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An Empirical Study on the Impact of the European Central Bank's Asset Purchase Programme on the European Green Bond Market

Master Thesis

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This thesis is a part of the MSc programme at BI Norwegian Business School. The school takes no responsibility for the methods used, results found, or conclusions drawn.

Abstract

In this empirical study, we investigate the causal effect of the European Central Bank's announcement of its green bond purchase under the Corporate Sector Purchase Program in 2016 on the European green bond market. Employing a Difference-in-Difference analysis, we find that the announcement has positively impacted the green bond market in Europe in the short term, resulting in increased demand, higher bond prices, and lower yield to maturity. Nevertheless, capturing causal effects over an extended period becomes complex without obtaining error estimates. Thus, based on our findings, there is suggestive evidence that the European Central Bank's announcement has stimulated the green bond market in Europe, particularly in the isolated context of the short-term period.

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List of Abbreviations

APP - Asset Purchase Programme

CBI - Climate Bond Initiative

CH₄ - Methane

CICERO - The Centre for International Climate and Environmental Research

CO₂ - Carbon Dioxide

CSPP - Corporate Sector Purchase Programme

CSR - Corporate Social Responsibility

DiD - Difference-in-Difference

DNSH - Do No Significant Harm

ECB - European Central Bank

ESG - Environmental, Social and Governance

EU - European Union

EU GBS - European Green Bond Standard

EUR bn - Euro in Billion

GHG - Greenhouse Gasses

N₂O - Nitrous Oxide

PSPP - Public Sector Purchase Programme

QE - Quantitative Easing

SRI - Socially Responsible Investment

USD bn - United States Dollars in Billion

YTM - Yield to Maturity

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1.0 Introduction

As the world attempts to manage the severe effects of climate change, lowering the planet's overall carbon footprint has emerged as an increasingly important priority that calls for rapid movement. The United Nations has acknowledged the magnitude of the problem and emphasized the significance of fast global action to mitigate the detrimental consequences of climate change (United Nations, 2023). Furthermore, public policy is critical in communicating the necessity of reaching Net-Zero by 2050, which entails, among other things, lowering fossil fuel subsidies and managing natural resources to decrease emissions and climate hazards, as well as considering the world's resource scarcity. Experts have determined how much financing is required to facilitate the green transition. Estimates differ, but the conclusion is that the necessary investments cannot be covered solely by public funds (World Bank, 2023).

Achieving Net-Zero requires global carbon neutrality, where all greenhouse gas (GHG) emissions, such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) (EPA, 2023), are offset by those eliminated through innovative technologies and changed behaviours. Significant changes in how investors allocate capital and engage with companies are essential to address current global challenges. The increasing emphasis on sustainable investments and impact investing, where investors aim to generate financial returns while positively impacting environmental or social issues, stems from a growing recognition that investors prioritize the opportunity to invest in projects that align with their values (Credit Suisse, 2023). When there is a greater emphasis on sustainability, it becomes reasonable that more investors want to contribute to purpose-driven investing. These developments have led to various requirements for financial institutions and stakeholders, including heightened scrutiny of assets and restrictions on funding and investments to companies and sectors that harm the natural world. As a result, in terms of expectations and reputation, investors and banks are under growing pressure to move to a sustainable economy.

The realm of green bonds is a rapidly growing market that offers a solution for funding environmentally beneficial initiatives. These financial investments provide a viable avenue for financing environmentally beneficial projects and empower investors to allocate their funds towards initiatives that promote sustainability and facilitate the green shift. Through investing in green bonds, investors have the potential to receive financial returns and play an

active role in mobilizing vital funds for long-term initiatives that strive to accomplish global climate objectives (Investopedia, 2022). In 2007, the European Investment Bank became the first organization to issue a green bond, and the number of issuances has risen substantially since that (European Investment Bank, 2023). According to data provided by the Climate Bond Initiative (CBI), the total value of green bonds issued on the global bond market increased by USD bn 360 between 2016 and 2021, from USD bn 84.5 to USD bn 444.3, which represents a growth of 426% (Climate Bond Initiative, 2023).

The expansion of financing that fosters increased investment into promoting sustainable development, also known as green financing, is a significant step toward facilitating climate action (United Nations Environment Programme, 2023). It is still complex to assess the effect that green bonds have on lowering emissions of GHG, partly because firms need more transparency and regulations on reporting data on their emissions. Nonetheless, green bonds are a significant step in promoting sustainable finance, particularly in carbon-intensive sectors (ESMA, 2021). The European Central Bank (ECB), a substantial component of the Eurosystem, has recently taken a significant step toward incorporating green requirements and investments into its Quantitative Easing (QE) program through its Asset Purchase Programs: The Corporate Sector Purchase Program and the Public Sector Purchase Program. This action increased awareness of the expanding significance of sustainable financing in the financial sector (European Central Bank, 2021).

The objective of our thesis will be examined utilizing the following research question:
What influence has the European Central Bank's purchases of green bonds had on the European green bond market?

1.1 Research Objective

This thesis explores the impact of the European Central Bank's recent adoption of green investments in its acquisition program on the European green bond market traded in the secondary market as part of its decarbonization efforts. The analysis aims to investigate whether the green bond purchase announcement in March 2016 affected the average yield to maturity on green bonds in Europe compared to non-green bonds during the same period. As part of an effort to fill in gaps in the extant literature, this analysis examines two time periods:
i) January 2015 to December 2017: To examine the long-term impact

ii) November 2015 to June 2016: To examine the short-term effect

The hypothesis of the thesis is as follows:

H₀: *The ECB announcement did not lead to changes in demand for green bonds in Europe*

H₁: *The ECB announcement led to an increasing trend in demand for green bonds in Europe*

The methodology employed in this study relies on a quantitative approach, utilizing collected data that will be leveraged for a Difference-in-Difference (DiD) analysis. This analysis aims to capture the causal impact of an intervention, specifically the ECB's announcement to implement green investments.

The DiD method performs a multiple linear regression on a sample of bond yields to maturity. Given the scarcity of data on green bonds in Europe, we selected a sample of 21 green bonds from the population and acquired monthly data on their YTM development over the period. The control group is defined as non-green bonds, the treatment group as green bonds, and the intervention as the date the ECB proclaimed the implementation of green initiatives within their monetary policy. A regression was constructed with the average YTM serving as the dependent variable, dummy variables representing *green bonds* and *post announcement*, and an interaction term designated as *post x green*. We will analyse this interaction term further to determine the causal effect of the ECB's announcement.

1.2 Structure of the Thesis

This chapter provides a framework for the thesis, comprising several essential components. The study begins by examining the climate challenge and the broader context of the green bond market as a part of the solution. Then it analyses the key characteristics and elements that fall under the European Central Bank's monetary policy. *Chapter 2* provides the study's background, and the ECB's monetary policy is elaborated. In *Chapter 3*, the thesis employs multiple theories to support the presented hypothesis and research question. In this context, the chapter examines the fundamental concept of bonds, the distinctions between green and traditional bonds, and the dynamics of the demand for green bonds. Furthermore, *Chapter 4* will cover pertinent articles and analyses that address significant issues that can be related to the thesis research question. The thesis then discusses the econometric method employed during the study in *Chapter 5*. Specifically, the chapter discusses the use of Difference-in-

Difference analysis to determine the announcement's causal factors. *Chapter 6* will focus on data collection, followed by a discussion of the empirical findings from the conducted studies and their relationship to pertinent theory in *Chapter 7*. Finally, *Chapter 8* will contain the conclusion and discussion of the thesis, followed by critics, limitations, and further research in *Chapter 9*.

2.0 Background

This chapter goes deeper into the green bond market, addressing essential features and associated elements under the purview of the European Central Bank's monetary policy.

2.1 The European Green Bond Market

Green bonds have emerged as a vital tool for addressing pressing environmental concerns. These bonds are a form of an interest-bearing instrument designed to finance green initiatives while offering investors fixed or interest-based payments.

The European green bond market has grown over the past few years, accelerated by rising demand for sustainable investments and increased pressure to meet goals such as the Paris Agreement. The Climate Bonds Initiative (CBI) estimated that the total value of green bonds issued worldwide reached around USD bn 578 in 2021, with Europe accounting for almost half of this total value (Climate Bond Initiative, 2023). The growth has been driven partly by institutional investors, who focus more on responsibly investing while achieving predictable returns (Investopedia, 2022). Furthermore, by funding projects more likely to be resilient in the face of environmental issues such as climate change, green bonds can help minimize investment risk.

Data retrieved from Refinitiv Eikon show that the European green bond market increased by 1,521% between 2015 and 2020, as shown in *Figure 1* (Refinitiv, 2023). This growth can be attributed to increased awareness of environmental and social concerns, increased availability of green projects, and investors' interest in adopting social responsibility. Furthermore, the market has been met with regulation and political support from the EU and national authorities, which has created a more favourable regulatory environment for the issuance of green bonds.

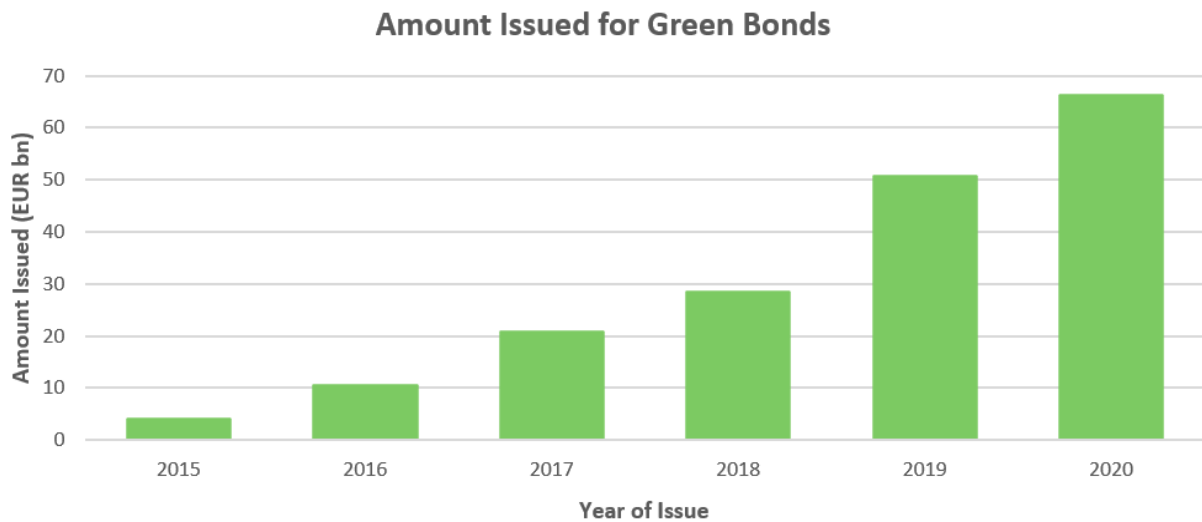


Figure 1: Amount Issued (EUR bn) for Green Bonds

Source: Refinitiv Eikon

Figure 2 below illustrates the growing significance of green bonds as a source of funding for a wide range of projects and activities, such as clean transportation, energy efficiency, and renewable energy projects. The development in the green bond market reflects the recognition that environmental concerns exceed specific sub-sectors or businesses, highlighting the importance of a coordinated and collaborative strategy to tackle them. Several central banks, including the Bank of England, the European Central Bank, and the Bank of Japan, have incorporated sustainability into their operational processes (Green Central Banking, 2023). Using monetary policy instruments, central banks can aid in the transition to a more sustainable economy by establishing regulatory frameworks, investing in green bonds, and supporting sustainable finance initiatives.

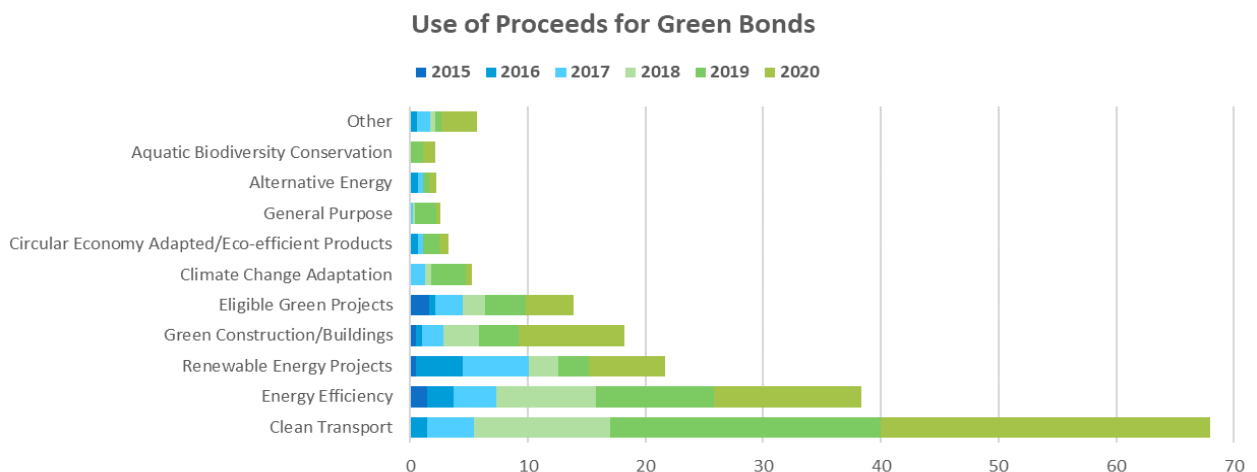


Figure 2: Use of Proceeds for Green Bonds (EUR bn)

Source: Refinitiv Eikon

2.2 The European Central Bank and Green Central Banking

The European Central Bank has recently emphasized climate action as a vital component of its long-term strategy and has set ambitious objectives for addressing this issue. This aspiration is motivated by three main factors, illustrated in *Figure 3*.

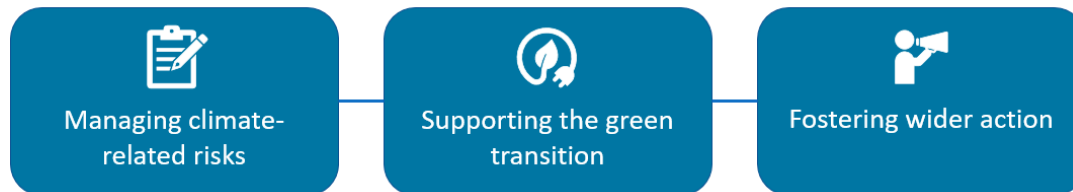


Figure 3: Illustration of ECB's Climate Change Objectives

Source: The European Central Bank, Climate change and the ECB: "Our Objectives"

The objective is to manage and mitigate potential climate-related hazards, given their potential to influence the economy. Managing potential risks requires a cautious oversight and regulation of risks associated with climate change in investments and monetary policy to safeguard the stability of pricing and financial systems in the long term. The second rationale is to facilitate the green transition by implementing various measures, including providing incentives for adopting an environmentally sustainable economic approach. Lastly, the third objective involves collaborating with partners to address the issue and fostering broader participation in sustainability efforts (ECB, 2023).

The President of the European Central Bank, Christine Lagarde, is leading the ongoing initiatives to promote the integration of climate change considerations in the Eurosystem's Asset Purchase Program (APP), which entails procuring green bonds. However, there are several conflicting viewpoints regarding this change in monetary policy. Critics argue that central banks should avoid taking a position on environmental issues and maintain their neutrality on price stability. They also question a central bank's ability to effectively manage climate risks in its operations. On the contrary, Lagarde believes it should be part of the ECB's responsibility, as the climate crisis will significantly affect inflation, credit flow, and other factors in the coming years (Euractiv, 2021).

The ECB's acquisition of green bonds can have several impacts on the market, including an anticipated increase in demand for such bonds, establishing a benchmark for their evaluation, and an enhanced appeal for issuers. Moreover, the ECB's emphasis and initiatives have the

potential to signal to the financial market their legitimacy and attractiveness as investment options, consequently raising investor awareness and mobilizing increased funding for sustainable activities. These factors will facilitate the market's liquidity growth while enhancing its inclusivity for a broader range of investors.

2.3 Quantitative Easing

The European Central Bank employs asset purchases, known as Quantitative Easing (QE), to promote economic growth and achieve its inflation target in the medium term of 2%. The underlying mechanisms involve purchasing bonds, including green bonds, which can increase prices and inflow funds into the financial system. Consequently, interest rates decrease, borrowing becomes more affordable, supporting the economy and encouraging consumption and growth, as illustrated in *Figure 4* (ECB, 2021).

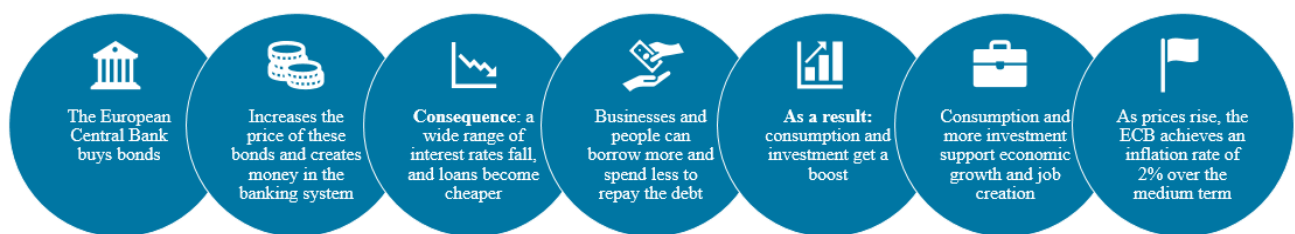


Figure 4: Illustration of ECBs Quantitative Easing

Source: The European Central Bank

The ECB has acquired various assets under the APP, such as government bonds, securities issued by European institutions, corporate bonds, asset-backed securities, and covered bonds. Considering the ECB's role as a central bank, the primary objective of asset purchase programs is not primarily focused on generating the highest profit or earnings. Instead, the primary objective of the ECB's asset purchase programs is to uphold price stability in the market while achieving monetary policy goals. Additionally, it aims to influence financial conditions through three key channels (ECB, 2021).

Purchases of private sector assets, such as covered bonds and securities linked to bank loans to households and businesses, have immediate effects by increasing demand, increasing prices, and pressuring banks to provide additional loans, which they can use to create and sell more securities or bonds. Increased credit availability leads to reduced lending rates for banks, which improves financing conditions and stimulates the economy (ECB, 2021).

Furthermore, the ECB's acquisition of private and public sector assets from investors such as pension funds, banks, and households will result in *portfolio rebalancing*. Investors can reinvest funds received in exchange for assets sold to the ECB. In this approach, the ECB will assist in increasing asset demand, resulting in the portfolio balancing mechanism driving prices up and returns down, even for assets not directly suited for the ECB's asset programs. As a result, the costs of borrowing or re-financing in the financial markets will be reduced for corporations. If, on the other hand, the investors choose to utilize the funds for investments outside the Eurozone, the euro exchange rate will fall, pushing inflation additionally higher. Where investors choose to invest once the ECB has acquired assets directly from investors will assist in improving household and company financial circumstances and boost investment and consumption. When inflation is considered low, dynamic demand aids in returning to the 2% inflation goal (ECB, 2021).

As the ECB's last primary channel for influencing economic circumstances, the central bank employs the *signalling effect* as a central tool. During longer times of low inflation, the ECB's asset purchases will suggest that the bank intends to maintain benchmark interest rates low over the period. As a result of giving a signal to the market, volatility, and uncertainty about future interest rate changes will be lessened, making investment choices for businesses and consumers easier to implement. Long-term loan interest rates will stay low since banks anticipate a more extended era of low-interest rates (ECB, 2021).

2.4 Asset Purchase Programs of the European Central Bank

To achieve its inflation targets, stimulate the economy, and manage risks, the ECB employs significant asset purchase initiatives, including the Public Sector Purchase Program and the Corporate Sector Purchase Program. These programs serve as vital instruments in the ECB's monetary policy toolkit (ECB, 2023).

2.4.1 Corporate Sector Purchase Programme

The Corporate Sector Purchase Programme (CSPP) is a bond-buying initiative launched by the ECB in 2016 to stimulate the Eurozone economy and promote financial stability in the region. CSPP is one of several purchasing programs offered by the ECB aimed at boosting market liquidity by purchasing corporate bonds. The program focuses on providing liquidity

to the corporate bond market and supporting European companies' financing while aligning with the EU's climate and energy goals. In addition to purchasing corporate bonds, the CSPP also includes buying corporate bonds that fulfil sustainability requirements, such as green bonds that meet specific environmental standards. This aligns with the ECB's commitment to sustainable finance. In 2022, the ECB announced its objective to gradually decarbonize its holdings over the next few years and increase the purchase of corporate bonds that fulfil sustainability requirements. The ECB purchases CSPP-eligible bonds through competitive bidding, and to be considered for the CSPP the corporate bond must meet specific eligibility criteria, including having a minimum remaining maturity of six months, having an investment grade rating, and not containing any credit-linked or equity-linked features (ECB, 2023).

2.4.2 Public Sector Purchase Programme

The fundamental goal of the ECB's Public Sector Purchase Programme (PSPP), implemented in 2015, is to promote and encourage economic activity through increased inflation. By purchasing Eurozone government bonds, the ECB achieves its goal of increasing the money supply in the European economy and stabilizing inflation at the desired rate. Additionally, the PSPP may encourage sustainable investments in the market by purchasing green bonds and enforcing criteria for which bonds qualify for the acquisition program, creating a uniform definition of a "green" bond (ECB, 2023).

2.5 Problem Discussion

Our research efforts have identified a notable gap in the existing literature on this topic. Due to the recent nature of the ECB's purchases of green bonds, our contribution emphasizes examining previous years by utilizing the most recent data from 2015 to 2017. Previous research has investigated numerous aspects of green bonds, including market trends, investor behaviour, and environmental impact. However, only some analyses have scrutinized the ECB's announcement to include green bond purchases in its asset purchase program. What constitutes a green bond also distinguishes these analyses from others. There has yet to be an agreement on a unified definition or standard for a *green* bond. This can influence the market's perception, investors' preferences, and potential misunderstandings between market participants. The analysis is therefore predicated on determining whether the role and influence of central banks on the market for green bonds are significant, as well as discussing these definitional variations and their repercussions. By addressing these knowledge gaps and

concentrating on the ECB's incorporation of green bonds in the CSPP, our research contributes to a greater understanding of the central bank's effect on the green bond market.

The data compilation for this analysis relies on information sourced from Refinitiv Eikon, a reputable financial data service. Furthermore, Refinitiv uses data from the CBI, where the Climate Bonds Standard and Certification Scheme is an essential framework that deals with a labelling scheme that ensures that bonds and loans meet strict scientific criteria in line with the Paris Agreement's 1.5°C warming limit. Bond issuers, authorities, investors, and financial markets use this designation system to designate investments that significantly contribute to combating climate change. By utilizing Refinitiv data, including information from CBI, we ensure that the analysis is founded on credible sources and provides insight into green bonds' sustainable characteristics and climate impact (Climate Bond Initiative, 2023).

3.0 Theoretical Background

This chapter explores several theories that support the hypothesis presented. It investigates the fundamental concept of bonds, compares green and traditional bonds, and analyses the dynamics of green bond demand.

3.1 Bonds as a Fixed-Income Instrument

Bonds are financial instruments that represent loans made to governments and corporations to finance their operations or projects. The bond's coupon may be fixed or variable, depending on the bond's terms. The value of a bond can be influenced by varied factors, including prevailing interest rates, inflation expectations, and the issuer's creditworthiness, typically evaluated by credit rating agencies (DNB, 2022).

When investors acquire bonds, they become the issuer's creditors, entitling them to the principal and interest payments associated with the bond. In situations involving bankruptcy or liquidation, bondholders typically receive priority over shareholders, increasing their likelihood of recovering all or a portion of their investment. Bondholders face risks, such as the possibility of default or a decline in bond value due to fluctuations in interest rates or market conditions. The degree of risk and future return varies across various bond types. Government bonds, regarded as relatively secure, are backed by the complete faith and credit

of the issuing government. In contrast, corporate bonds are exposed to credit risk associated with the issuer, affecting their yield to maturity and price.

Including bonds in an investment portfolio can provide diversification, income, and a potential hedge against volatility. However, the relative benefits of bonds compared to other asset classes may depend on an investor's specific objectives, risk tolerance, and market conditions (DNB, 2022).

3.2 Green Bonds

The concept of green bonds is identical to that of traditional bonds. The distinction is that their sole objective is to support financing for environmentally and climate-conscious initiatives such as energy efficiency, renewable energy, and sustainable transportation (Investopedia, 2022). A growing number of market participants have become aware of the environmental problems the world is currently facing and have expressed a desire to participate directly in the transition to a low-carbon economy by funding green initiatives. Consequently, the market for green bonds has become increasingly knowledgeable. At times, green bonds may offer investors tax benefits, increasing their appeal (Corporate Finance Institute, 2023).

There are several types of green bonds, with four groups prevailing, as indicated in *Figure 5*. The primary bond form is the *Standard Green Use of Proceeds Bond*, tailored specifically for environmentally sustainable projects and operates like a conventional bond. The *Green Revenue Bond* is a type of bond frequently issued by governments or states, which earmarks a portion of their cash flow, such as taxes, to finance environmentally friendly projects. The *Green Project Bond* is the third type, characterized by its distinct features and attributes and exclusively allocated to financing a singular environmentally friendly initiative. The *Green Securitized Bond* combines various environmentally friendly initiatives into a single debt portfolio, thereby granting bondholders the ability to seek legal action against the assets that support the complete collection of projects (CBI, 2023).

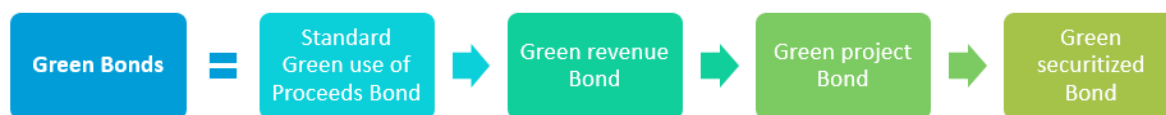


Figure 5: Types of Green Bonds

Source: Climate Bond Initiative

The green bond market has grown significantly in recent years but still faces some challenges. One of the most highly debated topics is the standardization of labelling green bonds, including defining what constitutes a *green* bond. These standards are based on voluntary criteria, which issuers may use to boost their credibility. Without standardized criteria, there is a risk of greenwashing. Green bond certification is therefore crucial for investors who want to ensure that their investment supports development in green projects and that the issuer is committed to sustainable practices. Additionally, the accreditation promotes transparency and accountability, which encourages market growth and aids in meeting climate and energy objectives.

Another challenge facing the green bond market is the authentication procedure. There is a need for uniformity and consistency in the standards used by green certification and verification issuers, as they may have varying requirements and limitations. However, recognized international standards are used to label bonds as green, so there is a greater likelihood of receiving similar assessments from different providers.

3.2.1 Why green bonds?

According to the CBI, green bonds appeal to both issuers and investors due to several factors. For bond issuers, the issuance of green bonds provides several advantages, including increased diversification of funding sources, greater engagement and participation from investors, and the potential of oversubscription, which underscores the strong demand for environmentally focused investments. On the investor side, participation in green bonds may reduce its risk due to the incorporation of rigorous environmental criteria in the selection of projects. Additionally, in certain instances, green bonds may trade at a premium, further enhancing the potential financial returns for investors (CBI, 2016).

Issuers can enhance their corporate image and attract socially responsible investors by demonstrating a commitment to sustainable financing. Similarly, investors aligning their portfolios with green investments can bolster their reputation as environmentally conscious entities, attracting clients who prioritize sustainability considerations (CBI, 2016).

3.2.2 Certification and Verification of Green Bonds

Green bond *certification* is the procedure through which an independent third party verifies that a bond fulfils specified sustainability standards. Green bonds are certified by numerous organizations, including the Climate Bonds Initiative, the International Capital Market Association, Sustainalytics, and The Centre for International Climate and Environmental Research (CICERO) (ICMA, 2018). These organizations assess openness in reporting on the issuer's environmental and social performance, using bond proceeds, and the effects of investments (Bis, 2023).

Green bond *verification* is a supplementary procedure aimed to ensure that the bond's proceeds are being utilized for its intended purpose. This verification process involves engaging an independent third-party to scrutinize the bond documents and assess the implementation of the underlying projects (ICMA, 2018). Notable corporations that provide green bond verification services include auditing firms such as EY, PwC, Deloitte, and KPMG (CBI, 2023).

The advantage of voluntarily obtaining certification/verification for green bonds from a reputable provider is that it may increase interest in green bonds, thereby facilitating the financing of society with reduced emissions. However, there are some drawbacks, and currently, having the bonds certified or verified can be costly, which could result in fewer participants choosing to do so. Given that obtaining a green certificate requires both time and money, companies with the ability to issue green bonds tend to be larger and better able to afford such an investment. This may affect those companies' perception as reliable investments, particularly by the ECB.

3.3 The EU Green Bond Standard

The EU Green Bond Standard (EU GBS) is a set of voluntary standards developed by the European Commission that are essential in facilitating sustainable finance within the EU. The

objective of this standard was to establish a common framework for green bonds. This standard should benefit both issuers and investors. From an investor's perspective, it should make it easier for them to compare, trust, and analyse whether the bond is truly green. On the issuer side, it will be less complex to determine whether the projects they find are green and aligned with the EU Taxonomy (Eurosif, 2023).

3.3.1 The EU Taxonomy

The EU Taxonomy is a complex classification system that forms a list of sustainable economic activities which includes six environmental objectives:

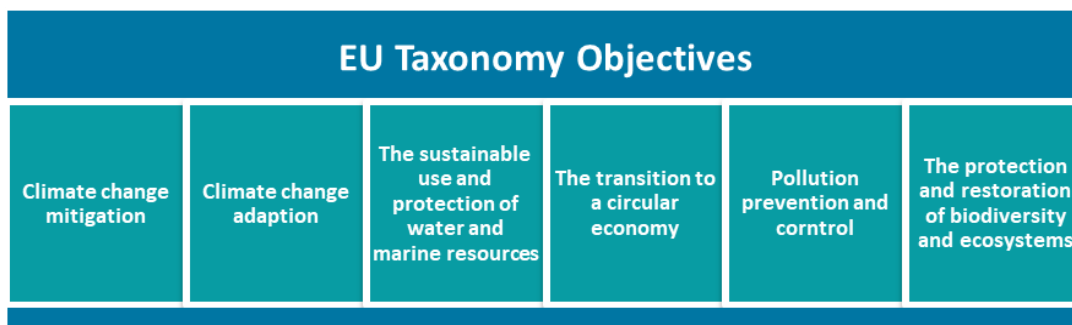


Figure 6: EU Taxonomy Objectives (S&P Global, 2021).

This framework is initiated to clarify the definition of what is sustainable and what is not for investors, businesses, and regulators and to improve transparency within the EU. If the economic activity is to be taxonomy aligned, the activity must meet the following requirements: “contribute to at least one of six environmental objectives listed in the Taxonomy; and do no significant harm (DNSH) to any of the other objectives” (S&P Global, 2021). In addition, the activity must meet minimum social safeguards (S&P Global, 2021).

One of the goals listed in the EU Taxonomy under the European Green Deal, an action plan to achieve carbon neutrality by 2050, is adopting a European standard for green bonds, known as the EU GBS (S&P Global, 2021). The standard aims to align on Taxonomy criteria, which provides credibility since these requirements are comprehensive.

3.4 Mechanisms in Economic Theory

The acquisition of bonds by the ECB through CSPP may positively impact the demand for green bonds. As a reputable central bank implements sustainable investment strategies, the market will perceive a growing demand for green bonds resulting in a positive shift in the

demand curve. This phenomenon could increase the number of issuers interested in offering green bonds, particularly given the ECB's potential to be a significant purchaser of these instruments.

Suppose economic theory and market behaviour are consistent. In that case, it is anticipated that the ECB's announcement and subsequent purchase of green bonds will increase market demand for green bonds, increasing bond prices. With a potential heightened demand for green bonds, more companies will likely express interest in issuing them to take advantage of favourable market conditions. Consequently, this may increase supply, but this positive shift may not be as significant as the demand shift.

If the ECB's announcement of green bond purchases causes the demand curve to shift positively, it will also affect interest rates and YTM. An inverse relationship exists between bond prices and YTM, whereby an increase in the former leads to a decrease in the latter. Consequently, the YTM of green bonds is expected to decrease in this scenario, and bond investors will also receive a lower rate of return on interest and a reduction in the general interest rate level. Since higher demand causes bond prices to rise, and YTM tends to fall, it can be advantageous for investors who seek to allocate their capital through lower-risk and more stable investments. If the demand for green bonds increases substantially, their interest rates will continue to decline. This is justified because issuers will attract investors by offering a reduced coupon rate in response to rising demand.

The ECB is also anticipated to influence the yield spread after the announcement. In this instance, the yield spread, referring to the difference in yields between green bonds and their corresponding conventional bonds, is expected to diminish after the announcement.

3.4.1 Navigating the Rise of Green Bonds: Analysing the Shift in Demand

Drawing upon the Green Bond Market Roundup reports released by CBI in 2015 and 2016, it can be inferred that the demand for green bonds has consistently surpassed the available supply. The oversubscription rates for green bonds have also demonstrated an upward trend (CBI, 2016). Given these observations, it is reasonable to anticipate a favourable shift in the demand curve for green bonds after the ECB's announcement. Nonetheless, the supply is also expanding, although at a slower rate than demand. The positive shift in the demand curve is

depicted in *Figure 7* below, and following the ECB's announcement, a potential new price equilibrium will be established, resulting in an increase in the quantity of green bonds from Q_0 to Q_1 and an increase in green bond prices, from P_0 to P_1 .

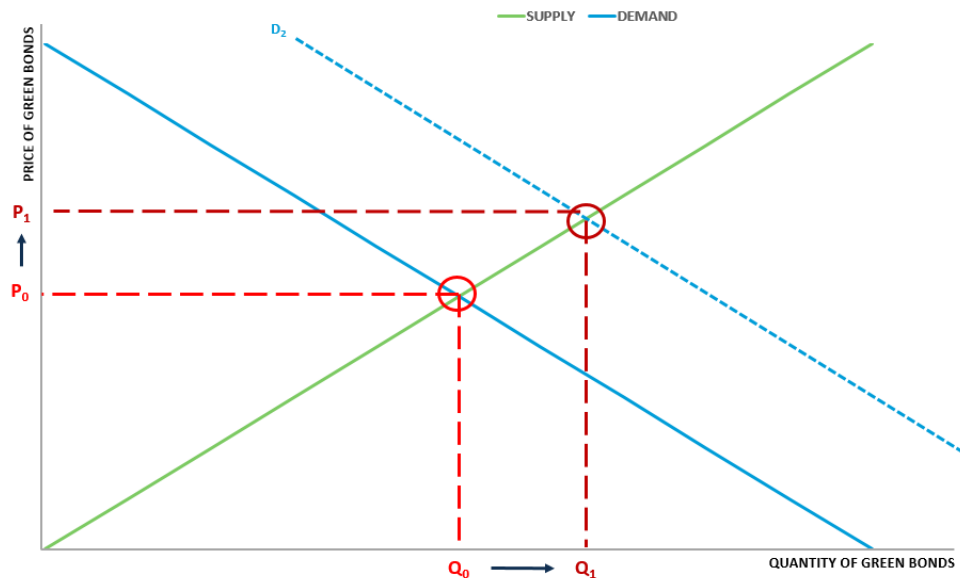


Figure 7: A potential positive shift in demand after the announcement of ECB

4.0 Literature Review

In this chapter, the thesis elaborates with relevant articles and analyses that deal with issues that are significant and can be related to the research question. The articles cover topics such as the definition and function of green bonds, “the greenium,” the European Central Bank's impact on yield spread, and the role of central banks in combating climate change.

4.1 Prior Research and the Thesis' Contribution

In recent years, little research and analysis has examined the impact of the European Central Bank's implementation of green investments in its purchase program on the European bond market. The literature review highlights a small number of studies examining this specific policy and emphasizes the significance of this research as a substantial contribution to existing knowledge. Other studies dealing with this policy have relied primarily on graphical presentations and qualitative analyses, thus lacking quantitative analyses, such as regression analyses.

Consequently, there is a glaring deficiency in the literature concerning formal analysis and statistical significance assessment of the impact of the ECB's green investments. To help cover this gap, this study is founded on a methodology involving the precise implementation of regression analyses utilizing a Difference-in-Difference model. This method permits evaluating and estimating the statistical significance of the effects of the ECB's investment initiatives within the context of its monetary policy.

4.2 The Definition and Function of a Green Bond

There has been a substantial increase in the issuance of green bonds in the past few years, and studies such as "Green bonds for sustainable development: Review of literature on development and impact of green bonds" written by Bhutta et al. underlines that one of the reasons is that the investors' preferences regarding sustainability have increased. The article also highlights the significance of augmenting the issuance of green bonds as a viable approach to reaching climate objectives and securing funding for sustainable initiatives. However, a current obstacle in this new market is the need for established standards and frameworks that define the characteristics of a green bond (Bhutta *et al.*, 2021).

The authors Serena Fatica, Roberto Panzica, and Michela Rancan also argue in their article "The pricing of green bonds: Are financial institutions special?" that there is no yet standard definition for green bonds. They, therefore, suggest that high transparency and disclosure requirements are crucial to attracting investors. The authors find that green bonds that received an external review, as opposed to those that have self-labelled, may have a more significant advantage in terms of premium (Fatica *et al.*, 2021).

Nevertheless, the recent rise in the green bond market has led to a corresponding increase in regulatory measures. As per the research paper: "The Role, Opportunities and Challenges of Green Bonds," authored by Andrea Giulio Maino, it has been illustrated that numerous regions across the globe are currently developing or have already implemented regulatory frameworks, such as the EU Taxonomy. The article further explains the significance of the involvement of central banks in addressing climate change. This involvement encompasses various roles, such as facilitating the funding of sustainable investments and incorporating climate risk into identifying potential hazards (Maino, A.G., 2022). The information noted

above is relevant to the research question about the favourable impact of a central bank's intervention, specifically the ECB, on promoting environmentally sustainable practices.

The issuance of green bonds entails certain benefits as well as related costs. According to Maino (2022), it is asserted that green bonds offer advantages such as decreased financing expenses, diversification of portfolios, and mitigation of environmental risks. Nevertheless, certain expenses ensue, such as obtaining certification and engaging in reporting procedures to prevent the occurrence of greenwashing. The report underlines that enhanced transparency is one of the highest priorities for investors as it strengthens credibility (Maino, A. G., 2022).

4.3 Pricing of Green Bonds and “The Greenium”

Pricing is a crucial aspect Maino (2022) highlights in the research paper for both issuers and investors of green bonds. Determining the existence of a price premium, commonly called *greenium*, on green bonds is a comprehensive task. Under certain circumstances, greenium can be attributed to heightened demand or restricted supply, thereby increasing pricing for investors who prioritize environmental, social, and governance (ESG) considerations. The identification of greenium presents a challenge due to the necessity of a substantial dataset comprising both green and non-green bonds with equivalent characteristic features, thereby enabling a comparative analysis. Furthermore, an increasing focus and heightened demand for sustainable investments make it complex. The research paper presents instances where greenium is observed and instances where greenium is not detected, resulting in blended outcomes. In addition, the paper explains that there is a high probability of more proof in the coming years emerging to determine the existence of greenium, according to Maino (2022). The matter is relevant to our analytical segment as we examine the YTM for green and non-green bonds within the European Union, both pre-and post-green bond purchase announcements by the ECB.

4.4 The European Central Bank’s Asset Purchase Programme

According to the discussion paper, "The Impact of ECB Corporate Sector Purchases on European Green Bonds" (2021) by Franziska Bremus, Franziska Schütze, and Aleksandar Zaklan, the ECB's purchases of green bonds had a significant beneficial effect on the market in terms of decreased yields for green bonds (DIW Berlin Discussion Paper No. 1938, 2021). The study employs a difference-in-difference analysis, similarly, utilized in this particular

assignment. Nonetheless, it is worth noting that this study diverges from our examination in that it incorporates green bonds denominated in euros, US dollars, and Swedish crowns. In contrast, our analysis solely focuses on bonds issued in euros. The similarity is that we analyse the effect of an act by the ECB on bond yields, but in our analysis, we compare green with non-green in the difference-in-difference research. These findings are consistent with a similar study published on the ECB's official website by Roberto A. De Santis *et al.* (2018) called "Purchases of Green bonds under the Eurosystem's asset purchase program." (ECB, 2018). Both studies conclude that the yields decreased for green bonds during the period and increased demand for green bonds in the European bond market. This suggests that the ECB's actions may have positively impacted promoting sustainable finance and supporting the growth of the European green bond market.

4.5 The Role of Central Banks Addressing Climate Change

The research paper "May Unconventional Monetary Policy Contribute to Climate Action?" (2022) from the Swiss Finance Institute, written by Alice Eliet-Doillet and Andrea Maino, explores the role of central banks in addressing climate change and reducing the environmental impact of businesses. The study focuses on the ECB's announcement in 2021 that it would eventually take a position on climate change and examines how this might affect the market for green bonds. The study found that following the ECB's announcement, there was an increase in the issuance of green bonds, which suggests that the ECB's statement may have had a positive impact on the development of the green bond market (Swiss Finance Institute Research Paper No. 22-35, 2022). The study also highlights the importance of central banks taking an initiative-taking role in addressing climate change and promoting sustainable finance. The researchers suggest that central banks can play a key role in encouraging businesses to transition to more sustainable practices by using tools such as asset purchases, lending operations, and communication strategies. The findings from this research support the idea that central banks can make meaningful contributions to the fight against climate change by promoting sustainable finance (Swiss Finance Institute Research Paper No. 22-35, 2022).

The following main aspects are highlighted in Alessandro Ferrari's paper "Toward a Green Economy: The Role of Central Bank Asset Purchases," released by the ECB. It admits Green Quantitative Easing's modest success but argues it might still be explored for secondary aims

within the central bank's mission. The gradual installation of a permanent carbon tax has had mixed results, lowering output for brown businesses while increasing output and pricing via Green QE. A carbon price that rises over time has the potential to be deflationary. The article suggests beginning with a more aggressive Green QE and progressively attaining market neutrality. The elasticity of substitution between brown and green commodities is critical to enhancing efficacy when acquiring green bonds. This technique would make transitioning to a green economy easier (ECB, 2023).

4.6 The European Central Bank's Signalling Effects

The study by Caroline Flammer titled "Corporate Green Bonds" analyses the use of corporate bonds to finance climate-friendly initiatives by corporations. The study finds that investors responded positively to the announcement of these bonds, especially first-time issuers, and third party-certified bonds. The issuers exhibit enhanced environmental performance and attract long-term, environmentally conscious investors. The findings support the signalling effect of green bonds, whereby corporations demonstrate their environmental commitment credibly (Flammer, 2020). According to our research question and the ECB's monetary policy, the ECB's participation in the green bond market can entice more investors because it provides evidence and credibility that a central bank values green investment.

4.7 Corporate Social Responsibility & Sustainability

The research "Why Do Investors Hold Socially Responsible Mutual Funds?" by Paul Smeets investigates the elements that motivate investors in selecting socially responsible mutual funds. The findings provide significant insights by studying a mix of administrative data, survey answers, and incentive trials. It is demonstrated that investment decisions in socially responsible investments (SRI) are driven by social preferences and the desire to advertise one's principles. Economic considerations, on the other hand, have a negligible influence. Investors in socially responsible funds expect lower returns than traditional funds and are willing to pay higher management costs. This shows that individuals can forego financial rewards to correlate their investments with their social preferences.

5.0 Methodology

This chapter outlines our econometric approach, which involves conducting a Difference-in-Difference analysis to determine the announcement's causal effects. It starts with explaining

the DiD method, followed by an illustration of the multiple linear regression model, and the hypothesis gets presented. In addition, data collection and processing are elaborated, as well as an interpretation part, to clarify how we will interpret the results.

5.1 Econometric model: Multiple Linear Regression Model

$$YTM = \alpha + \beta_1 post_t + \beta_2 green_i + \beta_3 (post_t \times green_i) + \varepsilon_{it} \quad (1)$$

The model used in our analysis is a multiple linear regression aiming to capture YTM variations. It incorporates dummy variables to predict the bond's issuance timing and green status. Moreover, including the third interaction term allows for capturing the combined effect of both the ECB's announcement and the bond's green status, considering their additive impact on YTM.

5.2 Difference-in-Difference Analysis

The research question will be answered from an econometric standpoint using a Difference-in-Difference (DiD) analysis. The method employs a quasi-experimental approach, an empirical study used to estimate the causal effect of an intervention on the target population. This method makes drawing a conclusive and causal inference regarding the intervention's impact possible. Since factors other than the treatment can affect the outcome over time, it is impossible to draw precise conclusions from simple before-and-after changes in the outcome. In addition, comparing two groups can produce an inaccurate result due to selection bias and unobservable differences. Combining these two methods makes it possible to compare changes in the treatment and control groups before and after an intervention, representing a DiD analysis (World Bank, 2023).

As a result, the research includes green bonds as the treatment group and non-green bonds as the control group, both before and after the ECB announcement in March 2016, which represents the intervention. The DiD model investigates the treatment group's results before and after the announcement, representing the first difference ($\beta_1 + \beta_3$) by comparing the differences between the treatment group and itself. The comparison is repeated for the control group, representing the second distinction (β_1). In the last step of the DiD analysis, differences in differences are examined by subtracting the second difference from the first difference, yielding the impact estimate (β_3), as illustrated in *Figure 8* (World Bank, 2023).

$$\begin{array}{l}
 \text{Green Pre} = \alpha + \beta_2 \\
 \text{Green Post} = \alpha + \beta_1 + \beta_2 + \beta_3 \\
 \\
 \text{NonGreen Pre} = \alpha \\
 \text{NonGreen Post} = \alpha + \beta_1
 \end{array}
 \begin{array}{l}
 \left. \vphantom{\begin{array}{l} \text{Green Pre} \\ \text{Green Post} \end{array}} \right\} \beta_1 + \beta_3 \\
 \\
 \left. \vphantom{\begin{array}{l} \text{NonGreen Pre} \\ \text{NonGreen Post} \end{array}} \right\} \beta_1 \\
 \\
 \left. \vphantom{\begin{array}{l} \beta_1 + \beta_3 \\ \beta_1 \end{array}} \right\} (\beta_1 + \beta_3) - \beta_1 = \beta_3
 \end{array}$$

Figure 8: Construction of the DiD-analysis

In performing a DiD analysis, discussing the distinction between *correlation* and *causality* is vital. It is imperative to exercise caution in attributing the influence on the YTM of green and non-green bonds in the EU solely to the ECB's announcement, as many factors may have contributed to the change in YTM. These factors may include macroeconomic conditions, interest rates, and liquidity. Therefore, it is necessary to avoid establishing a causal relationship between the ECB's announcement and the observed YTM changes early in the analysis.

Correlation refers to the relationship between two variables, wherein a change in one variable is accompanied by a corresponding change in the other variable, either in the same or opposite direction. In this scenario, a change in one variable does not inevitably result in a related change in the other variable. However, the concept of causality pertains to this matter, where a change in one variable induces a corresponding alteration in the other variable, thereby creating a causal relationship between the two variables. Establishing causal effects can be a complex undertaking, so it is imperative to approach the DiD analysis with prudence (ABS, 2023).

It is imperative to determine whether the observed changes in the yields of green bonds are attributable to the actions of the ECB or other factors. While a DiD model alone cannot prove a causal relationship, it can enhance the support for the hypothesis. Thus, given that our study aims to determine whether an intervention has had an impact, it will be appropriate to utilize a DiD model to answer the research question.

5.2.1 Limitations

When conducting a regression analysis, employing control variables to increase explanatory power and reduce error estimates is appropriate to provide a more comprehensive understanding of the relationship between the ECB's announcement and the YTM on green bonds. Our research did, however, not include control variables for several reasons.

Incorporating control variables complicates the study and requires significant data to quantify factors affecting the groups' YTM. To isolate the effect of the ECB announcement, we restricted the analysis to a standard DiD analysis, which included two dummy variables and an interaction term. We, therefore, concentrated on making an overall assessment by understanding the impact of the ECB's announcement without examining the specifics of individual control factors.

In addition, we have evaluated whether non-green bonds are an appropriate control group. Since both categories of bonds share relative risk, return, and maturity characteristics, we will infer that they share similar features when comparing the two groups. Furthermore, they are exposed to the same macroeconomic and environmental factors, making isolating the effect more feasible. As a result, we conclude that our control group is sufficient and therefore excludes control variables.

Nevertheless, it is essential to acknowledge that the absence of control variables in our study represents a notable limitation, as these variables have the potential to impact the variance in YTM. We were aware of this limitation and interpreted our results, accordingly, considering the potential influence of uncontrolled factors on the observed outcomes.

5.3 Hypothesis

H₀: *The ECB announcement did not lead to changes in demand for green bonds in Europe*

H₁: *The ECB announcement led to an increasing trend in demand for green bonds in Europe*

5.4 Data Gathering and -Processing

Data on green and non-green bonds issued between January 2015 and December 2017 was collected from the financial database Refinitiv Eikon to address the research question. The

key variables of interest in this data collection are "YTM" and "Issue Date." We aim to understand how YTM's have evolved comprehensively by compiling panel data.

5.5 Interpretation

The analysis results will be interpreted based on the fact that the variable of interest is the interaction term β_3 . It will be interpreted as if it has a positive sign, indicating a steeper upward trend in YTM, resulting in a decrease in the price of green bonds. On the other hand, a negative sign indicates a steeper decline in YTM and a decline in the prices of green bonds. A significance level of 0.05 is typically used to determine whether a coefficient is statistically significant. Suppose the p-value is greater than the significance level (α). In that case, the effect may be uncertain, and the null hypothesis remains valid since it indicates insufficient evidence to conclude that the null hypothesis is correct.

6.0 Data

This chapter will elaborate on data description, sample construction, and a variable overview for some of the study's most important variables.

6.1 Data Description

In our thesis, we conducted a regression analysis using a necessary data selection for X and Y variables extracted from Refinitiv Eikon. The dependent variable accrues to the average yield to maturity over the selected period, while dummy variables were used for both the status of green bonds and the period after the announcement to the ECB, through *green* and *post*, respectively. In addition, an interaction term was included for interaction between the period after the announcement and the status of green bonds through the term *post x green*. The correct values for the dummy variables were assigned using if statements in Excel.

6.2 Sample Construction

The data sample was generated by computing the YTM for green bonds from January 2015 to December 2017, representing the most extended duration examined. Subsequently, another regression analysis is conducted from February 2016 to April 2016 to narrow the focus solely on the period encompassing the announcement, thereby isolating the effect from any extraneous factors that may impact the conclusion.

The complete dataset is based on the following subsequent filters:

Table 1: Filters used to retrieve the data sample from Refinitiv

Filter	Outcome
Issuer type	Corporate
Bond type	Bonds
Status	Active/inactive
Bond grade	Investment grade
Sukluks	Exclude
Domicile	Europe
Green bond	Yes/no
Yield to Maturity	0 < YTM < 30
Issue date	01/01/2015 - 31/12/2017

Based on existing literature and previous research, numerous studies have examined the occurrence over a span of several years. To demonstrate the impact of the ECB's announcement, this study has limited its investigation to a specific period. This approach aims to determine whether the observed reduction in YTM is a direct consequence of the ECB's announcement or a result of the overall expansion of this green bond market.

6.3 Variable Overview

The following is a variable summary of the most important attributes and features that are contained in the data set.

Table 2: Variable Overview (YTM)

Yield to Maturity	Green Bonds	Non-green Bonds
Mean	1,45	1,47
Standard Error	0,04	0,03
Median	1,02	0,88
Standard Deviation	1,48	1,61
Variance	2,18	2,59
Minimum	-0,40	-0,52
Maximum	6,77	7,48
Number of bond issuance	67	3 455
Number of observations	1 680	2 408

Table 3: Variable Overview (Bond Maturity)

Note: The periods are defined as: *Short*: $1 \leq \text{Maturity} \leq 20$, *Medium*: $20 < \text{Maturity} \leq 50$, *Long*: $>50+$. Excluded from the summary are 47 bonds that lack a maturity date in the data sample.

Maturity (# of bonds)	Green Bonds	Non-green Bonds
Short	57	3 073
Medium	7	333
Long	1	4

7.0 Empirical Results

This chapter discusses the empirical findings from the Difference-in-Difference analysis conducted. In addition, the results will be related to pertinent theory and placed in the context of existing literature.

7.1 Empirical Results #1: Long-Term

After producing a random selection from the population of 21 green bonds and 52 non-green bonds, the average YTM for all associated bonds for each month is plotted into a visual representation to observe any patterns or trend breaks, as shown in *Figure 9*.

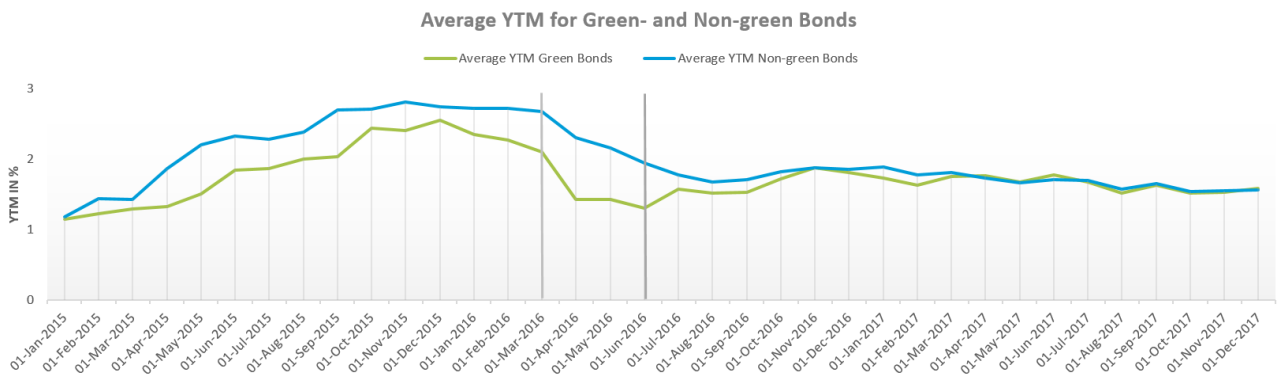


Figure 9: Average YTM for Green-and Non-Green Bonds from January 2015 to December 2017

Notes: YTM is based on the average yield to maturity for the respective active months. Bonds with extreme outliers were removed, resulting in 120 observations. The light grey vertical line represents the announcement of the CSPP on March 10, 2016, and the dark grey vertical line represents the beginning of CSPP purchases on June 8, 2016.

The graph depicts a constant increase in the average yield to maturity followed by a decline for both green and non-green bonds after the announcement. In addition, it has been observed that the spread has decreased since the implementation of ECB acquisitions in June 2016. Based on the graph, there is a positive trend for the growth of the green bond market, which may depend on a range of factors such as interest rates expectations over the period and the natural development of the yield curve since the closer the bond's maturity date will approach

par value. Another factor could be that investors may be increasingly interested in green bonds. These various elements may be the cause of a resulting in a positive shift in the demand curve, as shown in *Figure 7*.

The research is based on examining the outcomes derived from the Difference-in-Difference analysis. It is achieved by employing the same data as the graphical representation of the population sample's average YTM. The summary of the output is presented below in *Table 4*.

Table 4: Summary Output Long-term

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.498					
R Square	0.248					
Adjusted R Square	0.229					
Standard Error	0.412					
Observations	120					

	df	SS	MS	F	Significance-F
Regression	3	6.499	2.166	12.755	0.000
Residual	116	19.702	0.170		
Total	119	26.201			

	Coefficient	Standard Error	t-Stat	P-value	Lower 95%	Upper 95%
α	2.252	0.110	20.448	0.000	2.034	2.470
$post_t$	-0.660	0.126	-5.248	0.000	-0.909	-0.411
$green_i$	-0.376	0.156	-2.413	0.017	-0.684	-0.067
$post_t \times green_i$	0.315	0.178	1.771	0.079	-0.037	0.667

Given the regression analysis, an additive impact is regarded as the independent variable's direct contribution to the dependent variable. The results obtained from plotting the regression equation (1) are as follows:

$$YTM_{LT} = 2.252 + (-0.660) post_t + (-0.376) green_i + 0.315 (post_t \times green_i) + \epsilon_{it} \quad (2)$$

The constant term represents the average YTM for bonds that are neither affected by the announcement nor classified as green bonds, which is 2.252%. In addition, the beta coefficient for the dummy variable $post$ is -0.66, which indicates the expected change in YTM when the ECB announcement has an effect. In other words, if $post$ is 1, the ECB announcement had an impact, and YTM will be reduced by 0.66 versus in the case in which there was no effect when $post$ is 0. Similarly, to determine the beta coefficient for the variable $green$, the same procedure used for $post$ is applied. If the bond is classified as $green$, the

dummy variable will be assigned the value 1, reducing the YTM by an additional 0.376 units compared to when the dummy variable is set to 0.

According to the DiD coefficient, *post x green*, which is 0.315, there is a positive and statistically significant difference in the average return between green and non-green bonds following the ECB's announcement. This suggests that the YTM trend for green bonds has experienced a greater increase compared to the non-green bond market from 2015 to 2017, even though the average YTM for non-green bonds remains consistently higher than that of green bonds, as illustrated in *Figure 9*.

Furthermore, the p-value of 0.079 indicates that the result is moderately significant, surpassing the standard alpha level of 0.05. This indicates that the outcome is not statistically significant and that the null hypothesis remains valid. However, the null hypothesis can be rejected if an alpha of 0.10 is used.

7.1.1 Analysis of the Findings Considering the Long Term

Although the most common method within an analytical approach is to use a long-term perspective, it may be challenging to capture causal effects. Based on various macroeconomic factors and previous research, a negative DiD coefficient was anticipated to be observed, while the long-term impact on YTM was positive. Short-term volatilities and market disturbances, for instance, can influence a potential underlying effect and result in a positive DiD coefficient, contributing to estimation bias. Moreover, changes in economic and political factors over time can influence the outcome incorrectly by obscuring an anticipated negative effect. To obtain a more relevant and accurate depiction of the impact of ECB advertising, the analysis will also include a DiD approach that considers a short-time perspective in *Chapter 7.2*.

7.2 Empirical Results #2: Short-Term

To evaluate the impact of the ECB's announcement in isolation, a new regression covering November 2015 to June 2016 is conducted. This analysis adopts a shorter-term perspective as a result shown in the red box.

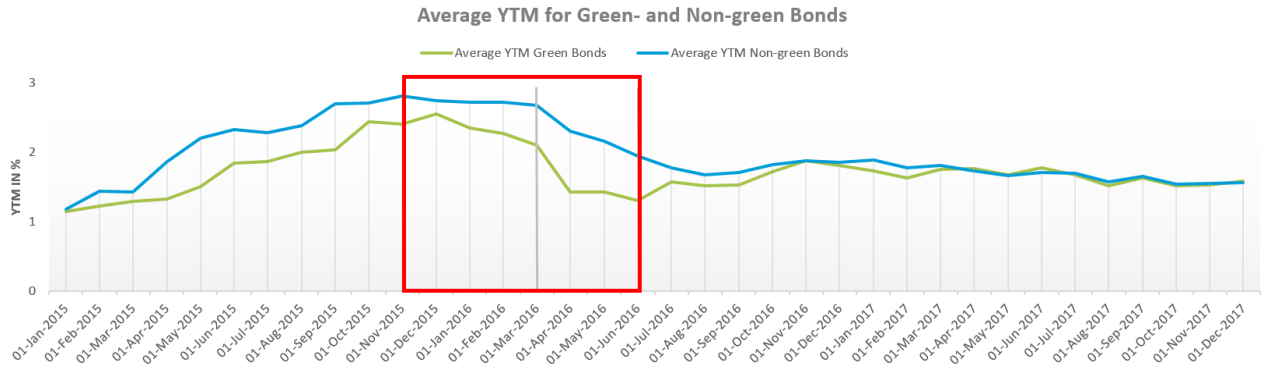


Figure 10: Average YTM for Green- and Non-green Bonds with narrowed time horizon

Notes: YTM is based on the average YTM for the respective active months. Bonds with extreme outliers were removed, resulting in 16 observations. The light grey vertical line represents the announcement of the CSPP on March 10, 2016, and the dark grey vertical line represents the beginning of CSPP purchases on June 8, 2016.

The visual depiction is identical to what was previously explained during the long-term perspective analysis. The distinction rests in that this analysis focuses on a brief time window to reduce noise and capture immediate effects related to the ECB announcement. The summary of the DiD analysis for the shortened time interval produced the following results:

Table 5: Summary Output Short-term

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.803
R Square	0.645
Adjusted R Square	0.556
Standard Error	0.288
Observations	16

	df	SS	MS	F	Significance-F
Regression	3	1.808	0.603	7.264	0.005
Residual	12	0.995	0.083		
Total	15	2.803			

	Coefficient	Standard Error	t-Stat	P-value	Lower 95%	Upper 95%
α	2.494	0.116	21.563	0.000	2.242	2.746
$post_t$	-0.221	0.146	-1.508	0.157	-0.539	0.098
$green_i$	-0.123	0.185	-0.664	0.519	-0.525	0.280
$post_t \times green_i$	-0.486	0.251	-1.939	0.076	-1.033	0.060

Like regression equation (2), equation (3) demonstrates the relationship between YTM, $post$, $green$, and the interaction term $post \times green$.

$$YTM_{ST} = 2.494 + (-0.221) post_t + (-0.123) green_i + (-0.486) (post_t \times green_i) + \varepsilon_{it} \quad (3)$$

The methodology underlying the beta coefficients is equivalent from the long-term perspective approach above. Similarly, the average YTM value for bonds unaffected by the dummy variables will correspond to 2.494%. The coefficient for *post* indicates an expected decrease of 0.221 in YTM when a bond is affected by an ECB announcement versus when no announcement occurs. In addition, the coefficient for *green* is -0.123, resulting in a reduction in YTM when the bond is considered green. If both *post* and *green* have the value 1, indicating that the ECB announcement has occurred and the bond is green, the expected YTM is reduced by 0.486 units compared to the case where neither variable has a value. This indicates that, compared to non-green bonds, the YTM for green bonds decreased more rapidly from November 2015 to June 2016 than for non-green bonds. This indicates that green bonds have experienced a more significant decline, which may suggest that the announcement impacts both price and demand. Nonetheless, it is essential to note that the graph for green bonds had already begun to decline before the announcement, with a significant drop occurring in March 2016.

In addition, the P-value for the regression analysis comes in at 0.076, which is regarded as relatively low. Although the P-value is not low enough to reject H_0 at a 5% significance level, it is low enough to reject it at a 10% significance level. This means that the evidence supporting the analysis's conclusions is insufficient to be convincing when alpha is 5% but that the data provides some support when the results are evaluated at a significance level of 10%.

7.2.2 Discussion of the Results from the Short-Term Perspective

When analysing causal effects using a DiD analysis, a shortened time window appears less complex and more reliable in identifying a specific effect. In this instance, the research provides a negative DiD coefficient consistent with previous studies and our expectations.

In the analysis for the short-term perspective, we are therefore more capable of isolating the observed effects, as it provides a snapshot of the specific shift in the market caused by the ECB announcement. This approach may increase the reliability of our findings by reducing

potential confounding variables and irrelevant impacts that may arise due to the use of an extended time perspective.

8.0 Conclusion

The European Central Bank has played an essential role by purchasing green bonds and sending a noteworthy signal about promoting sustainable investments. Their purchases may have increased the interest of investors and the demand for green bonds. In this instance, we have conducted a Difference-in-Difference analysis to identify causal effects on the green bond market in Europe regarding the announcement.

Considering the previous arguments, a positive DiD coefficient would indicate that green bonds had a faster increase in YTM than non-green bonds. This was the case from a long-term perspective, as the DiD coefficient resulted in 0.315, indicating a relative decrease in demand, which leads to an increase in YTM and a price decrease. In contrast, a negative DiD coefficient would indicate a steeper decline in YTM, resulting in an analysis of -0.486 for the shortened time perspective. Theoretically, this could indicate an increased demand for green bonds during the specified period, resulting in higher prices and a reduced YTM.

As a result, the long-term analysis finds minimal evidence and does not reflect the impact of the ECB's announcement. This might be attributed to the uncertainty of the estimates due to the complexity and volatility of economic factors. A more extensive analysis encompassing various variables, such as governmental changes, market development through time, and general economic trends, would be essential to comprehend the long-term market effects further. Such an investigation would have necessitated significant data collecting over a more extended period than 2015 to 2017. On the other hand, it is worth noting that existing literature and research suggest that the ECB's actions have influenced demand in the green bond market and contributed to the market's long-term stimulation. This can boost the growth of green bonds in the coming years by promoting green financing initiatives. The ECB published a study indicating that the yield spread on green bonds has continuously declined since 2016 (ECB, 2020). This is another aspect that has the potential to help support the ECB's impact over the long term, also shown in our graphical illustration below.

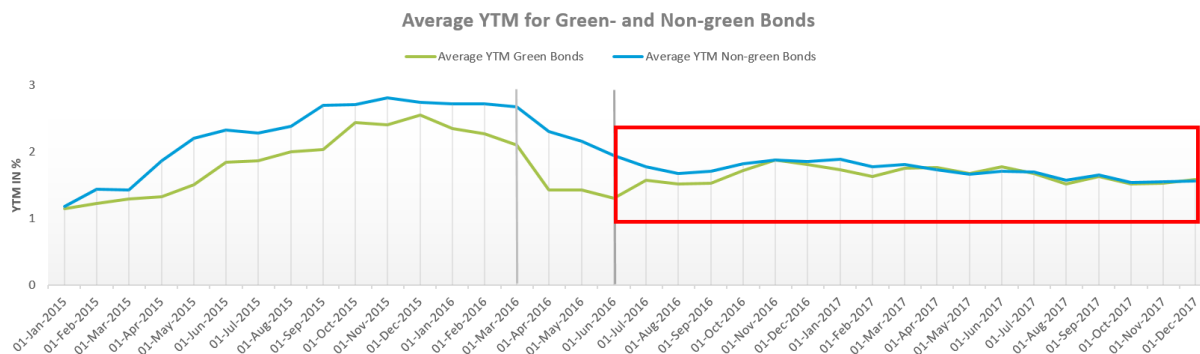


Figure 11: Graphical illustration of a steadily decreased yield spread

However, a conclusive decision based on this indicator should be made cautiously, as numerous factors may have influenced the market scenario. As a result of this and the findings of our analysis, there needs to be more evidence to conclude the long-term causal effects of the ECB's actions.

Considering the short-term analysis, we find suggestive evidence that the European Central Bank has influenced the European green bond market through its Corporate Sector Purchase Programme. By evaluating the exact impact of the announcements, we can better understand the immediate market impact, which may imply an immediate market reaction in this situation. The short-term estimates are deemed more reliable because the ECB's action reduced the YTM during the announcement. Remembering that an instant market reaction does not always represent the long-term effects of the ECB's actions is crucial. The market can be volatile and influenced by short-term factors such as investors' immediate behaviour patterns and market psychology. As a result, we discovered suggestive evidence indicating that the ECB's Corporate Sector Purchase Program directly influenced the green bond market.

Thus, we conclude that the European Central Bank influenced the market immediately following the announcement of its actions and contributed to an immediate market effect, as the analysis found suggestive evidence in accordance with our hypothesis in the short term. This is further supported by extant literature and extensive research on the subject, indicating that the central bank has played an essential role in stimulating demand for green bonds and influencing the market in the short term.

9.0 Criticism, Limitations, and Further Research

In this chapter, we will discuss thesis criticism, limitations, and future research to emphasize that we are conscious of our thesis's shortcomings and clarify the context of the research question.

9.1 Criticism

The initial criticism of this study is that the analysis contains few observations, resulting in a small sample size. In our research, there are more traditional bond data than green bond data, which can contribute to modelling bias. Moreover, omitting crucial variables may also have a significant impact.

Causal effects are complicated, as knowing what causes a change and finding evidence for causality is challenging. Although the DiD coefficients imply a relationship between the ECB's purchase of green bonds and the YTM, there may be additional variables not accounted for by the model that influence the outcome. Our long-term analysis illustrates that capturing causal effects over an extended time horizon is challenging, and due to methodological difficulties with the data analysis in a long time window we obtained a positive DiD coefficient.

9.2 Limitations

The primary limitation of our master's thesis is the absence of data. Green bonds are a new segment of the financial markets, so detailed data is limited. As interest and demand for green financing alternatives have grown in the past few years, there is more robust data in recent years that has yet to be accounted for by our analysis.

Another constraint on our data collection is that issuers choose whether to report voluntarily and publish information about their green bonds. This, in turn, may result in data restrictions and insufficient information regarding critical variables associated with green bonds.

Furthermore, there will be a constraint connected with Refinitiv data gathering, as we did not have access to some features during data collection, limiting our ability to extract all relevant data.

9.3 Further Research

As the green bond market in 2015 was less developed than it is today, it would be interesting to examine the effects of additional actions the ECB has taken in recent years for further research. It may also be interesting to study the long-term effects of ECB purchases of green bonds and what occurs if they withdraw or reduce their purchases.

Investors and financial institutions curious about sustainable investments may find our findings insightful. In addition, it may interest scientists and academics who study climate and the function of central banks in the green transition. As sustainable finance is still a new topic with limited literature, it may also interest students.

References

ABS. (n.d.). Correlation and causation. *Australian Bureau of Statistics*. Retrieved from <https://www.abs.gov.au/statistics/understanding-statistics/statistical-terms-and-concepts/correlation-and-causation>

AllianceBernstein. (n.d.). Understanding Green Bond Performance in Market Setbacks. Retrieved from <https://www.alliancebernstein.com/corporate/en/insights/investment-insights/understanding-green-bond-performance-in-market-setbacks.html>

Bhutta, U. S., Tariq, A., Farrukh, M., Raza, A., & Iqbal, M. K. (February 2022). Green bonds for sustainable development: Review of literature on development and impact of green bonds. *Science Direct*. Retrieved from https://www.sciencedirect.com/science/article/pii/S004016252100809X?casa_token=oBZEL7lIHMoAAAAA:YsN8DSPv4KR8SpRQOeuGqYevCSTciBBfkam6ohEw_9tzT91fQ4E9hc0fQzJrvuECzGW3K0MXLQBK

Bremus, F., Schuetze, F. & Zaklan A. (2021, March). The Impact of ECB Corporate Sector Purchases on European Green Bonds. *DIW Berlin Discussion Paper No. 1938*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3810492

CBI. (n.d.). Approved Verifiers under the Climate Bonds Standard. *Climate Bond Initiative*. Retrieved from <https://www.climatebonds.net/certification/approved-verifiers>

CBI. (n.d.). Climate Bonds Scientific Framework. *Climate Bond Initiative*. Retrieved from <https://www.climatebonds.net/standard/governance/scientific-framework>

CBI. (n.d.). Explaining green bonds. *Climate Bond Initiative*. Retrieved from <https://www.climatebonds.net/market/explaining-green-bonds>

CBI. (June 2016). Green Bond Labels and Standards. *Climate Bond Initiative*. Retrieved from <https://www.climatebonds.net/files/files/Green%20Bond%20Labels%20and%20Standards%2010-06-2016.pdf>

CBI. (2015). Green Bond Market Roundup. *Climate Bond Initiative*. Retrieved from <https://www.climatebonds.net/files/files/2015%20GB%20Market%20Roundup%2003A.pdf>

CBI. (2020). Green Bond Market Summary H1 2020. *Climate Bond Initiative*. Retrieved from https://www.climatebonds.net/files/reports/h1_2020_highlights_final.pdf

CBI. (2016). Green Bonds Highlights 2016. *Climate Bond Initiative*. Retrieved from <https://www.climatebonds.net/files/files/2016%20GB%20Market%20Roundup.pdf>

CFI. (January 12, 2023). Green Bond. *Corporate Finance Institute*. Retrieved from <https://corporatefinanceinstitute.com/resources/esg/green-bond/>

Credit Suisse. (n.d.). Impact Investing. *Credit Suisse*. Retrieved from <https://www.credit-suisse.com/sustainability/en/sustainable-investing/impact-investing.html>

De Santis, R. A., Hettler, K., Roos, M., & Tamburrini, F. (2018). Purchases of green bonds under the Eurosystem's asset purchase programme. *ECB Economic Bulletin, Issue 7/2018: The European Central Bank*. Retrieved from https://www.ecb.europa.eu/pub/economic-bulletin/focus/2018/html/ecb.ebbox201807_01.en.html

Doyle, D. H. (May 12, 2021). A Short Guide to the EU's Taxonomy Regulation. *S&P Global*. Retrieved from <https://www.spglobal.com/esg/insights/a-short-guide-to-the-eu-s-taxonomy-regulation>

ECB. (n.d.) Asset purchase programmes. *The European Central Bank*. Retrieved from <https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html>

ECB. (n.d.). Climate change and the ECB. *The European Central Bank*. Retrieved from <https://www.ecb.europa.eu/ecb/climate/html/index.en.html>

ECB. (n.d.). Corporate sector purchase programme. *The European Central Bank*. Retrieved from <https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html#cspp>

ECB. (February 22, 2023). FAQ on the corporate sector purchase programme. *The European Central Bank*. Retrieved from

https://www.ecb.europa.eu/mopo/implement/app/html/ecb.faq_cspp.en.html

ECB. (n.d.) FAQ on incorporating climate change considerations into corporate bond purchases. *The European Central Bank*. Retrieved from

https://www.ecb.europa.eu/mopo/implement/app/html/ecb.cspp_climate_change-faq.en.html

ECB. (November 25, 2022). How does the ECB's asset purchase programme work? *The European Central Bank*. Retrieved from

<https://www.ecb.europa.eu/ecb/educational/explainers/tell-me-more/html/app.en.html>

ECB. (August 25, 2021). How quantitative easing works. *The European Central Bank*. Retrieved from

https://www.ecb.europa.eu/ecb/educational/explainers/show-me/html/app_infographic.en.html

ECB. (n.d.). Purchases of green bonds under the Eurosystem's asset purchase programme. *The European Central Bank*. Retrieved from

https://www.ecb.europa.eu/pub/economic-bulletin/focus/2018/html/ecb.ebbox201807_01.en.html

Ehlers, T. & Packer, F. (September 2017). Green bond finance and certification. *BIS Quarterly Review*. Retrieved from https://www.bis.org/publ/qtrpdf/r_qt1709h.pdf

EIB. (July 19, 2022). From niche to mainstream. *The European Investment Bank*. Retrieved from <https://www.eib.org/en/stories/15-years-green-bond>

Eliet-Doillet, A. & Maino, A. (2022, April 19). Can Unconventional Monetary Policy Contribute to Climate Action? *Swiss Finance Institute Research Paper No. 22-35*.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4090616

EPA. (April 19, 2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks. *United States Environmental Protection Agency*. Retrieved from

<https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>

European Commission. (n.d.). EU taxonomy for sustainable activities. *European Commission*. Retrieved from

https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

European Commission. (n.d.). European green bond standard. *European Commission*.

Retrieved from

https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/european-green-bond-standard_en

Eurosif. (n.d.). EU Green Bond Standard. *Eurosif*. Retrieved from

<https://www.eurosif.org/policies/eu-green-bond-standard/>

Fatica, S., Panzica, R., & Rancan, M. (June 2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability*, Volume 54. Retrieved from

<https://www.sciencedirect.com/science/article/pii/S1572308921000334>

Ferrari, A. & Landi, V. (2021). Toward a green economy: the role of central bank's asset purchases. *The European Central Bank*. Retrieved from

<https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2779~a4eca2101a.en.pdf>

Flammer, C. (April 14, 2020). Corporate Green Bonds. *Journal of Financial Economics*,

Forthcoming. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3125518

Furuseth, T. (March 24, 2022). Obligasjoner for nybegynnere. *DNB*. Retrieved from

<https://www.dnb.no/dnbnyheter/no/bors-og-marked/obligasjoner-for-nybegynnere>

Green Central Banking. (n.d.). Central Banks. *Green Central Banking*. Retrieved from

<https://greencentralbanking.com/central-banks/>

Hayes, A. (March 31, 2023). What Is Greenwashing? How It Works, Examples, and Statistics. *Investopedia*. Retrieved May 23, 2023, from <https://www.investopedia.com/terms/g/greenwashing.asp>

ICMA. (June 2018). Green Bond Principles. *The International Capital Market Association*. Retrieved from <https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/Green-Bonds-Principles-June-2018-270520.pdf>

Investopedia. (September 21, 2021). Green bond. *Investopedia*. Retrieved from <https://www.investopedia.com/terms/g/green-bond.asp>

Maino, A. G. (2022). Changing regulatory landscape. In *Financing the Energy Transition: The Role, Opportunities and Challenges of Green Bonds* (pp. 22-26). *Oxford Institute for Energy Studies*. Retrieved from https://www.jstor.org/stable/pdf/resrep39500.12.pdf?refreqid=excelsior%3Ab604889e5d26b2a80a29c5d96a31d02d&ab_segments=0%2Fbasic_search_gsv%2Fcontrol&origin=&initiator
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Maino, A. G. (2022). Costs and benefits associated with green bonds. In *Financing the Energy Transition: The Role, Opportunities and Challenges of Green Bonds* (pp. 11–12). *Oxford Institute for Energy Studies*. Retrieved from https://www.jstor.org/stable/resrep39500.9?searchText=&searchUri=%2Faction%2FdoBasicSearch%3FQuery%3DECB%26prq%3Dgreen%252Bbonds%26swp%3Don&ab_segments=0%2Fbasic_search_gsv%2Fcontrol&searchKey=&refreqid=fastly-default%3Af6f3951ad7dd35d854e141d95294eedc&seq=2

Maino, A. G. (2022). Green bonds pricing and the ‘greenium.’ In *Financing the Energy Transition: The Role, Opportunities and Challenges of Green Bonds* (pp. 12–16). *Oxford Institute for Energy Studies*. Retrieved from https://www.jstor.org/stable/resrep39500.10?searchText=&searchUri=%2Faction%2FdoBasicSearch%3FQuery%3DECB%26prq%3Dgreen%252Bbonds%26swp%3Don&ab_segments=0%2Fbasic_search_gsv%2Fcontrol&searchKey=&refreqid=fastly-default%3Af6f3951ad7dd35d854e141d95294eedc

Refinitiv. (n.d.). ESG DATA AND SOLUTIONS FROM REFINITIV ESG. *Refinitiv*.

Retrieved from

https://www.refinitiv.com/content/dam/marketing/en_us/documents/brochures/esg-research-brochure.pdf

Riedl, A. & Smeets, P. (August 1, 2017). Why Do Investors Hold Socially Responsible Mutual Funds? *The Journal of Finance*, 72: 2505-2550.

<https://onlinelibrary.wiley.com/doi/10.1111/jofi.12547>

Segal, T. (September 21, 2022). Green Bond: Types, How to Buy, and FAQs. *Investopedia*.

Retrieved from <https://www.investopedia.com/terms/g/green-bond.asp>

Taylor, K. (2021, January 26). European Central Bank sets up climate team, considers green bonds. *Euractiv*.

<https://www.euractiv.com/section/energy-environment/news/european-central-bank-sets-up-climate-team-considers-green-bonds/>

The World Bank. (n.d.). Difference-in-Differences. *The World Bank*. Retrieved from

<https://dimewiki.worldbank.org/Difference-in-Differences>

The World Bank. (n.d.). What are green bonds? *The World Bank*. Retrieved from

<https://documents.worldbank.org/en/publication/documents-reports/documentdetail/400251468187810398/what-are-green-bonds>

The World Bank. (December 8, 2021). What You Need to Know About IFC's Green Bonds.

The World Bank. Retrieved from

<https://www.worldbank.org/en/news/feature/2021/12/08/what-you-need-to-know-about-ifc-s-green-bonds>

UN. (n.d.). Climate Change. *The United Nations*. Retrieved from

<https://www.un.org/en/climatechange>

UN. (n.d.). Green Financing. *United Nation Environment Programme*. Retrieved from <https://www.unep.org/regions/asia-and-pacific/regional-initiatives/supporting-resource-efficiency/green-financing>