium:** the price is higher than the par value (>100);
- **At a discount:** the price is less than the par value (>100).

Table 2.5 shows that the larger number of green bonds, 61.41%, were issued at a pair, while the issuance at a premium and at a discount are 11.1% and 22.47% respectively.

Table 2.5
Green bonds price.

Price	Number of GB issuance	Percentage (%)	Price (mean)	Total number of ZCB	Percentage (%)	Price (mean)
At a discount	1,905	22.47	97.77	23	0.27	98.12
At a pair	5,206	61.41	100	186	2.19	100
At a premium	1,366	16.11	102.76	20	0.24	101.35
Total	8,477	100	99.92	229	2.70	99.92

[15] For example, a bond quote of 95 means 95% of the par value. If the par value is 1.000 $ the bond's market price is 950 $. The practice is to refer to the price at the percentage of the pair value

Compared with bonds that pay coupons, the remuneration for zero-coupon bonds (ZCB) depends exclusively on the difference between the issue price, or the purchase price, and the pair value. The number of ZCB labelled green is limited. However, it might surprise that 186 bonds were issued at a pair and 20 at a premium and thus with a negative return.

With the negative interest rate policy, the number of issuances at a premium increased. During that period, the secondary market quoted at a premium several bonds, including zero coupon bonds. The new issues, therefore, had to reflect the market conditions.

The issuance at a premium should not attract investors when the return equals the difference between the pair value and price. In general, investing under the certainty of losing money is something unintuitive and inexplicable. However, with the aggressive central banks' policy, investing in bonds with a negative yield was an opportunity to lose less money. This is the case, for instance, of the European banks that have faced the European Central Bank (ECB) negative rates on cash deposits. Thus, liquid bonds, even with a negative yield, were an interesting alternative, especially in the short-term[16].

In contrast, it turns out to be less clear the motivations behind the issuance of Zero-Coupon bonds with medium or long-term maturity. An example is the green bond issue by Deutch Bank (see table 2.6) in August 2021. It is a ZCB with 10 years of maturity and an issue price equal to 102, which means a negative interest rate. In August 2021, the ECB's interest rates on the deposits facility were still negative[17] and during the first semester, in line with the Federal Reserve, had been confirmed the accommodative monetary policy. However, the inflation was about to explode. The COVID-19 fiscal stimulus packages and, later, the war in Ukraine, have been an unexpected booster for consumer prices. The 9 June 2022, the ECB increased the interest rate on the refinancing operations, from 0% to 0,25%, ushering in the most important period of rate hikes in recent history. In June 2023, the ECB interest rate on the main refinancing operations and the interest rates on the marginal lending facility and the deposit facility are 4.00%, 4.25% and 3.50% respectively.

Koch and Noureldin (2023), economists in the International Monetary Fund's (IMF) research department, state: *"Despite our repeated revisions to the inflation forecasts between the first quarter of 2021 and the second quarter of 2022, misses have been sizable and persistent.*

[17] The interest rate on the main refinancing operations and the interest rates on the marginal lending facility and the deposit facility were 0.00%, 0.25% and -0.50% respectively.

These inflation surprises preceded the Russian invasion of Ukraine. While the war amplified inflationary pressures from the supply side through the disruption of global commodity markets, we argue that the pandemic shock and the ensuing economic recovery with strong fiscal backing provided the first spark.

While being aware of the power of the hindsight bias, it is reasonable to argue that in 2021, considering the whole situation, the risk for investments in long-term bonds, with negative interest rates, was extremely high. On the other side, placement has been good financing for issuers.

The price chart in Table 2.6 is an effective example of the bond price trend during restrictive economic policies. Furthermore, it is consistent with the idea that by buying zero coupon bonds with a premium, in 2021, investors exposed themselves to a high price risk.

The reasons to buy bonds with negative returns may not be easily explained with the **homo economics** theory and they have to be sought in regulatory constraints.

However, it is interesting to understand whether the "green" label may influence investors' choices to such an extent that they prefer investments with suboptimal risk-return profiles in the face of positive environmental impact. Recent literature investigates whether investors are willing to receive less interest in investments with a positive environmental impact. This aspect will be deeply analysed in Chapter 3.

Table 2.6

Example of Zero-Coupon Bond with a negative interest rate.

DEUTSCHE BANK AG.

Series 10 €1,000,000,000 Non-Step-Up Non-Cumulative Contingent Convertible Perpetual Preferred Tier 1 Green Securities

Issuer: DEUTSCHE BANK AG

***Country of Issue*:** Eurobond

***Issuer Sector*:** Banking

ISIN: XS2011165037

Issue Date: 31 August 2021

Maturity Date: 29 August 2031

Issue Price: 102

Amount outstanding: € 50,000,000.

Coupon Type: Zero Coupon

***Pair Value*:** 1,000

***Green Bond*:** Yes

ESG Bond: Yes, Self-Labeled Green Bond

Source: Refinitiv-Eikon. Accessed 18 May 2023.

2.4 Coupon Rate

The coupon rate, or nominal rate, is the interest paid by the issuer each year. Bondholders receive the coupon that is determined by multiplying the coupon with the par value[18].
The green bond market mainly features instruments with coupon structures that are not particularly complex.

Table 2.7 shows how the green bond market is dominated by *Plain Vanilla Fixed Coupon*, which represents 76% of the sample. They are a basic version of a bond: all the bond features are fixed and predetermined. The average coupon rate is 2.99[19]. More detail about *Plain Vanilla* labelled green is provided in Table 2.8.

Bonds which a *Fixed Margin Over Index* coupon rate are the second most popular type, although they represent a significantly lower percentage compared to Plain Vanilla (10 %). Their characteristic is to periodically pay coupons based on the value of a benchmark, such as EURIBOR, plus a fixed remuneration.

[18] A bond with an 2% coupon rate and par value of 1,000 € will pay each year 20 €.
[19] It is important to highlight that coupon is just one element to consider evaluating the yield to maturity.

An example is the bond issued by the European Investment Bank in 2013 in Swedish Krona. The prospectus of the bond describes the interest type as a floating rate equal to the 3 month STIBOR[20] + 0.43% per annum[21].

Table 2.7
GBs Coupon type

Coupon Type	Frequency	Percentage
Plain Vanilla Fixed Coupon	6,429	75.94
Fixed Margin over Index	844	9.97
Zero Coupon	246	2.91
Pay at Maturity Fixed	234	2.76
Fixed Resettable	178	2.10
Step Up / Step Down	173	2.04
Fixed then Floating	153	1.81
Other / Complex Floating Rate	83	0.98
Range Coupon	52	0.61
To Be Priced Coupon	52	0.61
Zero then Fixed	6	0.07
Fixed Then Zero Coupon	4	0.05
Step Up-Margin over Index	4	0.05
Pay at Maturity Floater	3	0.04
Discount	1	0.01
Floating then Fixed	1	0.01
Multiple Payment Frequencies	1	0.01
Resettable then Floating	1	0.01
Step Down-Margin over Index	1	0.01

Table 2.8
Coupon rate in Plain Vanilla Fixed Coupon GB. The coupon variable is winsorized at 1% and 99%.

Coupon	**Obs**	**Mean**	**Min**	**Max**
2008	1	3.50	3.5	3.5
2009	3	2.32	2.0	2.95
2010	51	4.76	.5	10
2011	27	2.97	.5	6.1
2012	22	2.81	.5	7.6
2013	40	2.91	.35	8.77
2014	81	3.34	.25	10.18
2015	252	3.75	.125	11.25

[20] The Stockholm Interbank Offered Rate (*STIBOR)*, is an interest rate benchmark calculated and published on each business day in Sweden.
[21] For more details about different Coupon Type see Fabozzi (2007) and De Vincentiis (2018).

2016	194	2.86	0	8.8
2017	369	3.88	0	10.17
2018	420	3.53	0	11.25
2019	719	2.89	0	11.25
2020	910	2.45	0	11.25
2021	1,575	2.43	0	11.25
2022	1,318	3.12	0	11.25
2023	444	3.96	.04	11.25

2.5 Embedded options: Callable and puttable bonds

In the previous paragraphs, analysing perpetual bonds, call options have been mentioned.

Green bonds, like ordinary ones, can embed options that provide the issuer or the investor with specific rights regarding the redemption of the underlying bond. Issuers can redeem callable bonds ahead of maturity to take advantage of potentially lower interest rates. Investors can redeem puttable bonds before maturity if interest rates increase (Barnes *et al.* 2019).

In the green bond market, 1,637 (19%) bonds are callable while 363 (4%) are puttable.

As mentioned previously, the call option allows issuers the right to redeem the bond ahead of its maturity. Issuers will be incentivized to exercise the option in the event of lower interest rates, thus being able to refinance at better conditions.

This is a particularly disadvantageous option for the investor who has to be compensated with a higher interest rate.

Typically, callable bonds include a protection period, such as five years, during which it is not possible to exercise the option. In the green bond market, the presence of a call option may allow issuers to be more flexible by adapting the strategy to the sustainable goal over time.

Puttable green bonds are less common. They provide investors with the right to redeem bonds before maturity. This option becomes convenient for bondholders if interest rates increase. Moreover, it might be considered investors protection which offers the opportunity to have the money back if necessary. To mitigate the uncertainty of long-term climate and sustainability risks, as well as the challenge in evaluating specific green projects, the inclusion of put options provides an exit strategy, thereby helping to mitigate risk.

From the issuers' perspective, including a put option in green bonds can help increase may demand and attract risk-aversion investors. Although the cost of funding may rise, the presence of put options may be perceived as a signal of the issuer's financial strength and green project validity.

2.6 Sector: Who issues green bonds?

The first green bond was issued in 2007 by the World Bank and European Investment Bank (EIB) with the aim to lend renewable energy and energy efficiency projects.

The number of issuances in the following year was limited and involved only supernatural institutions. According to Climate Bond Initiative the turning point in the market is the issuance of the first corporate green bond by Vasakronan, a Swedish property company. As shown in the Table 2.6 from 2013 companies from different sectors started to issue this new instrument.

However, the financial sector takes a leading role as the years go by. In terms of number of issuances, from 2007 to May 2023, 21% of green bonds were issued by the banks and 23% by other financial, which are thus the most important and active players in this market.

For banks, there is an indirect relationship between raising and the use of funds. Money, indeed, is used to finance companies that want to invest in green projects. This role makes banks a different issuer and a special player[22].

Electric power companies and manufacturing companies are also very active in the green bond market, followed by the supernatural and agency sectors.

The number of green bonds issued by companies operating in the transportation sector is limited. However, it is important to highlight that since 2018 it is constantly increasing. This is a crucial sector with a potential great contribution to the environmental goals. European Environmental Agency describes transport as a vital sector with a current mobility system not sustainable. This sector can cause negative impacts on the environment and human health[23]. According to the European Environment Agency(2022), global emissions of greenhouse gases from the transport sector increased by 33% from 1990 to 2019. However, the European Union emissions fell by 24% during the same period[24]. These different trends could explain – among other reasons - why some countries are more active in this market. Our analysis shows that China has issued the largest number of green bonds in the transportation sector. This data is not surprising, considering China's large emission of greenhouse gases and its critical role in the global effort to combat climate change. As suggested by the World Bank (2022), in China urgent actions are needed in order to achieve the ambitious goals.

[22] The banks' role is deeper analysed in the chapter 3.

[23] See Transport and mobility topic, available at https://www.eea.europa.eu/en/topics/in-depth/transport-and-mobility.

[24] In 2020, The COVID-19 pandemic restrictions have reduces by 18% the greenhouse gas emissions from compare to 2019 emissions. (European Environment Agency, 2022)

Several green bonds were issued also by companies operating in the manufacturing sector. Deep analysis within each sector, see Appendix 3, shows that the Real Estate sector absorbs about 37% of the total manufacturing issuance. The real estate contribution to address long-term environmental issues has been recognized by IMCA publishing the "Green Bond Guidelines for Real Estate Sector" (IMCA 2016).

However, focusing on sectors could be misleading due to the relevance of the banking system in this market. Indeed, we are not able to capture which projects could be financed by banks underestimating consequently some sectors. For a complete framework, is necessary to analyse the *use of proceeds*.

Table 2.3

Green bonds at sector level

sector	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Banking							11	3	28	54	87	124	157	271	44	448	12	*1,734*
Other Financial						1	2	16	18	37	18	115	243	37	554	384	141	*1,926*
Eletric Power						1	3	9	147	36	91	59	125	152	293	263	57	*1,236*
Supernatural	1	1	5	48	26	18	2	41	65	49	35	49	56	63	76	5	27	*63*
Agency		1		5	3		5	11	25	27	49	32	74	86	126	95	39	*578*
Service Company						1		9	3	11	14	2	59	78	186	12	88	*589*
Manufactoring							2	8	1	28	35	79	138	133	253	227	73	*986*
Official and Muni						3	2	12	7	12	18	25	29	27	42	45	22	*244*
Transportation										1	6	19	37	61	96	88	18	*326*
Energy Company								2		1	6	19	19	9	43	19	7	*125*
Gas Distribution								1				1	3	6	6	15		*32*
Consumer Goods								1	2		2		6	5	18	5	6	*45*
Telephone													3	3	4	5	3	*18*
Independent Finance																3	1	*4*
Sovereign												1			1	1	1	*4*
Total	*1*	*2*	*5*	*53*	*29*	*24*	*45*	*14*	*35*	*256*	*451*	*543*	*949*	*121*	*212*	*1,768*	*63*	*8,477*

2.7 Use of proceeds.

The features described in the previous sections are common to green and non-green bonds. The main aspect that makes green bonds different from traditional ones is the use of proceeds. As described in Chapter 1, the proceeds must be used to finance Green Projects that have to be described in the legal documentation by issuers. The green bonds principles provide a list of the common aims that issuers set to achieve with the green bonds.

For greater reading fluency we report the main eligible Green Projects categories:

- Renewable energy
- Energy efficiency
- 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/or certified eco-efficient products;
- Green buildings

However, this list is not exhaustive, but represents the most common green project categories. This section empirically analyses the use of proceeds for the green bond universe.

Figure 1 shows the main *use of proceeds* in our sample.Green bonds are predominantly used to finance projects related to *Clean Transport* and *Energy Efficiency,* which represent 28% and 25% respectively[25]. This predominance is not unexpected. Clean Transports are crucial for reducing the whole emissions. The importance to improve low carbon transport has prompted the creation, , of the "Low Carbon Transport Technical Working Group" in 2014, with the aim to develop the certification criteria for transport for green bonds[26].

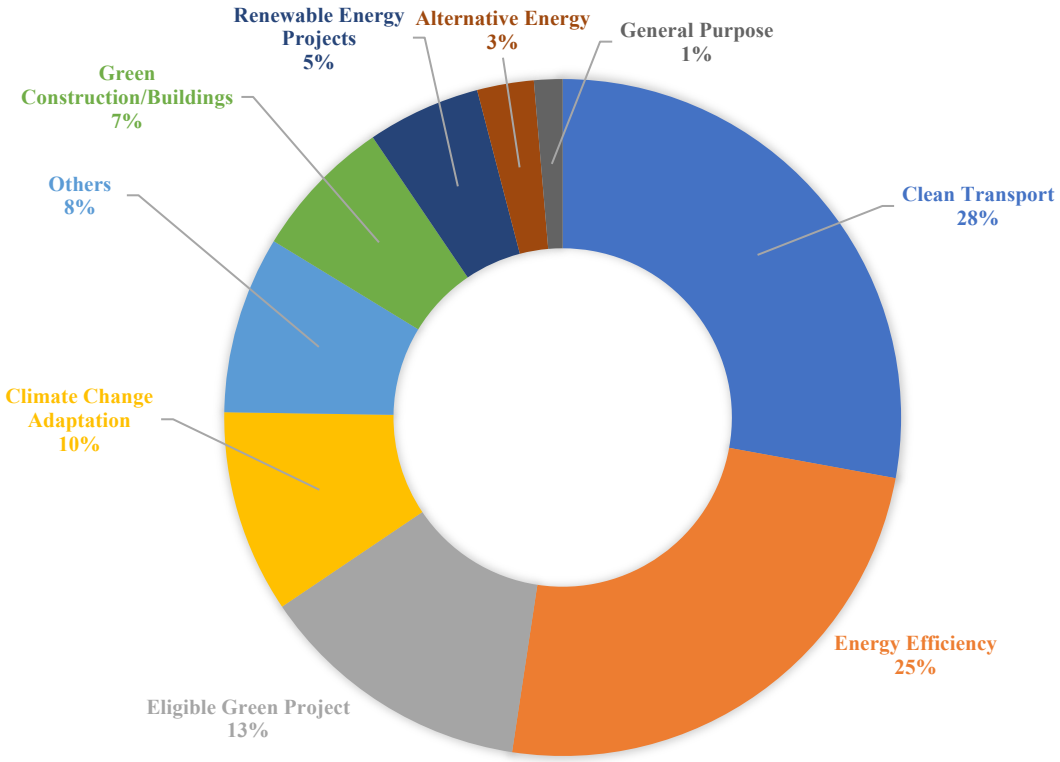
[25] As mentioned above, the Clean Transport percentage is not in contradiction with the results in the sector analyses results. In the banking system we are not able to capture all the companies that could benefit from the green bonds issuances.

[26] The working group includes 12 academics and experts, with representation from the International Energy Agency (IEA), European Investment Bank (EIB), Universities of California at Berkeley and Davis, Partnership on Sustainable Low Carbon Transport (SLoCAT), and Institute for Transport and Development Policy (ITDP).
According to these criteria, the eligible asset can be divided into two groups: a) automatically eligible (such as fully electric, hydrogen or others zero-direct emissions transport); b) Thresholds and other considerations required (such as hybrid private vehicles or fossil fuelled public transport). The thresholds are based on a per passenger-km (p/km), for passenger transport, or a per tonne-km (t/km), for freight, basis. Methodological notes on the use of thresholds and the formulae for determining the compliance with the transport criteria see Climate Bond Initiative (2023) – *Land Transport Criteria Document.* Available

The transport criteria include the following eligible *use of proceeds*:

a) Passenger cars and commercial vehicles;
b) Public passenger transport by road;
c) Freight transport by road;
d) Passenger rail rolling stock;
e) Freight rail rolling stock;
f) Railway networks and lines;
g) Infrastructure for low carbon transport.

Figure 1
Use of proceed. The chart shows the main use of proceeds for the green bonds.



Eligible use-of-proceeds can also include key supporting components and infrastructure that enable mitigation in transport systems or vehicles such as electric batteries, or zero direct emissions vehicles that support other industries such as waste collection vehicles (CBI 2023).

at: https://www.climatebonds.net/files/files/standards/Land%20transport/Sector%20Criteria%20-%20Land%20Transport%20%28April%202023%29.pdf.
More details about Transport Criteria are available at: https://www.climatebonds.net/standard/transport.

Figure 2 shows an example of the process that guides the certification process for transport and infrastructure.

The relevance that the market ascribes to clean transports is also observable in the amount issued. For this use of proceeds the average amount issued is 342 million dollars, higher than the average data in our sample, which is 252 million dollars.

The second most relevant *use of proceeds* is "Energy Efficiency". The average amount issued to finance projects for energy efficiency is slightly lower than the overall average figure..

The increase in Energy Efficiency is a priority for aiming the greenhouse reductions target[27]. Excluding increases in the cost of energy due to negative shocks, such as the recent war in Ukraine, energy efficiency produces less consumption with an impact on the overall costs. In contrast to other benefits, such as air quality or overall emissions, that are less tangible in the short time, cost reduction is immediately measurable and can incentivize this type of investments by both companies and private entities.

The Refinitiv Eikon database classifies 13% of the use of proceeds with a generic "Eligible Green Projects". This might suggest a lack of transparency. However, some issuance can envisage different uses of the capital raised, not necessarily specified at the time of the issue. One example is a bond issued in 2015 by European Investment Bank (EIB)[28]. The prospectus reported the following sentences:

"Lending projects in the fields of renewable energy and energy efficiency include, but are not limited to:

- *renewable energy projects such as wind, hydro, solar and geothermal production; and*
- *energy efficiency projects such as district heating, co-generation, building insulation, energy loss reduction in transmission and distribution and equipment replacement.*

The above are merely current targets. Revisions of such targets will not be notified to Bondholders. No undertaking is given that such targets will be met."

"*The net proceeds of the issue of the Bonds will be allocated within EIB's treasury to a sub-portfolio of the operational money market portfolio. So long as the Bonds are outstanding, the balance of the sub-portfolio will be reduced, at the end of each quarter, by amounts matching*

[27] the new 2030 target of reducing greenhouse gas emission by at least 55% (compared to 1990). European Commission, 2030 Climate Target Plan. See: 203ClimateTargetPlan.
[28] ISIN: XS1317148580

disbursements made during the quarter to lending projects within the fields of renewable energy and energy efficiency. Pending such disbursement, the sub-portfolio will be invested in money market instruments."

Figure 2.2
Transport core eligibility

This bond's feature allows EIB flexibility. This feature ensures the EIB flexibility on the projects to be financed. However, flexibility is limited. The boundary is represented by the *principles* which must be respected during the bond's life.

The generic "Eligible Green Project" reflects (or is in line with) the Banks' and Supernatural entities' activities. Indeed, banks, other financial, and supernatural entities cover more the 51% of the bonds classified as Eligible Green Projects. However, issuances with this aim are not limited to these three sectors. In the GB market, it is possible to find this use of proceeds also related to bonds issued in manufacturing (16%), electric power (12%) and Service Company sector. (9%).

To have a complete overview, we investigate the use of proceeds at a sector level. The aim of the analysis is to understand whether there are significant differences between the environmental goals. Data (see Appendix 3) confirm the evidence that came to light in the previous analyses. Banks and other financials are the most important players in the two most common use of proceed, namely Clean Transport and Energy efficiency. Alternative energy is boosted by utilities (energy power) companies[29]. Full data are available in Appendix 3.

2.8 Countries and currency denomination.

As traditional bonds, the green ones can be issued in any currency. Figure 2 shows that GBs are mainly issued in euros and US dollars, which represent 22% and 18% of the sample respectively. The third currency is the Chinese renminbi (19%) followed by Swedish Krona (10%). Issuances in other currencies are less common.

The currency in which bondholders are remunerated may differ from that of the country in which the issuing company is based. For this reason, looking at the country of the issue offers a different perspective of the whole market.

Table 2.10 summarises the number of issuances for the top 5 countries. and provides more details about GB distribution[30].

Following the Refinitiv - Eikon database, Eurobond is classified as a "country of issue" and includes 33% of the sample. This data is less interpretable from a geographical point of view.

[29] Full data are available in the appendix 2
[30] Appendix 3 provide data for the entire dataset

With the aim to provide a clear overview, leading countries in terms of of green bonds value in 2022 are represented in Figure 3. China issued green bonds for 85.4 billion US dollars, followed by the United States and Germany with 64.4. and 61.2 billions, respectively.

Figure 2.3.
Currency. Other includes all the currency less the 1%.

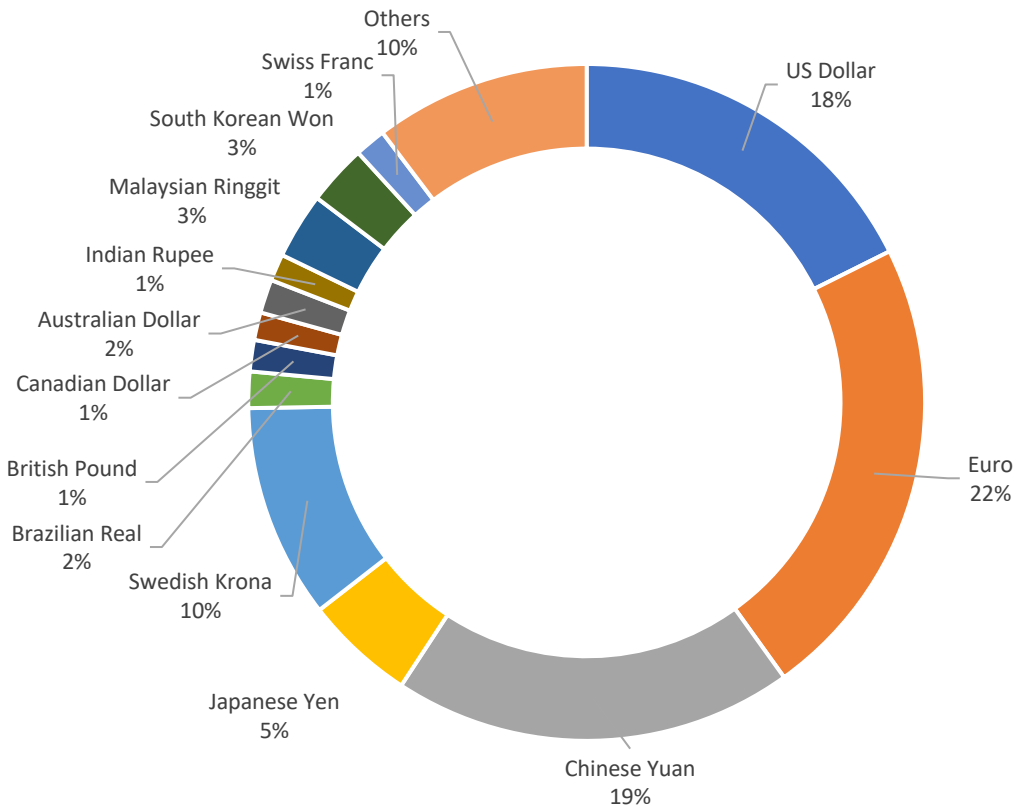


Table 2.10
Country of Issue

Country of Issue	Frequency	Percent	Cumulative
Eurobond	2,808	33.17	56.21
China (Mainland)	1,566	18.5	22.56
United States	770	9.1	99.98
Sweden	502	5.93	87.4
Germany	478	5.65	64.32

Appendix 1

Perpetual green bonds: looking to the future or a need for the present?

To understand how regulation can influence banks' funding policy, the main rules on minimum capital requirements are recalled in this appendix. The 2008 global financial crisis (GFC) highlighted numerous capital weaknesses of banks and regulation frameworks not robust enough to deal with negative shocks[31]. Several interventions by policy makers were necessary. In 2010, the Basel III reforms were unveiled by the Basel Committee on Banking Supervision (BCBS) to substantially reinforce the quality of banks' capital and increase capital standards. In addition, the BCBS introduced more stringent disclosure requirements.

Basel III has been implemented slowly over time. Notwithstanding it is a complex reform, for our aim it is useful to sum up the minimum capital requirements for banks.

The bank Regulatory Capital consists of the sum of two main elements:

1) Tier 1 Capital (going-concern capital)
    a) *Common Equity Tier 1 (CET1)*
    b) *Additional Tier 1 (AT1)*
2) Tier 2 Capital (gone-concern capital)

For each category, there are a set of criteria that capital instruments must satisfy to be included in the corresponding category .

Tier 1 Capital is made of Common Equity Tier 1 (CET1) and Additional Tier 1 (AT1).

CET 1 is the highest quality regulatory capital, allowing banks to promptly absorb possible losses. Additional Tier 1 can absorb losses on a going-concern basis as well. However, AT1 includes instruments that do not satisfy the restricted criteria to be included in the CET1. Only perpetual instruments are eligible for AT1. Meeting the capital requirements could therefore be one of the reasons for issuing perpetual bonds.

Table 2.10 summarizes the components of regulatory capital.

[31] "Definitions of capital varied widely between jurisdictions, regulatory adjustments were generally not applied to the appropriate level of capital and disclosures were either deficient or non-comparable. These factors contributed to the lack of public confidence in capital ratios during the GFC", *Definition of capital in Basel III – Executive Summary.* Available at: https://www.bis.org/fsi/fsisummaries/defcap_b3.pdf.

Banks must always meet specified minimum capital requirements. More specifically, Common Equity Tier1 must be at least 4,5% of risk-weighted assets (RWA); Tier 1 must be at least 6% of RWA; Total capital must be at least 8.0% of RWA[32] (BIS 2023).

Table 2.11 summarizes the components of the bank regulatory capital.

Table 2.11
Components of bank regulatory capital

			RWA
TIER 1 (going concern)	***CET 1***		CET1 > 4,5%
	AT 1	• instruments issued by the bank that meeting the criteria for inclusion in Additional Tier 1 capital (and are not included in Common Equity Tier 1); • stock surplus (share premium) resulting from the issue of instruments included in Additional Tier 1 capital; • instruments issued by consolidated subsidiaries of the bank and held by third parties that meet the criteria for inclusion in Additional Tier 1 capital and are not included in Common Equity Tier 1 capital. regulatory adjustments applied in the calculation of Additional Tier 1 Capital	CET 1 + AT1 > 6%
TIER 2 (gone concern)		Tier 2 capital consists of the sum of the following elements: • instruments issued by the bank that meet the criteria for inclusion in Tier 2 capital (and are not included in Tier 1 capital); • stock surplus (share premium) resulting from the issue of instruments included in Tier 2 capital; • instruments issued by consolidated subsidiaries of the bank and held by third parties that meet the criteria for inclusion in Tier 2 capital and are not included in Tier 1 capital. • certain loan-loss provisions as specified in Cap10.18CAP10.18 and Cap10.19; • regulatory adjustments applied in the calculation of Tier 2 capital.	Tier 1 + Tier 2 > 8%

Table 2.12 shows the green bonds currently classified as Additional Tier 1. For banks, even if meeting the capital requirements could be one of the reasons for issuing perpetual bonds, data show that the number of Additional Tier 1 bonds is very limited . Therefore, we can conclude that the Basel III core capital requirements are not the main reason for issuing green bonds without maturity.

[32] The Basel Framework for risk-based capital requirement specify: "*In addition, a Common Equity Tier 1 capital conservation buffer is set at 2.5% of RWA for all banks. Banks may also be subject to a countercyclical capital buffer or higher loss absorbency requirements for systemically important banks".* Chapter RBC 20.1: Minimum risk-based capital requirements.

Table 2.12

Green Bond Additional Tier 1. All the bonds are perpetual and callable.

Issuer	ISIN	Issue Date	First Call Date	Coupon Type	Country of Issue	Amount Issue (USD)
KB Financial Group	KR6105562B58	28/05/2021	28/05/2021	Fixed Resettable	South Korea	81.942.178
Axis Bank Ltd (Gandhinagar Branch)	US05464XAA37	08/09/2021	08/09/2026	Fixed Resettable	United States	600.000.000
Hong Leong Bank Bhd	MYBUZ2201443	29/04/2021	29/04/2027	Step Up / Step Down	Malaysia	n.d.
de Volksbank NV	XS2454874285	15/06/2022	15/06/2027	Fixed then Floating	Eurobond	325.439.614
Banco Bilbao Vizcaya Argentaria SA	ES0813211028	15/07/2020	15/01/2026	Fixed Resettable	Spain	201.027.473
Bank of Baroda Ltd	INE028A08083	02/12/2016	n.d.	Plain Vanilla Fixed Coupon	India	121.182.743

Appendix 2
Green bonds at country level

Table 2.13

Green bonds at country level.

Country of Issue	Frequency	Percent	Cumulative
Eurobond	2,808	33.17	56.21
China (Mainland)	1,566	18.5	22.56
United States	770	9.1	99.98
Sweden	502	5.93	87.4
Germany	478	5.65	64.32
Japan	406	4.8	70.4
Malaysia	264	3.12	73.66
South Korea	243	2.87	81.14
Norway	235	2.78	77.17
France	198	2.34	58.67
Switzerland	126	1.49	88.88
Taiwan	103	1.22	90.1
Brazil	94	1.11	2.95
Canada	90	1.06	4.02
Australia	64	0.76	1.1
Thailand	59	0.7	90.8

Austria	47	0.56	1.65
India	42	0.5	65.27
New Zealand	34	0.4	74.37
Denmark	30	0.35	23.05
Argentina	29	0.34	0.34
Spain	28	0.33	81.47
Mexico	22	0.26	73.92
South Africa	22	0.26	78.27
Singapore	18	0.21	77.91
Hong Kong	16	0.19	64.55
Belgium	15	0.18	1.84
Hungary	13	0.15	64.71
Indonesia	13	0.15	65.43
Italy	13	0.15	65.6
Russia	13	0.15	77.7
Panama	12	0.14	77.31
Colombia	10	0.12	22.68
Finland	10	0.12	56.33
Slovakia	8	0.09	78.01
Latvia	7	0.08	70.48
Iceland	6	0.07	64.78
Philippines	5	0.06	77.42
Poland	5	0.06	77.47
United Kingdom	5	0.06	90.88
Chile	4	0.05	4.06
Greece	4	0.05	64.36
Peru	4	0.05	77.36
Portugal	4	0.05	77.52
Ireland	2	0.02	65.45
Liechtenstein	2	0.02	70.51
Lithuania	2	0.02	70.53
Netherlands	2	0.02	73.97
Nigeria	2	0.02	74.39
Romania	2	0.02	77.55
Turkey	2	0.02	90.82
Vietnam	2	0.02	100
Bangladesh	1	0.01	1.67
Costa Rica	1	0.01	22.69
Luxembourg	1	0.01	70.54
Morocco	1	0.01	73.93
Namibia	1	0.01	73.94

APPENDIX 3

Use of proceed in different sectors

Table 4. *Number GBs use of proceeds for each sector*

Use of Proceeds	Banking	Other Financial	Eletric Power	Supernatural	Agency	Service Company	Manufactoring	Official and Muni	Transport	Energy Company	Gas Distribution	Consumer Goods	Telephone	Independent Finance	Sovereign
Access to Essential services	1	6		2	6		1	4	1						
Acquiring and distribution of vaccine		1													
Acquisition	1	5	1			2	2		1		2				
Affordable Basic Infrastructure					2										
Agriculture				2											
Alternative Energy	24	2	117	35	11	3	6	5		5	3				
Aquatic Biodiversity conservation	22	5	6	1	13	1	6	14	3			2			
Capital expenditure			1									2			
Capital expenditure/Financing expenses		5					4								
Carbon reduction through reforestation				2			4				1				
China Urban Construction		2	1			8	3		1						
Circular Economy Adapted/Eco-efficiency	16	21	5		4	8	51	1	1	2	2	5	1		
Clean Transport	568	563	131	234	24	15	251	76	173	25	3	16	5	4	
Climate Change Adaptation.	235	89	62	117	85	39	6	16	15	6	1	1			4
E-education programs/projects	1														
Economic Development	1	1							1	1					
Electric & Public P..	2	1	2				5		1	1					
Eligible Green Projects	15	39	137	112	39	97	178	13	63	9	2	4	1		
Employee stock ownership plan	1														
Energy Efficiency	462	488	446	99	147	152	17	12	2	52	12	5	1		

Environmental Protection Projects	6	11	2	4	1	8	4	2		1		
Environmentally Sustainable Products	1	7	2		2	5	7		1			
Equipment Upgrade/Construction		3	3				3					1
Financing of Subordinated Loan				1	1							
Food Security and Sustainable Food Systems						1						
Funding new technologies to reduce GHS emissions		1								4		
Gas									1	1		
General Purpose	4	23	53	9	1	1	19		2	3		
General Purpose/Acquisition			7									
General Purpose/Refinance	2	4	1			1	1					
General Purpose/Working Capital			1			1						
Green Construction/Buildings	139	164	12	4	17	83	136	3	16		1	
Higher Education	1											
Industrial Development		1					3					
Infrastructure	1	1	1	1	1				3		1	
Land Preservation		1					2					
Merger or Acquisition		2							1			
Other			1			1	5					
Other Education	1											
Other Housing	2	3					2					
Other Public Service								4				
Other Transportation									2			
Pandemic		1										
Pollution Control		1	1				1					
Pollution Prevention & Control	6	16	5		1	15	1	1	4	2		2
Production/Supply of Cannabis							1					

Project Finance	1	1	16			1	1								
Property Expendit (acquisit/development)							1								
Redeem Existing Bonds or Securities		3	2			3	2		3	1					
Refinance/Financing expenses	1	12	2		2										
Renewable Energy Projects	64	95	194	3	17	17	39		9	11	3	5	1		
Repay Bank Loan or Bridge Financing		2	1			1			1						
Repay Intercompany Debt		1													
Ship finance							1		1						
Social Housing/Affordable Housing					4										
Socioeconomic Advancement And Empowerment	1														
Solar projects		1	1			1									
Sustainable Development Projects	1	2	1		1		1								
Sustainable Economic Growth	1														
Sustainable Management of Land Use	1	1	1		1	1				1					
Sustainable Management of Living Natural Resources		2				1									
Sustainable Transport		1							1						
Sustainable Water or Wastewater management	1	16	2	3	16	21	3	1				2			
Terrestrial Biodiversity Conservation			1												
The Belt and Road Initiative	4						1								
Waste Management		3				2	2								
Water & Sewer		3	1			9		1	1						
Wind projects		3	1								1				
Working capital		1	4												
Total	1,731	1,920	1,234	629	576	588	986	243	326	125	32	45	18	4	4

CHAPTER 3

THE *GREENIUM* IN THE BANKING SECTOR

3.1 Introduction

Sustainability has become one of the most relevant topics that involve individuals, companies and policy makers around the world.

In recent years, the Environmental, Social, and Governance (ESG) investment has rapidly grown. According to European Commission[33], Sustainable Finance has a key role in achieving the Paris Climate Agreement goals, channelling financial flows towards low-carbon and climate-resilient development.

Within sustainable finance, Green Bonds (GBs) have become very popular and represent a central instrument for sustainability's goals, particularly financially supporting the transition to a low-carbon economy (Sartzetakis, 2021)

The International Capital Market Association (ICMA 2021) defines Green Bonds as *"any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects".*

Green bonds are fixed income securities whose purpose, unlike traditional fixed income bonds, is to support specific projects with a positive environmental benefit. According to the Green Bond Principle (GBP),[34] issuers have to disclose to stakeholders transparent and accurate information. Relevant information is related to the use of proceeds, process for project evaluation and selection, management of proceeds and reporting.

Initially, the new bonds were issued by supranational financial institutions, such as the World Bank or the European Investment Bank, and then municipalities, State Agencies and Corporate companies started to use this new instrument. The first green bond was

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[33] See "Overview of sustainable finance", available at: https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en.

[34] The Green Bond Principles (GBP) are voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the Green Bond market by clarifying the approach for issuance of a Green Bond. See Green Bond Principles Voluntary Process Guidelines for Issuing Green Bonds, June 2021: https://www.icmagroup.org/assets/documents/Sustainable-finance/2022-updates/Green-Bond-Principles_June-2022-280622.pdf

issued in 2007 by the European Investment Bank (EIB). However, only since 2016 the number of issuances, and their total amount, has gradually grown. In the thirteen years since the market inception, Climate Bonds Initiative have calculated an average annual growth rate of approximately 95%. From 2007 to June 2023 the cumulative issuances reach about 2.3 trillion dollars[35].

The term "green" is used in several contexts and there is no universally accepted definition. Notwithstanding, the green bond issuances are driven by Green Bond Principles (GBP) (ICMA 2021), which aim to support issuers and investors clarifying the main aspects during the bonds' life and promoting transparency.

Compared to traditional bonds, GBs issuances embedded several constraints. According to the GBP, issuers have to implement a specific investment policy in order to select green projects. This could strongly reduce investment opportunities. Furthermore, other constraints, such as external certification, disclosure obligations and monitoring activities, may increase the overall costs.

Due to several constraints, green bonds could be considered a choice in contrast with the *homo economicus* theory, both from the issuers' perspective and investors' perspective.

The reasons that may lead stakeholders to prefer green bonds are therefore extremely relevant.

Flammer (2021) identified three potential reasons to issue this new financial instrument:

1) the first is that green bonds represent a strong market signal regarding the companies' attention towards environmental issues;
2) the second refers to the *greenwashing* practice. The lack of efficiency controls in the green market, allows companies to issue green bonds even if they do not implement actions with positive environmental impact;
3) The third reason to issue green bonds is related to the *cost of capital* and it is the core of this study. In order to achieve sustainability goals, investors could accept less returns and, consequently, for issuers green bonds may represent a cheaper source of financing compared to traditional bonds. This phenomenon is called *greenium*.

From an investors' perspective, it is not clear whether they are willing to receive a lower return to finance projects with a potential positive environmental impact.

[35] Climate Bonds Initiative update constantly data in the website home page. Accessed 26 June 2023.

For these reasons, we investigate the existence of *greenium*. We focus on the primary market, examining the differences in yield-to-maturity between green and non-green bonds in the banking system. Several motivations prompted us to analyze banks. First, Banks issued 26% of the total amount issued in the green bonds market[36]. Second, the relationship between banks' green bonds and the use of proceeds for green projects could be an indirect relation. Indeed, banks are only the ones that can issue green bonds to finance their own projects, like other companies, or can use the proceeds of green bonds for lending, financing customers' green projects. In the second option, details about the projects to finance could be unknown, or less clear, ex-ante.

Third, the banking sector is crucial for sustainable finance. Banks, due to their relevant role in the intermediation system, are and will be fundamental players in the achievement of sustainable goals and assistance to the real economy (Panetta 2021).

Finally, the number of studies that focus on green bonds in the banking system is very limited and does not consider a large number of issuances in the last few years.

Even though the interest of academia in green bonds is increasing, the literature regarding this specific financial instrument is still in the first stages. Previous studies investigate the green bond in the US municipal market, others focus on the corporate green bond or the whole financial sector. Existing literature lacks contributions specifically focused on the banking industry.

The evidence on the greenium is conflicting and results vary based on the methodology used (Flammer 2021). Furthermore, most contributions do not consider the green bonds' boom of recent years.

Our paper aims to fill this gap and extend the literature regarding this financial instrument.

Our study contributes to the literature in several ways. First, we extend the growing literature that studies the green bond markets and sustainability in the banking industry.

Moreover, this paper contributes to the recent literature on impact investing that refers to the new instruments that aim to generate social and environmental positive impact[37].

We contribute also to the literature that studies investors' preference towards ESG (Dimson et al. 2015; Dyck et al. 2019).

[36] Authors' calculation based on Refinitiv-Eikon database. The second sector in terms of Amount Issued, based on TBCR classification is "Government and Government Finance" which represented the 9%.

[37] Global Impact Investing Network, "Impact Investing", 2018, provides more details.

3.2 Literature review

The literature on banking and ESG is still not widespread. Scholars have mainly focused on CSR, specifically, the social dimension of ESG within CSR and the creation of value for a company with only a timid interest in environmental issues (Galletta et al. 2022).
Recent studies suggest that people value sustainability (Hartzmark and Sussman 2019). The positive market reaction to green bond issuance (Flammer 2021; Tang and Zhang 2020) confirms the investors' interest towards environmentally friendly instruments.
The *greenium* presupposes investors' willingness to accept lower returns in exchange for a positive environmental impact. Despite the impact of non-pecuniary benefits in investments is not something new (i.e. Andreoni 1989), recent studies based on socially responsible investments (SRI) show that investors are willing to forgo financial performance. In accordance with their social preferences, they pay higher management fees for SRI funds (Riedl Smeets 2017). In line with this result, prior literature found that investor cash flow in SRI funds has less volatility compared to conventional ones and cash outflows are less sensitive to lagged negative return. (Bollen 2007; Renneboog et al. 2011).
Bedendo et al. (2022) analyzed the characteristics of banks that issue green bonds in order to understand which banks are more likely to use this instrument and if the issuance leads to an improvement in a bank's environmental footprint.
The existence of *greenium* is currently opaque and the previous studies, analysing different markets and using different methodologies, show opposite results.
Karpf and Mandel (2018) focus on green bonds in the US American municipal bonds market and investigate the yield term structures of green and standard bonds from issuers. Using secondary market yields, they find on average a green bond discount of approximately about eight basis points.
US municipal bonds, issued from 2010 through 2016, were analysed also by Baker et al. (2018) who have found opposite results according to which green municipal bonds are issued at a premium to otherwise similar ordinary bonds. Baker *et al.* (2018) explain that their results are more accurate as compared to the previous study that shows due to the fact that many municipal bonds included by Karpf and Mandel (2018) in their sample were taxable, and the US municipal market is highly sensitive to tax features.

Zerbib (2019) expand the analysis and investigate green bonds' pricing outside the US municipal bonds market. The author has examined a sample of 110 green bonds issued from July 2013 to December 2017. The dataset includes bonds of various kinds: supranational, sub-sovereign and agency (SSA), municipal, corporate, financial and covered bonds. For each were selected a counterfactual conventional bond in order to estimate the yield differential. The results show on average a premium of two basis points. Ehlers and Packer (2017), analysing 21 green bonds between 2014 and 2017, found that investors are willing to pay a premium of 18 basis points. The same results, even though with a different magnitude, were found by Hachenberg and Schiereck (2018) which focus on secondary markets and investigate daily data of a sample of 63 green bonds in different sectors from October 1, 2015, to March 31, 2016. They found a premium of 1 basis point. Even though these results seem to be consistent with the existence of *greenium*, subsequential studies revisit previous literature questioning their results. Larcker and Watts (2020) whose study is close to Karpf and Mandel (2017) and Backer (2018), state that prior results are biased by the methodical design.

Larcker and Watts (2020) implemented a strong matching procedure that allows the selection of the comparable "brown" bond of the same issuer solving some methodological problems. The results are the opposite and show that, in the US municipal market, the *greenium* is zero. Similar methodology and similar results are those obtained by Flammer (2021) who, examining 152 corporate green bonds from 2010 to 2018, finds no pricing difference between corporate green bonds and non-green bonds. Hence, it strengthened the idea that the new instrument may not be considered a cheaper source of debt financing. Nevertheless, Fatica et al (2021), using a large sample of bonds issued worldwide from 2007 to 2018, find a premium for green bonds issued by supranational institutions and corporates but no yield differences in the case of issuances by financial institutions. Moreover, the European Securities and Markets Authority (ESMA) Report on Trends, Risks and Vulnerabilities (ESMA 2022) show evidence of the existence of a *greenium* for investment rate bonds with a residual maturity of more than ten years.

We are therefore faced with a phenomenon on which the literature has produced mixed results and deserves further analysis to clarify the reasons behind the spread of this financial instrument.

3.3 Data

We construct the data set from the Refinitiv Eikon database. The data collection process can be divided into two steps.

First, we selected all green bonds issued by Banks[38]. Due to the several numbers of missing information for the Yield to Maturity at the issuance, we directly calculate this variable. We thus restrict the sample to bonds with non-missing information in the Price at Issuance, in order to be able to calculate the Yield to Maturity. The decision to not extract the dependent variable directly from the database, allows us to have a larger number of observations. We randomly compare the results of our Yield to Maturity calculation with the ones provided by Rifinitiv Eikon. We verified that there are no differences in the formula we apply. Furthermore, we keep just the Zero-Coupon bond and the Plain Vanilla Fixed Coupon.

A total of 1,149 green bonds have been included in the sample issued by 280 different banks.

In the second step, we extracted the traditional bond (or brown bonds or non-green) issued by the same banks, in order to create the control sample. We follow the same strategy used for the green bonds except for the period. Since the first green bond in our sample was issued in 2013, we do not include issuance before this year. The number of brown bonds is 200,530.

The initial sample includes 201,679 bonds and covers the period from 2013 to 2023[39]. For each bond, we selected a set of variables.

The descriptive statistics of our sample are summarized in Table 1. The table is divided into Panel A, Panel B and Panel C, which report the descriptive statics of the total sample, green bonds, and non-green bonds, respectively.

The number of observations for the rating variable is extremely limited, both for green and non-green bonds. Flammer (2021) based the first step of the matching approach on the Rating. Due to the several missing values in our sample, we do not use this variable for the matching, even though we tested our results also including the rating. However,

[38] We selected all the bonds in the sector Banks, for which the Green Bond indicator is "Yes"

[39] The data extractions have been done in March 2023.

using the bank as a parameter for our matching, we strongly reduce the risk to match bonds with similar characteristics and different risks.

Table 2 shows the total number of issuances, and the total amount has constantly grown. Our sample cover just the first three months of 2023. Nevertheless, this year is characterized by an increase in the amount issued.

A breakdown by country of issue is provided in Table 3. Based on the Refinitiv-Eikon data, the larger number of banking green bonds are classified as Eurobonds, which represented almost 37% of the sample, followed by Europe and Asia. The North American issuances are limited, even though the mean amount issued is higher compared to the other countries. More details about each country are reported in Table 4.

Table 1

Summary statistic

This table shows the summary statistic for the overall sample (Panel A), green bonds (A) and Non-green bonds (Panel C).

Yield is the Yield to maturity at Issue. *Coupon* is the annual interest rate for Plain vanilla fixed coupon bonds. *Amount* is issuance amount (in Mln $). *Rating* is the credit rating at the issuance level. The variable assumes values from 1 (top rating) to 19 (worst rating). *Maturity* is the maturity of the green bond (in years). *Call* is a dummy variable that is equal to one if the bond is callable. *Put* is a dummy that is equal to one if the bond is putable. *Bank size* is the log of the Total Assets in the issuance year.

Yield, Coupon, and Amount have been winsorised at 1% and 99%.

Panel A: Green and Non-Green Bonds					
Variable	**Obs**	**Mean**	**Std. dev.**	**Min**	**Max**
Yield	201,679	0.0482	0.0627	-0.0050	0.3171
Coupon	202,349	5.84	5.3954	0.0000	23.4000
Amount (Mln USD)	196,310	27,5	126	0.1	1,000
Maturity (Years)	201,679	2.635	4.648	0.005	1010.671
Call	201,679	0.1352	0.3421	0	1.
Put	201,679	0.0001	0.0111	0	1
Rating	10,051	4.5678	2.8209	1.	18
Bank Size	37,850	27.3192	0.7827	21.6479	29.3795
Panel B: Green Bonds					
Yield	1,149	0.0198	0.0215	-0.0033	0.1752
Coupon	1,074	2.0795	2.1333	0	17.5200
Amount (Mln USD)	1,149	260.00	302.00	0.0756	1,070.00
Maturity (Years)	1,149	5.9485	3.9927	1	34.0247
Call	1,149	0.0722	0.0000	0	1
Put	1,149	1.9437	2.1255	0.0000	17.5200
Rating	511	4.1350	2.9624	1	17
Bank Size	315	27.0539	1.4298	22.9015	29.3796

Panel C: Non-Green Bonds					
Yield	200,530	0.0483	0.0628	-0.0050	0.3171
Coupon	200,530	4.1642	5.2734	0.0000	23.4000
Amount (Mln USD)	195,161	25.4	118	0.0863	1,000.0000
Maturity (Years)	200,530	2.6157	4.6446	0.0055	1,011
Call	200,530	0.1358	0.3425	0.0000	1.0000
Put	0.0001	0.0112	0.0000	1.0000	0.0001
Rating	4.5910	2.8114	1.0000	18.0000	4.5910
Bank Size	27.3284	0.7687	21.6479	29.3796	27.3284

Table 2
Green bonds over time.
This table reports the number of green bond years and the total issuance amount. The variable amount has been winsorised at 1% and 99%.

Year	Obs	$ Amount (Mean)	$ Amount (Std. dev.)	$ Amount Min	$ Amount Max
2013	4	174,000,000	219,000,000	41,200,000	500,000,000
2014	14	69,000,000	103,000,000	1,450,692	372,000,000
2015	22	352,000,000	267,000,000	3,041,140	800,000,000
2016	44	450,000,000	356,000,000	790,696	1,000,000,000
2017	73	264,000,000	274,000,000	340,089	1,000,000,000
2018	91	306,000,000	302,000,000	361,344	1,000,000,000
2019	109	306,000,000	310,000,000	307,048	1,000,000,000
2020	183	112,000,000	198,000,000	168,000	1,000,000,000
2021	291	192,000,000	253,000,000	86,343	1,000,000,000
2022	301	330,000,000	311,000,000	107,359	1,000,000,000
2023 (March)	17	577,000,000	285,000,000	6,441,569	1,000,000,000

Table 3
Number of issuances for main geographic areas and relatively Amount issue.

Area	Number	$Mln Amount (mean)	Total Amount
Eurobond	420	315.48	133,478.76
Noth America	32	565.36	18,091.51
Europe	401	164.35	65,906.27
Asia	245	299.5	73,378.10
Africa	1	32.61	32.61
Others	50	1633.0	8,157.32

Table 4. *Green bonds country*

Country of Issue	Freq.	Percent	Amount Mln $ (mean)
Australia	3	0.26	260.00
Austria	24	2.09	80.30
Canada	1	0.09	798.00
China (Mainland)	185	16.11	559
Eurobond	420	36.59	12.00
France	14	1.22	322.00
Germany	346	30.14	72.10
Hong Kong	1	0.09	134.00
Hungary	2	0.17	41.30
India	2	0.17	467.00
Indonesia	5	0.44	89.30
Italy	1	0.09	194.00
Japan	1	0.09	246.00
Netherlands	1	0.09	787.00
Nigeria	1	0.09	32.60
Panama	6	0.52	3.22
Philippines	1	0.09	184.00
Romania	2	0.17	123.00
Russia	1	0.09	156.00
Slovakia	5	0.44	75.20
South Korea	6	0.52	145.00
Spain	2	0.17	538.00
Sweden	4	0.35	6.24
Switzerland	39	3.4	146.00
Taiwan	44	3.83	98.00
United States	31	2.7	44.8
Total	1,148		

3.4 Methodology

In the existing literature is it possible to find different approaches for measuring a potential premium. The analyses of previous studies highlight how methodology is crucial for our purpose. To explain our methodology, an explanation regarding the discussion about how to measure the *greenium* is needed.

At the beginning of the green bond market, the number of corporate bonds was very small. For this reason, the first studies focused on municipal bonds which ensured broader coverage.

Karpf and Mendel (2018) investigate the existence of *greenium* in the secondary market of the municipal bond. They use OLS regression and Oaxaca–Blinder decomposition[40] and found that green bonds returns are, on average, higher than ordinary bonds. Backer *et al*. (2018) test the prediction that municipal green bonds sell for a small premium, i.e. lower yields, compared to municipal ordinary ones. They use a pooled regression with the yield at issue as a dependent variable and several control variables and fixed effect for this aim. They found a *greenium* at about 6 basis points.

Backer *et al*. (2018) approach has been reviewed by Larker and Watts (2020), who state that the use of pooled fixed-effect regression model is not the correct way to measure the greenium. They also investigated municipal bonds and inspired by Crabbe and Turner (1995), Bernstein et al. (2019), and Schwert (2020), the authors propose a matching approach. They match each green bond with a non-green issued by the same issuer on the same day. Issue green and non-green bonds with the same features at the same time is common for municipal bonds[41] and allow authors to estimate the treatment effect[42] using a model-free matching method (Crabbe and Turner 1995).

Larker and Watts's (2020) results using the matching approach show no evidence of the existence of greenium. This study has striking implications because sheds light on the methodology's crucial aspect. Using the pooled fixed-effect regressions, the authors find similar results to Baker (2018)[43]. However, using the matching approach, the results change and the greenium disappears.

Larker and Watts's (2020) methodology were used by Flammer (2021) highlighting thus how matching represents a consistent approach for measuring premium. Flammer (2021) matched each green bond with the most comparable brown issue from the same issuer. The author has used nearest-neighbor matching, using Mahalanobis distance as the

[40] Authors explained that Oaxaca–Blinder basic two-fold decomposition was initially introduced to quantify gender discrimination in the labour market. For more details see Oxaca (1973) and Blinder (1973).
[41] Corporate bonds do not have this feature and the exact match is thus extremely rare.
[42] Considering green bonds identical ordinary bonds, except for the use of proceeds, it is possible to consider the impact of the "green treatment".
[43] Larcker and Watts (2020), entitle the section 5.4 "*Reconciling with Baker et al. (2018)"*. In this section they provide a deep deep explanation about Backer's methodology issue.

distance metric. Analysis shows no statistical significance in difference-in-means and difference-in-medians tests.

Fatica *et al.* (2021) follow the Backer approach, despite they use Propensity Score Matching as robustness check, to evaluate if green bonds are issued at a premium. They found evidence of greenium just for green bonds issued by supranational institutions and corporates.

It is therefore evident that the previous studies have led to different results also based on the methodology used, as well as the type of issuer or the coverage of the sample.

Following Larker and Watts (2020) and Flammer (202 1), we use the matching approach to investigate whether, in the banking system, green bonds are issued at a lower yield compared to ordinary bonds.

5.1 Matching methods

Matching is becoming an increasingly popular method for causal inferences in observational data.

(Stuart 2010) defines "matching" broadly to be any method that aims to equate (or balance) the distribution of covariates in the treated and control groups.

Matching is a non-parametric approach that is powerful when the assignment of units to treatment and control groups is not random and not under the control of the researcher. (Iacus, King, and Porro 2019). In our dataset, we can consider green bonds as the treatment group (T: green=1) and ordinary bonds as a control group (C: green=0).

Matching methods optimize the balance[44] between the treated and control groups, reducing the *model dependent.* Model dependence is related to the researcher's

[44] Ho *et al*. (2007), in the introduction, provide a clear explanation about model dependance: "*Political science research typically begins by first spending considerable time collecting, correcting, recollecting, merging, and recoding data. When all the data are finally available in the right format and loaded into one's favorite statistical package, researchers obtain a causal estimate by running some parametric statistical procedure—linear regression, logit, probit, duration models, structural equation models, count models, etc. This run typically takes only a few seconds and, according to some textbooks, it would be time to write up the results. Of course, this never happens. Instead, we do a second run with different control variables, a third with a different functional form, a fourth with a different measure of our key causal variable, one with different sample periods or observation subsets, and then each of these and others are repeated with slight variations over and over again. Although this usual procedure produces hundreds or thousands of alternative estimates of our single causal effect, we typically only choose one, and rarely more than 5–10, to present in a paper. Yet, we know that our estimates depend on their corresponding modeling assumptions and*

discretionary choices, so its decrease means also reduces estimator errors and bias (Cochran and Rubin 1973; Rubin 1974; King *et al.* 2017).

Before briefly describe the most common matching methods, it is useful clarify what we refer using with the term "*distance".* Distance is a measure of the similarity between two individual (Stuart, 2010). Exact matching is the ideal option (Imai *et al.* 2008). However, it is very rarely applicable, especially with a larger number of covariates, since it would limit matching to just a few units.

Without exact matching, the idea is to match treatment and control units by reducing the distance between the treatment unit and the control unit.

There are different matching approaches. In order to explain our choice, we briefly describe some of the most common: Propensity Score Matching (PSM), Mahalanobis Distance Matching (MDM), Neighbor Nearest Matching (NNM) and Coarsen Exact Matching (CEM).

1) Propensity Score Matching (PSM) is the most popular matching method. It has been used for several studies in a huge number of fields[45]. The propensity score is the probability for unit *i* to receive the treatment, given a set of observed variables. Despite its popularity, Kind and Nielsen (2017) deeply analyze the limitation of PSM as a matching approach. The title of this study, *"Why Propensity Scores Should Not Be Used for Matching"* summarizes in a very effective way the weakness of this method[46]. The aim of PSM (1985) is to analyze an observational dataset replicating, as much as possible, a completely randomized experiment. However, if possible, fully blocked randomized experiments are more efficient. Propensity score matching increases imbalance, model dependence and bias. (Kind and Nielsen 2017)

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that different specifications can yield very different causal inferences. Most causal effect estimates given in the literature are thus model dependent, at least to some degree (…).

For model dependance problems in casual inference see also King and Nielsen (2017), section 2.

[45] Web of Science (WOS), the 19 June 2023, provides 33,540 results for "Propensity Score" AND match*. The first five WOS categories are: Surgery, Cardiac Cardiovascular Systems, Oncology, Medicine general Internal and Economics. Despite the number of studies in medicine field, PSM is commonly used also, in Business Finance, Environmental Sciences, Management, Urban Studies, among others. It is thus a method used by researcher from different field.

[46] Presentation of the paper by first author is available at: https://www.youtube.com/watch?v=rBv39pK1iEs.

2) Mahalanobis Distance was introduced by P.C. Mahalanobis in 1936. The formula to measure the distance is:

$$D_{ct} = [(X_c - X_t)' S^{-1} (X_c - X_t)]^{1/2}$$

Where:

D_{TC} = Distance between the treatment unit and the control unit.

Xc = Vector for control unit.

Xt = Vector for treated unit.

S = if the interest is in the ATT, S is the variance-covariance matrix of X in the full control group; if interest is in the ATE, then S is the variance-covariance matrix of X in the pooled treatment and full control groups (Stuart, 2010)

It is possible to match each treated unit with the nearest control unit using the Mahalanobis distance measure. Researchers can define a minimum distance acceptable, beyond which matching could be not possible. As for the exact matching, the Mahalanobis distance is weak when the number of covariates is high.

Mahalanobis distance is basically the Euclidean with standardization of all the variables. This is a relevant point that makes Euclidean distance more appropriate in applications.

3) Neighbor Nearest Matching (NNM), is a common and effective method (Rubin 1973). It is also called greedy matching because each pairing occurs without reference to how other units will be or have been paired, and therefore does not aim to optimize any criterion[47]. The most common software, such as R or Stata, included NNM methodologies. The analysis in this study has been implemented using *Stata 17* which offers several options for the analysis of treatment effects from observational data. The command for neighbor nearest matching estimation is *teffects nnmatch* through which it is possible to estimate the average treatment effect (ATE) and average treatment effect on the treated (ATET or ATT). The average treatment effect is the gain in the population while ATET is the average gain for those who actually were treated.

[47] Graifer, N. describe Pyton command "MatchIT "providing a good explanation about matching methods. See: https://cran.r-project.org/.

We can formalize the two effects as follow:

$$ATE = E[\ Y(1) - Y(0)]$$

$$ATET = E[Y(1) - Y(0)\ |T=1]$$

Where:

Y(1) = the outcomes with treatment

Y(0) = the outcomes without treatment

T = binary variable equal 1 for treated units and 0 otherwise.

The two treatment effects, ATE and ATET, could also differ significantly.

The observations within the treated subsample are for researchers particularly interesting to focus on. Analysing the ATET for observation *i,* we can notice that while $Y_i(1)$ is observed, $Y_i(0)$ is unobserved.

The challenge is thus the estimation of the second part, namely E[Y(0) | T=1].

To solve this problem, the Stata *teffects nnmatch command "*determines the "nearest" by using a weighted function of the covariates for each observation. According to Stata treatment-effects manual description, NNM estimator *"imputes the missing potential outcome for each subject by using an average of the outcomes of similar subjects that receive the other treatment level. Similarity between subjects is based on a weighted function of the covariates for each observation. The treatment effect is computed by taking the average of the difference between the observed and imputed potential outcomes for each subject"* [48]

4) Coarsen Exact Matching (CEM) is a method for improving the estimation of causal effects by reducing the imbalance in covariates between treated and control groups (Blackwell et al. 2009). CEM approximate a fully blocked experiment. As mentioned above, it is almost impossible to find exact matches for a reasonable number of observations. CEM solve this problem by temporarily coarsening each variable into

[48] Stata treatment-effect reference manual: potential outcomes/counterfactual outcomes. Release 17, pag. 318. The Manual is available at: https://www.stata.com/manuals16/te.pdf.

substantively meaningful groups, exact match on these coarsened data, and then retaining only the original values of the matched data (Blackwell *et al.* 2009)[49].
CEM can be also used to improve other methods, including other matching methods, using the CEM-matched dataset.

For our analyses, we use Coarsen Exact Matching (Iacus *et al.* 2012). In addition to theoretical studies, strong empirical evidence about the effectiveness of the CEM arrived from different fields (Ripollone *et al*. 2020). Furthermore, although still not widespread, the CEM has been used in the finance banking sector, to reduce the imbalance.
Since exact matching is not possible, CEM allow us to preprocess our data, matching green bonds (treated group) with ordinary bonds (control group). As described above, the number of green bonds issued by banks represents just 0.57% of the total bonds.
First, we look at the imbalance in covariates between the treatment (green) and control group (non-green) (Iacus *et al.* 2008). The analysis is performed using the following variable: Amount Issued, Coupon, Years to Maturity, Year at Issue, Market and Issuer and call option (Flammer 202; Fatica *et al.* 2021). This step can provide information about the quality of the matched data. The overall imbalance is measured as follows:

$$Lf(x) = \frac{1}{2} + \sum_{l1.....lk} | f_{l1.....lk} - g_{l1.....lk} |$$

L=0 means perfect global balance, while L=1 complete separation.
Table …shows results based on variables used.
Based on the variables selected, our dataset is strongly imbalanced. It is not a surprise to find several differences in the features of bonds issued by different banks, in different periods and from different countries. However, this does not represent a problem for our goal.

[49] Blackwell *et al.* (2009) create the command *cem* for the most command softwarer (e.g. STATA and R.). They describe the algorithm's work as follow: 1) Begin with the covariates X and make a copy, which we denote as X*; 2) Coarsen X∗ according to user-defined cutpoints or CEM's automatic binning algorithm; 3) Create one stratum per unique observation of X*, and place each observation in a stratum.4)*Assign these strata to the original data, X, and drop any observation whose stratum does not contain at least one treated and one control unit.

Iacus *et al.* (2008) highlighted that this measure is not valuable on its own but must be used as a benchmark, providing information about the quality of the subsequent matching.

After having evaluated the imbalance of our data, we implemented the matching using the Coarsen Exact Matching. We performed 4 different matchings all based on the following variables: Issuer, Amount Issued, Coupon, Coupon type, Years to maturity at Issue, and Country of issue.
The CEM, as expected, can strongly reduce the imbalance of our data. Moreover, CEM allows us to perform Neighbor Nearest Matching (NNM) in order to analyse the treatment effect and thus the existence of greenium.
Details of each Coarsen Exact Matching and the results of the treatment effect are provided in the next section which is organized into 3 subsections. Each section shows the imbalance in the row data and the imbalance after performing CEM. Moreover, has been reported the results of NNM in different specifications, using different distance metrics.

3.5 Results

This section shows the results of our analysis based on different Coarsened Exact Matching.
The first step is to measure the imbalance analysis of our row data. We investigate the imbalance using mixed main variables.
For each CEM specification, we show how pre-process data reduce the imbalance.
Using CEM as a restriction for our row data, we performed the Nearest Neighbor Matching to evaluate if the "green treatment effect" can reduce the yield to maturity at issuance.

3.5.1 Coarsened exact matching (CEM): Specification A

The first CEM specification reduces the imbalance from 0.99659 to 0.82158. Despite the improvement in terms of balance, the multivariate distance remains high. Focusing on the univariate imbalance, it is possible to notice how there is a strong distance in the maturity variable. The difference is notable also looking at the summary statistic (see Table 1)

where it can be observed how the maximum year to maturity for the green bonds sample is 34 years while for ordinary bonds is about 1,000. The number of matches is 827, namely 72%. The NNM results show a difference between the average treatment effect (ATE) and the average treatment effect on treated (ATET). Except for one specification, the coefficient is negative for all the specifications performed. This suggests a negative impact on the yield to maturity at issuance time and, thus, the existence of greenium. However, while for ATE, using the Euclidean distance, the coefficient is significant at 1% using the Euclidean distance, the coefficient for ATET is not significant.

Table 5. *Imbalance for treated and control group. LogAmount* is the logarithm of the issuance amount (in US dollars). *Coupon* is the annual interest rate for Plain vanilla fixed coupon bonds. *Maturity* is the maturity of the green bond (in years). Year is the year when the bond is issue. *Country* is the country where the bond is issue. *Bank_id* is a variable which represents each issuer.
Yield, Coupon, and Amount have been winsorised at 1% and 99%.

Multivariate L1 distance: 0.99658217

Univariate imbalance:

	L1	**mean**	**min**	**25%**	**50%**	**75%**	**max**
LogAmount	.73515	4.1268	0	4.2049	4.9388	5.0415	0
Coupon	.38716	-2.3258	0	.3	-.35	-4.75	-5.88
Maturity	.66212	3.3755	.99452	2.6466	3.9863	4	-976.65
Year	.27313	1.3668	0	2	2	1	0
Country	.49541	-.21713	0	0	0	3	0
Bank_id	.7305	7.8518	0	-33	8	42	0

Table 6.
CEM–A results

Number of strata: 16670
Number of matched strata:427

	Non-Green	Green
All	200,530	1,149
Matched	8,911	800
Unmatched	191,619	349

Multivariate L1 distance: .82158136
Univariate imbalance:

	L1	**mean**	**min**	**25%**	**50%**	**75%**	**max**
LogAmount	.03444	.00908	.42063	0	.00204	0	0
Coupon	.14397	-.10383	0	-.015	-.325	-.05	-.64
maturity	.20308	-.73812	.96164	.98904	-.42192	-2	-6.0027
year	0	0	0	0	0	0	0

countryid	.00125	-.00125	0	0	0	0	0
Bank_id	.14056	-.09557	0	2	-3	0	0

Table 7
Treatment effect result using near neaigbor matching for CEM-A

	(1)	(2)	(3)	(4)
	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue
ATE green (1 vs 0)	-0.279	-0.7250***	-0.3023	-0.6633***
	(0. 209)	(0.086)	(0.209)	(0.086)
ATET green (1 vs 0)	-0.029	0.026	-0.066	-0.064
	(0.056)	(0.062)	(0.054)	(0.057)
Mahalanobis distance	Yes		Yes	
Euclidean distance		Yes		Yes
Bias adj	No	No	Yes	Yes
Observation	9705	9711	9711	9711

∗, ∗∗, and ∗∗∗ denotes significance at the 10%, 5%, and 1% level, respectively.

3.5.2 Coarsened exact matching (CEM): Specification B

The second coarsen exact matching differ from the previous one for the introduction of *k-to-k* option which allows to have the same number of treated and control observation for each strata. As a consequence, the number of observations decreased as shown in Table 8. The imbalance was measured using the same variable as the first specification so the multivariate L_1 distance is 0.99658217. The *k-to-k* reduce the imbalance with a L1 distance equal 0.69705094. Results from the treatment effect analysis do not provide evidence about the presence of greenium. Although the coefficient is negative for all the specifications, just the ATE using the Euclidean distance is significant at 10% (see table 9).

Table 8
CEM-B results.

Number of strata: 16670
Number of matched strata:427

	Non-Green	Green
All	200,530	1,149
Matched	746	746
Unmatched	199,784	403

Multivariate L1 distance: .69705094
Univariate imbalance:

	L1	**mean**	**min**	**25%**	**50%**	**75%**	**max**
LogAmount	0.02949	0.01059	0.12542	0.05677	0.019	0.12619	0
Coupon	0.11394	-0.10025	0	0.03	-0.3	-0.085	0
Maturity	0.14745	-0.51915	0.8411	0.98904	0.75069	-2	-6.0027
Year	0	0	0	0	0	0	0
Countryid	0	-0.00268	0	0	0	0	0
Bank_id	0.07239	-0.06702	0	2	1	0	1

Table 9
Treatment effect results using near-neighbor matching. CEM-B

	(1)	(2)	(3)	(4)
	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue
ATE green (1 vs 0)	-0.0596	-0.1416*	-0.0171	-0.0890
	(0.0583)	(0.0833)	(0.0567)	(0.0803)
ATET green (1 vs 0)	-0.0207	- 0.0861	-0.0182	-0.1363
	(0.0560)	(0.1206)	(0.732)	(0.241)
Mahalanobis distance	Yes	No	Yes	No
Euclidean distance	No	Yes	No	Yes
Bias adj	No	No	Yes	Yes
Observation	1492	1492	1492	1492

∗, ∗∗, and ∗∗∗ denotes significance at the 10%, 5%, and 1% level, respectively.

3.5.3 Coarsened exact matching (CEM): Specification C

We highlighted the differences between green and non-green in terms of maturity. In order to verify how bonds with very high maturity can influence our analyses, we exclude bonds with a maturity higher than 34.035 which is the highest maturity in our green sample. We also introduce the variable coupon type in order to create stronger matches. The imbalance check before the CEM implementation confirms a strong imbalance (table 10). The CEM results (table 11) exhibit less imbalance (0.525) even though fewer numbers match. NNM shows, again, a negative coefficient for all the specifications (table 12). The specification (4) shows that yield to maturity at issuance for green bonds is lower than traditional ones at 18 basis points using both ATE and ATET measures. The coefficient is statistically significant at 10%.

Table 10
Imbalance for treated and control group excluding bonds with maturity >34.035 and including the coupon type. LogAmount is the logarithm of the issuance amount (in US dollars). *Coupon* is the annual interest rate for Plain vanilla fixed coupon bonds. *Coupon type* is a dummy variable equal 1 if the bond is a plain vanilla fixed coupon and zero if it is a zero coupon. *Maturity* is the maturity of the green bond (in years). *Year* is the year when the bond is issued. *Country* is the country where the bond is issue. *Bank_id* is a variable which represents each issuer.

Multivariate L1 distance: 0.99704605

Univariate imbalance:

	L1	mean	min	25%	50%	75%	max
LogAmount	0.73493	4.1252	0	4.2049	4.9317	5.0389	0
Coupon	0.38804	-2.3195	0	0.3	-0.35	-4.75	-5.88
Coupon type	0.21331	0.21331	0	1	0	0	0
Maturity	0.66213	3.349	0.99452	2.6438	3.9863	4	0
Year	0.27371	-0.22122	0	0	0	3	0
Country	0.7305	7.8474	0	-33	9	42	0

Table 11
CEM-D results

Number of strata: 16670
Number of matched strata:427

	Non-Green	Green
All	200,369	1,149
Matched	518	518
Unmatched	199,851	631

Multivariate L1 distance: .52509653

Univariate imbalance:

	L1	mean	min	25%	50%	75%	max
LogAmount	0.16409	0.01384	0.123	0.17663	0.1137	0.0912	0
Coupon	0.14672	-0.11169	0	-0.06	-0.195	0	-0.75
cpntype	0	0	0	0	0	0	0
maturity	0.03089	0.00463	0.73151	0.00274	0	-0.17808	0
year	0	0	0	0	0	0	0
countryid	0.00193	-0.00193	0	0	0	0	0
Bankid	0.0044	0.23938	0	0	0	0	1

Table 12
Treatment effect results using near-neighbor matching, CEM-C.

	(1)	(2)	(3)	(4)
	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue
ATE green (1 vs 0)	-0.177**	-0.175**	-0.111	-0.183*
	(0.080)	(0.069)	(0.079)	(0.100)
ATET green (1 vs 0)	-0.143	- 0.025	-0.130	-0.183*
	(0.096)	(0.105)	(0.094)	(0.100)
Mahalanobis distance	Yes	No	Yes	No
Euclidean distance	No	Yes	No	Yes
Bias adj	No	No	Yes	Yes
Observation	1036	1036	1036	1036

∗, ∗∗, and ∗∗∗ denotes significance at the 10%, 5%, and 1% level, respectively.

3.5.4 Coarsened exact matching (CEM): Specification D.

To perform the last CEM we use the following variables: Issuer, Amount issue, coupon type, year at issue, and country of issue. Table 13 shows that the Multivariate L1 distance is very small, 0.151007, and the number of matches is 841. Despite these differences compared to the other CEM performed, the results are in line with previous evidence (table 14). The coefficient is negative and not statistically significant except for one specification. We confirm differences between the ATE and ATET with the ATE that suggest greenium for specifications one and two. The average treatment effect on treated remains not significant.

Table 13
CEM-D results

Number of strata: 8599
Number of matched strata: 445

	Non-Green	Green
All	200530	1,149
Matched	841	841
Unmatched	199,689	308

Multivariate L1 distance: 0.1510107
Univariate imbalance:

	L1	**mean**	**min**	**25%**	**50%**	**75%**	**max**
LogAmount	0.00357	00579	0.42063	0	-0.00638	0	0
cpntype	0	0	0	0	0	0	0
year	0	0	0	0	0	0	0
countryid	0	- 0.00193	0	0	0	0	0
Bankid	0.07253	0.05113	0	0	-4	0	1

Table 14
Treatment effect results using near-neighbor matching. CEM-D

	(1)	(2)	(3)	(4)
	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue	Yield to maturity at Issue
ATE green (1 vs 0)	-0.169**	-0.221**	-0.093	-0.101
	(0.070)	(0.090)	(0.068)	(0.086)
ATET green (1 vs 0)	-0.047	0.019	-0.098	-0.081
	(0.075)	(0.132)	(0.072)	(0.128)
Mahalanobis distance	Yes	No	Yes	No
Euclidean distance	No	Yes	No	Yes
Bias adj	No	No	Yes	Yes
Observation	1036	1036	1036	1036

∗, ∗∗, and ∗∗∗ denotes significance at the 10%, 5%, and 1% level, respectively.

3.6 Robustness analysis

In this section, we apply more tests to check our results based on the treatment effects analysis. Inspired by previous literature (i.e. Backer *et al.* 2018; Fatica *et al.* 2021) we performed regression with different specifications. However, in order to avoid biases in our analysis, regressions are based on the *coarsened exact matching* results.

Our baseline regression model is:

$$Yield = \beta_0 + \beta_1\, Green + \beta_2\, X + \delta + \phi + \varepsilon$$

Where Yield is the yield to maturity at issue, green, our main variable, is a dummy variable equal to 1 if the bond is labelled green, and X is a vector of control variables. We use also time fixed effect and firms fixed effect. Results (table 15) confirm our previous findings. The coefficient for the main variable green is negative, again suggesting the existence of greenium. However, in all specifications it is not significant.

Table 15

Regression results using CEM-A (1), CEM-B (2), CEM-C (3). Green is a dummy variable equal 1 if the bond is a green bond. *Coupon* is the annual interest rate for Plain vanilla fixed coupon bonds. *Maturity* is the maturity of the green bond (in years). *Call* is a dummy variable that is equal to one if the bond is callable. *Put* is a dummy that is equal to one if the bond is putable.
Yield, Coupon, and Amount have been winsorised at 1% and 99%.

	(1)	(2)	(3)
Green	-0.102	-0.107	-0.167
	(0.084)	0.081	(0.121)
Coupon	0.897***	0.950***	0.942***
	(0.055)	(0.030)	(0.035)
Coupon Type	-0.382	-1.424*	-1.290**
	(0.314)	(0.771)	(0.609)
Maturity	-0.006	-0.014	0.010
	(0.019)	(0.023)	(0.000)
Call	-0.300	-0.200	-0.368
	(0.224)	(0.196)	(0.262)
Amount Issue	-0.164	-0.131**	- 0.108
	(0.107)	(0.058)	(0.109)
_cons	4.229	5.323**	3.558*
	(2.583)	(2.072)	(1.959)

Observations	1,492	1,462	1,682
R-Square	0.7976	0,709	0,744
Issuer FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes

∗, ∗∗, and ∗∗∗ denotes significance at the 10%, 5%, and 1% level, respectively.

3.7 Conclusion

Green bonds are relatively new instruments that have rapidly grown in the last few years, becoming one of the most important instruments to finance environmentally friendly projects. Banks are the most important issuer both in terms of numbers and amount issued. Furthermore, the opportunity to finance green projects with issuance proceeds, makes them unique in the market. In this paper, we investigate whether the issuance of green bonds in the banking system is motivated by the opportunity to reduce the cost of funding and thus, if investors are willing to receive less interest when they invest in bonds with a positive environmental impact. We use the CEM methodology to match green bonds with ordinary bonds. Using the subsample obtained we measure the treatment effect. Different matchings, based on the main features of the bonds, has been performed, reducing bias evaluation risk.

The overall results suggest that there is no greenium in the banking system. The outputs of our analysis are, overall, not statistically significant even though the negative coefficients of almost all the specifications suggest the existence of greenium.

There is just one specification that shows a weak negative impact, in terms of significance, in the yield, showing a greenium of 18 basis points both for ATE and ATET. We obtain these results using the Euclidean distance e adjusted for continuous variables. However, we believe that the overall results are not robust to support the greenium.

The regressions performed for the robustness check, confirm the weak results regarding the existence of the greenium.

Our evidence confirms previous studies (i.e. Flammer 2021, Fatica *et al* 2021) and is inconsistent with the cost of capital as the reason to issue green bonds. Our results are also inconsistent with the literature that finds evidence about the investors' willingness to pay more for instruments that provide also non-pecuniary benefits.

The differences related to the misalignments between supply and demand that could explain the price differences in the first beginning of the green bonds issuance (Preclaw

and Bakshi, 2015) are today more limited. Banks are an issuer with unique characteristics since there is no direct link between the issue and the project to be financed. This could have an impact on the yield at issue (Fatica *et al.* 2021).

We believe our results have significant managerial implications. Because of the lack of empirical evidence about potential *greenium* in the banking industry, our study can help to understand the importance of issuing green bonds on bank cost of funding, beyond the positive externalities to finance green projects.

The green market is growing rapidly, and it is less explored. Future research should investigate how regulatory intervention affects the market. The introduction of new legislation about green criteria is unexplored. Moreover, future research should focus on the secondary market to analyse whether green bonds are riskier than traditional ones. Finally, the unique features of bank in the green bond market raise a transparency issue that should be deeper investigate.

CONCLUSION

This study aims to analyse green finance with a specific focus on market of the green bonds.

The first part of the study describes the historical steps that led to the spread the green finance. Green bonds represent one of the most important instruments to encourage and boost investments in sustainable and green projects.

Since their inception, in 2007, the number of issuances rapidly increased involving firms and investors from different sectors and different countries.

The features of green bonds, analysed in Chapter 2, highlighted that green bonds have characteristics similar to the traditional ones, except for the use of proceeds.

Banks and other Financial are the leading actors in the green bond market.

Banks were investigated in the last chapter with the aim to explore the existence of greenium, thus if investors are willing to pay more for investments with a positive environmental impact. The results show no evidence of greenium in the banking system.

To sum up, this study provides a comprehensive overview of the green bond market highlighting that banks' decision to issue green bonds is not motivated by the lower cost of funding compared to traditional bonds.

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