Erasmus School of Economics

Master's Thesis in Financial Economics

Green Bonds vs. Conventional Bonds

An Analysis of Yield Spreads in the Europe Green Bond Market through Normal and Crisis Periods (Covid 19 and Russia-Ukraine War) and Evidence of Heterogeneity among Green Bonds

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[1] The views stated in this thesis are those of the author and not necessarily those of the supervisor, second reader, Erasmus School of Economics or Erasmus University Rotterdam.

Abstract

This paper presents a comprehensive analysis of the performance of green bonds relative to conventional bonds across various dimensions. By exploring different time periods, sectors, issuance sizes, and regions, this study provides an in-depth understanding of green bond performance. Using Fama-French and Difference-in-Difference regression models, I investigate the factors influencing yield spreads and shed light on the complexities of the green bond market. I examine the impact of external shocks, which are the Covid-19 pandemic and Russia-Ukraine war, on green bond performance. Findings indicate that green bonds had lower yields than conventional bonds before Covid-19 while economic downturns affected green bonds negatively more than their conventional counterparts. However, green bonds are affected negatively by crises more than conventional bonds. Moreover, pandemic affected financial performance of green bonds more than Russia-Ukraine conflict. Additionally, this study revealed significant heterogeneity in the performance of green bonds in terms of sector, issue size, and geography. The size of the issue is an important feature affecting yield spreads. Among three issue sizes, medium size green bonds showed a better performance compared to non-green bonds. Also, green bonds issued by financial institutions are affected more negatively during periods of market stress. Finally, green bonds' financial performance varies across different geographies. Overall, the volatile performance of green bonds during crisis periods shows that investors exhibit a partial shift in their focus towards conventional bonds however green bonds still shows resilience to some extent. These findings might help issuers and investors in the green bond market to understand yield spread implications and develop strategies to mitigate performance impacts.

Key Words: Green Bonds, Green Premium, Financial Performance, Yield Spread, Climate, Covid, Sector, Issuer

Content

1. Introduction

As the world deals with the challenges posed by climate change, green bonds have emerged as an influential tool in sustainable finance. The global green bond market, according to a report by Climate Bonds Initiative (2022), has reached a significant $2159.4bn. The marker displays a moderate growth trajectory for the last years. Notably, these specialized financial instruments are attracting considerable attention for their environmental credentials as well as their unique financial characteristics. Europe has dominated green issuance with an amount of $997bn. Nearly half of the green bond issuance in the private sector came from European corporations. Additionally, Europe is the source of the most cutting-edge legislative initiatives and specialized investment mandates. Issuers can increase exposure and investor diversification by issuing EUR-denominated debt (Climate Bonds Initiative,2022). On the other hand, there is an ongoing debate about green bonds' performance compared to their conventional counterparts. There are varying results from different studies. This intricate landscape necessitates a thorough examination, especially given the vital role green bonds play in marshalling capital for environmentally-sustainable projects in the context of a looming climate crisis.

The scholarly discourse on the financial performance of green bonds versus conventional bonds is still growing. Zerbib (2019) suggested a small "greenium" or premium on green bonds, a finding that could imply superior performance compared to conventional bonds. However, Larcker & Watts (2020) offer contrary perspectives, arguing there is no significant difference in the pricing of green and conventional bonds on municipal securities of the US therefore so-called greenium is essentially zero. Furthermore, Fatica & Panzica (2019) reports mixed results for the global market that green bonds have tighter yield spreads for supranational institutions and non-financial institutions while there is no significant difference for financial institutions. These divergent views underline the need for further exploration, a need emphasized by the rising prominence of green bonds in sustainable finance.

Crucial to this research is the study of the resilience of green bonds during periods of market turbulence. Nofsinger and Varma (2014) suggest that sustainable investments, mutual funds focusing on ESG attributes in their case, can act as a safe haven during market downturns, a concept that merits further exploration in the context of green bonds. Flammer (2020) states that green bonds certainly capture the attention of investors however the interest stimulated by the prospect of increased environmental protection is not necessarily sustainable. This implies that green bonds do not have a stable investor base, making them exposed to downside risk under volatile market conditions. More importantly, a comprehensive empirical analysis examining their performance during recent crises such as the Covid-19 pandemic and Russia-Ukraine war is still largely missing.

Furthermore, exploring the potential heterogeneity within the green bond market is another central theme of this research. Karpf & Mandel (2017) in their study for the US municipal bonds market have suggested that bond characteristics like the size of issuance and credit rating might influence a green bond's liquidity and performance. Ando et al. (2023) proposed that geographical factors might also play a part. For instance, a green bond issued in a developed market with strict environmental regulations might perform differently from one issued in an emerging market.

These insights from the literature will be instrumental in guiding this study's analysis of the financial performance of green bonds compared to conventional bonds, both in normal and crisis times across different market segments. With this in mind, the following research aims to contribute a comprehensive understanding of the role of green bonds in the sustainable finance landscape.

To conduct the analysis, I used a comprehensive dataset with a coverage of bond data for the period starting from 2015 to the May of 2023 from Refinitiv Eikon Database which is a reputable source for financial data in the world of finance. The methodology of this study firstly employed the Fama-MacBeth procedure, applying several Fama-French models starting from the Fama-French three-factor model and progressing to an extended version of a Fama-French seven-factor model. The latter is chosen due to its superior explanatory power for the variances in green bond and conventional bond performance.

Firstly, in order to assess the changing dynamics between green and conventional bonds through crisis times, the study broke down the data into three distinct subsamples: the period before Covid-19, during Covid-19, and during Russia-Ukraine war. This enabled me to monitor the evolution of the yield spread between green and conventional bonds during these distinct phases.

Moreover, I looked into the heterogeneity of green bonds, segmenting the data based on different issuer sectors (financials and non-financials) and size classes (small, medium, and big size issues). Also, geographical nuances were not overlooked as the paper includes an examination of green bonds in Main Europe, Nordic Countries, Mediterranean Countries, and particularly in Germany, France, and Switzerland was conducted given their significant representation in the dataset.

Secondly, a Difference-in-Differences (DID) method was employed to provide robust results that adjust especially for the economic crisis effect combined with unobserved heterogeneity that Covid-19 and Ukraine war might influence different categories of green bonds to different extents. This robust empirical approach enabled the study to offer detailed insights into the financial performance of green bonds against conventional bonds, both under normal conditions and for during and after the crisis induced by the pandemic and war. The paper aims to provide an encompassing view of the dynamic behavior of green bonds from different angles in the context of sustainable finance.

This study anticipates uncovering a complex landscape when it comes to the performance of green bonds relative to conventional bonds. The expectation is to encounter varying degrees of performance as different categories such as issuer sector, size class, and geographical area are considered. The heterogeneity of the green bond market suggests that while some categories of green bonds may outshine their conventional counterparts, others might lag behind. This differentiation in performance is crucial to understand the nuanced dynamics of the green bond market.

Finally, this investigation also aims to explore green bonds' performance during economic turbulence. Amid the upheaval and volatility brought by the pandemic and war, it is plausible to anticipate that green bonds may have been affected more in comparison to conventional bonds. Since financial instruments often respond unpredictably to crises, the unique attributes of green bonds may have influenced their performance during this period. The underlying question is whether green bonds showed a different performance than conventional bonds across different periods. By studying these aspects, it is intended to offer comprehensive insights into the financial performance of green bonds against conventional bonds under varying conditions.

The remainder of this paper is structured as follows: Section 2 provides a detailed literature review on the topic, which gives important insights regarding the green premium phenomenon, green bond market and the papers studying this topic. Section 3 explains the data collection and source. Section 4 discuss the methodology behind this study. Section 5 provides the regressions results of the Fama-French and DID models. Section 6 concludes the paper and stating the possibilities of future research.

2. Literature Review

2.1 Green Bonds

Green bonds, also known as climate bonds or environmental bonds, are specifically issued to finance projects with positive environmental benefits. Green bonds are sustainability-oriented fixed-income securities that are designed to raise funds for environmentally friendly projects promoting a climate-resilient economy (Reboredo, 2018). Green bonds are similar to conventional bonds for general dynamics such as pricing and rating. However, the proceeds of green bonds are exclusively used to fund or refinance projects that have a clear environmental objective. This objective may include initiatives such as renewable energy projects, energy efficiency improvements, sustainable infrastructure, or waste management systems.

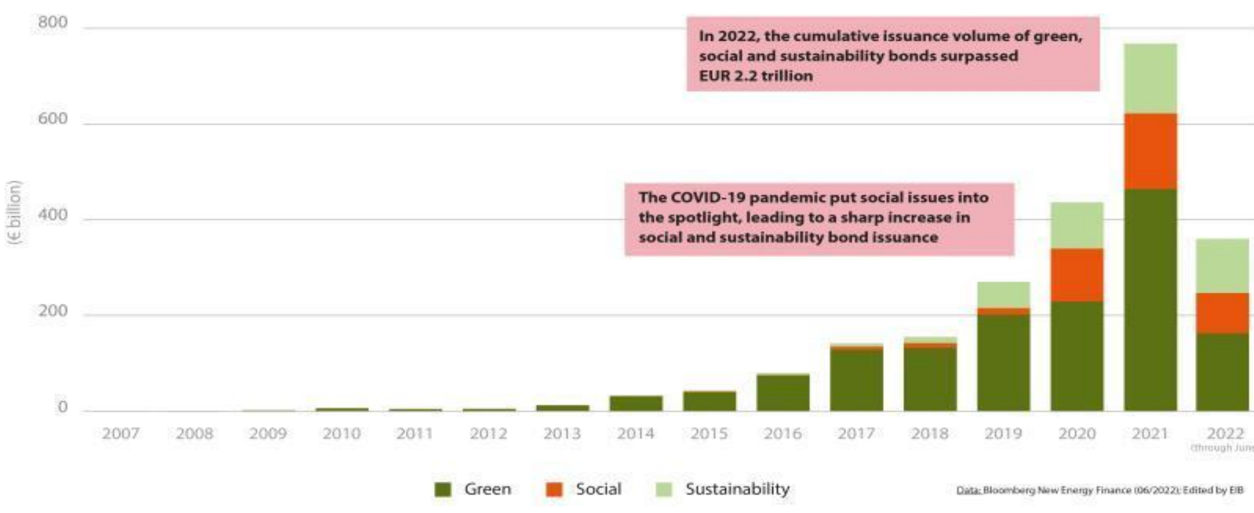
Moreover, green bonds play a crucial role in advancing global sustainability agendas, especially, in alignment with key international agreements such as the European Green Deal and the Paris Climate Agreement. The European Green Deal is a comprehensive plan by the European Union to transition to a climate-neutral economy, which emphasizes the importance of sustainable finance and green investments. The Green Deal Investment Plan seeks to mobilize at least €1 trillion of sustainable investments over the next decade, with green bonds expected to play a central role (European Commission, 2020). Green bonds contribute to the mobilization of capital towards environmentally friendly projects facilitating the achievement of the ambitious targets set out in the European Green Deal.

The labelization of green bonds is another critical aspect of these financial instruments. Green bonds are either self-labeled by the issuers or certified by recognized standard setters. These certifications ensure compliance with specific criteria and requirements that emphasize transparency and disclosure before and after the issuance. Respected international green bond standards include the Green Bond Principles and the Climate Bond Standards, which is compatible with other globally recognized standards such as European Green Bond Standard.

2.2 Green Bonds Market

In 2007, a group of Swedish pension funds displayed a keen interest in allocating funds towards climate-focused projects. Then, the first green bond was issued in late 2007 by European Investment Bank (EIB) (EIB, 2022). Since then, green bonds have emerged as a prominent financial instrument in the field of sustainable investing, playing a crucial role in funding environmentally friendly projects and addressing climate change challenges. Over the last decade , except 2022, the market for green bonds has experienced significant growth thanks to increasing investor demand for sustainable investments and regulatory initiatives promoting green finance. Moreover, the outbreak of the Covid-19 pandemic has demonstrated a notable influence on the issuance of green bonds as a sharp increase occurred in this period. Figure I shows the cumulative issuance of green bonds over the years. As can be seen on Figure I, green bond market has shown a dramatic growth between 2018-2021.

Figure I. Growth of green bond market over the years

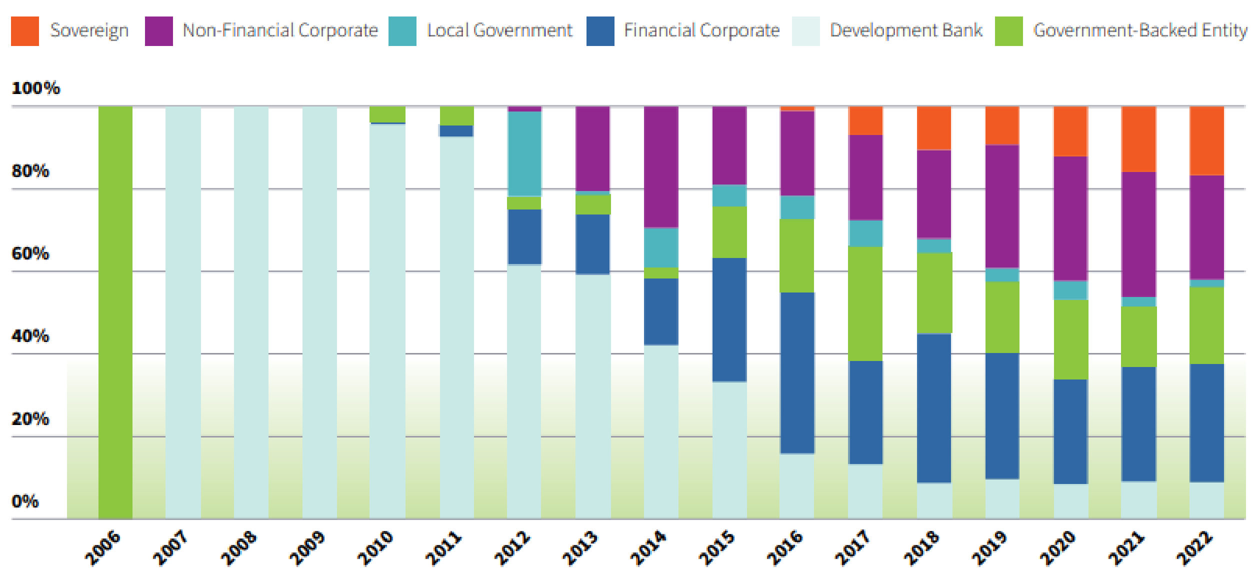


Source: European Investment Bank. (2022)

According to data from Climate Bonds Initiative (2022), the cumulative global issuance of green bonds reached a record high of $2159.4bn in 2022, highlighting the growing significance of this market in mobilizing capital towards environmentally responsible projects. The European region has demonstrated substantial leadership in driving the adoption and the growth of green bond market with its issuance accounting for approximately half of the global market while the Euro has been the leading currency in the world for green bond issuance. Figure II and Figure III in Appendix shows a detailed breakdown of green bond issues by different geographies and currencies.

In the early stages of green bond market development, governmental organizations and development banks led the market. Over the last decade, a shift of dominance on green bond issuance has occurred as Financial and Non-Financial Corporates had an increasing influence in green bond issuance accounting for approximately half of the market.

Figure IV. Breakdown of green bond issues by issuer types over the years shows the change in the issuer proportion in the green bond market.



Source: Climate Bonds Initiative (2022)

2.3 Green Premium

Several studies argue that specific demand and supply or liquidity conditions might influence bond yield differences (Greenwood and Vayanos (2014), Wang and Wu (2022), Chiang (2017).

The green premium is the yield difference between green and conventional bonds, which is arising from the pricing difference between these two types of bonds (Zerbib, 2021). This difference in yield is arising from a pricing difference, so called “greenium”, between similar green and conventional bonds. It means that investors are supposed to be willing to pay an extra amount to acquire green bonds, which results in lower yields for green bonds. Preclaw and Bakshi (2015) made the first study to claim that investors are paying a premium to buy green bonds in the secondary market. They ran an OLS regression decomposing the Option-Adjusted-Spread (OAS) into common risk factors and included a dummy variable for green bonds. They used a global sample of government and corporate bonds and found a 20-basis points difference between the yield spreads of green bonds and their conventional counterparts. They attributed this pricing difference to “opportunistic pricing” driven by the high demand from environmentally focused funds. Since then, several studies have been conducted to compare the yields of green and conventional bonds. There has been a remarkable increase in academic interest regarding green bonds in the last years especially between 2018-2020. Hachenberg and Schiereck (2018), Karpf and Mandel (2018), and Febi et al. (2018) have been the pioneering papers in this field. The studies regarding green bonds have been made mostly for the US or global market and revealed various results which will be discussed in detail later in this literature review.

Proponents of the Green Premium theory argue that several factors contribute to its existence. Firstly, the environmental and social benefits associated with green projects are expected to generate positive externalities, which can increase the perceived value of green bonds. Accordingly, investors may be willing to accept a lower yield for green bonds to align their portfolios with international green transition agenda. It aligns with the notion that some investors are willing to sacrifice a portion of their financial return in order to derive non-financial value from their investments (Dorfleitner and Utz, 2014; Riedl and Smeets, 2017). This phenomenon could be viewed as the opposite of the well-known sin-stock effect, where investor preferences cause stocks of unethical companies to generate a higher return than otherwise identical stocks because of neglect by norm-constrained institutions (Hong and Kacperczyk, 2009).

Furthermore, Höchstädter and Scheck (2015) show that impact investors who aim to make a positive impact on the environment or society are willing to accept a reduction in potential financial return. However, there is conflicting information regarding whether investments in sustainable, particularly environmentally friendly stocks, lead to financial under- or out-performance (Orlitzky et al., 2003).

Secondly, the increased transparency and stringent verification processes typically associated with green bonds reduce information asymmetry and enhance investor confidence. This improved transparency may lead to a higher valuation for green bonds compared to conventional bonds. Investors are more likely to trust the environmental claims made by issuers of green bonds, knowing that these claims have undergone thorough verification and certification processes by a third party (Flammer, 2020).

On the other hand, the notion of a Green Premium might be challenged with several counterarguments. Firstly, it may be argued that the demand for green bonds may be driven more by market sentiment and regulatory pressures rather than intrinsic value. This could result in inflated prices creating the appearance of a premium that is not justified by the underlying fundamentals. Secondly, the potential positive externalities of green projects may not be accurately priced into the market leading to an overvaluation of green bonds. Additionally, market forces such as supply-demand dynamics, investor risk preferences, and macroeconomic conditions may overshadow any perceived premium.

The existence of a Green Premium is a topic of debate among researchers and market participants. While proponents argue that the positive environmental and social attributes and increased transparency contribute to a higher valuation of green bonds, skeptics raise concerns about potential market distortions and overvaluation. There has been some scholarly attention towards green bonds' financial performance in primary and secondary markets examining potential yield differences between green and non-green bonds. Some of these studies have found negative green premia while others found positive premia or no significant conclusion at all. MacAskill et al. (2021) prepared a systematic literature review on green bonds yield differences. According to their study, the literature in this field states that there is green premium (lower yields) for 56% of primary and 70% of secondary market and the average green premium is between -1 to -9 basis points on the secondary market.

Östlund (2015) argued that there is no evidence of a green premium which indicates a yield difference between green and conventional bonds. Accordingly, Partridge and Medda (2020) and Hyun et al. (2020) are the others that stated there is no robust and conclusive evidence of a green premium. On the other hand, there are various studies that suggested the existence of a green premium (Bour (2019), Gianfrate and Peri (2019), Hachenberg and Schiereck (2018), and Wang et al. (2020)). Moreover, some studies produce mixed results signaling a heterogeneity in the market. For instance, Bachelet et al. (2019) suggests a green premium for green bonds from institutional issuers meaning a lower yield while green bonds from private issuers had a "positive premium" meaning a wider yield spread for green bonds compared to conventional bonds. Therefore, further research is needed to fully understand the dynamics and existence of the Green Premium in the context of sustainable finance.

2.4 Empirical studies on the Green Bond Premium

To understand the complex issue of green premium, it is crucial to understand the existing research in this field. As a key component of sustainable finance, green bonds have attracted some scholarly attention over the years. This literature review seeks to comprise the prevailing academic perspectives, disputed topics, and gaps that this study aims to address. Empirical studies have produced mixed results, with some supporting the existence of a Green Premium while others finding no significant difference between green and conventional bonds. These divergent findings underscore the need for further investigation and rigorous empirical analysis to fully comprehend the presence or absence of the Green Premium.

Zerbib (2019) conducted a thorough meta-analysis, reviewing over 1,800 green bonds issued between 2013 and 2017. His findings suggested -2 basis points, a small but statistically significant, greenium in the secondary market for green bonds. These studies established a baseline for subsequent research, focusing on more nuanced factors affecting green bond performance.

The seminal study by Ehlers and Packer (2017) investigated green bond pricing in both primary and secondary markets. They reported mixed results regarding green bonds' performance for primary and secondary markets. Authors noted that green bonds had lower yield spreads at issuance relative to conventional bonds. However, in the secondary market, green bonds did not perform better or worse than their conventional counterparts. They also segmented the sample by rating category and stated that ratings have an effect on yield spreads as the green yield difference is higher for riskier borrowers. This suggests that green bonds could outperform conventional bonds under specific conditions.

However, it is important to acknowledge that not all studies align with the notion of green premium or superior performance of green bonds. Karpf and Mandel (2017), in a notable deviation from earlier research, argued that green bonds underperformed compared to traditional bonds. They analyzed US American municipal bond market for the period between 2005 - 2016 and found that green bonds have been penalized by the market more than conventional bonds. They attributed this to a lack of awareness or skepticism regarding the market for green bonds. Flammer (2020) found similar results after an analysis that covers 152 green and 1690 brown bonds issued by public and private companies worldwide. The author argued that green bonds do not have any premium compared to their conventional counterparts. The author also discussed that she made interviews with several professionals including fixed-income analysts and high-level managers in sustainable finance, who stated that they would not invest in green bonds if yields were not comparable with conventional bonds. Another study by Larcker and Watts (2020) explored the green bond performance against non-green bonds. They analyzed 640 matched pairs of green and non-green bonds issued by the same municipality with the same rating and maturity. Their results suggested that greenium is exactly equal to zero that there is no difference between the yield spreads of green and conventional bonds. This finding counters the idea that the green bond market necessarily incorporates a "green premium".

According to Nanayakkara and Colombage (2019), there is a positive premium on green bonds with 63 basis points over comparable conventional corporate bonds. It indicates the motivation for issuers to enter the green bond market and provide investors with a chance for diversification.

Lebelle et al. (2020) applied several factor models including a 4-Factor Carhart model to a global sample of bonds data for the period between 2009-2018. They investigate the stock market reaction to issuance of green bonds. Their findings suggest that market reacts negatively to issuance of green bonds especially when it is the first issuance of a company. They stated that cumulative abnormal returns is between -0.5% and -0.2% after the green bond announcement date. Ahmed et al. (2023) made a similar study using factor models includin a Fama-French Five Factor model on a global sample for the period between 2013-2022. They argued that stock market positively reacts to the green bond issuance at varying levels, which is in the opposite direction of Lebelle et al. (2020).

Karpf and Mandel (2017) also pointed to credit ratings and issue size as important determinants of green bond performance, showing that larger issues and better-rated bonds tend to outperform their counterparts. This study highlights the need for more granularity in green bond research, a call that later research handled. Another important finding by Larcker and Watts (2020) is that they found no relationship between issuance size and estimated premiums however it must be noted that they do their analysis on mostly small-size issues ($5.36 million on average), which undermines the credibility of their statement. These diverse studies underscore the importance of considering multiple factors when studying green bond markets.

Bachelet et al. (2019) present a different perspective as they argue that while green bonds exhibit higher yields and lower variance, their liquidity and yield premiums vary depending on the issuer. Green bonds from institutional issuers show superior liquidity and tighter yield spreads before adjusting for lower volatility. On the other hand, those from private issuers demonstrate less favorable liquidity and volatility characteristics but tend to generate wider yield spreads if the issuer does not certify the bond's ‘green’ status, indicating the value of such verification in mitigating informational asymmetries and ‘greenwashing’ suspicions. Gianfrate and Peri (2019) echo this viewpoint, suggesting that green bonds, particularly those issued by corporate entities, offer greater financial convenience compared to non-green bonds. Their study, focusing on European green bonds, finds that this advantage persists even in the secondary market. Contrastingly, Fatica et al. (2019) report a mixed outcome, with yield differences varying by issuer type. While they find a premium for green bonds issued by supranational institutions and corporates, no yield differences were observed for those issued by financial institutions. Furthermore, their research suggests that financial institutions issuing green bonds reduce lending towards carbon-intensive sectors, highlighting a potential link between green bond issuance and green investment project financing.

Kapraun et al. (2021) stress the importance of issuer types in attracting a greenium. They observe that corporate green bonds with large issue sizes and those issued by governments or supranational entities tend to have tighter yield spreads than their conventional counterparts. Also, being denominated in EUR has a tightening effect on yield spreads, presumably due to the perceived stability of the currency. Caramichael and Rapp (2022) analyze a global panel of 129,043 conventional corporate bonds and 1,169 green corporate bonds from 2014 to 2021. Their study focuses on the borrowing cost advantage of green bond issuers at the time of issuance. The findings reveal that, on average, green bonds exhibit a yield spread that is 8 basis points lower than conventional bonds indicating a borrowing cost advantage. The authors also stated that the governance of green bonds plays a role in the greenium while the credibility of the underlying projects does not significantly impact it. Also, the greenium is more pronounced for large, investment-grade issuers, particularly within the banking sector and developed economies.

2.5 Empirical Studies on Green Bond Premium during Crisis Times

Another important issue is green bonds’ performance during an economic downturn. Chopra and Mehta (2023) investigate the hedging and safe haven properties of green bonds in relation to stock sectors. Their study for the period from October 2014 to March 2022, including the Covid-19 pandemic period from January to April 2020, reveals that green bonds act as a strong hedge for all stock sectors throughout the entire study period. During the Covid-19 pandemic, green bonds serve as a strong safe haven for most stock sectors, except for financials. The findings highlight the stability and resilience of green bonds during market downturns. Notably, the study emphasizes that the hedging and safe haven benefits of green bonds are independent of the environmental disclosure score of a firm. This implies that investors can incorporate green bonds into their portfolios as a hedging tool, regardless of the environmental consciousness of the underlying firms.

Fatica and Panzica (2021) conducted a study the period from 2018-Q3 to 2020-Q2 for the global market for institutional investors such as leading US public pension funds, insurance companies, and mutual funds. They examined the differences in sales between green bonds and conventional bonds for both Pre-Covid and during the Covid-19 outbreak. They found that there was no significant difference in sales between green bonds and conventional bonds until the end of 2019. However, during the first quarter of 2020, when the Covid-19 pandemic occurred, green securities experienced consistently lower sales compared to conventional bonds signaling green bonds' strong presence in the pandemic.

Yi et al. (2021) made an event study for the period between 2019-2020 to investigate the Covid-19 effect on China's green bond market and whether green bonds acted as a safe haven or not. They found that cumulative abnormal returns of green bonds increased greatly and decreased significantly after the pandemic. The authors attributed this to green bond issuers' governance capacity and their advantage in terms of information asymmetry. Adekoya et al. (2021) studied the U.S. green and conventional bonds and investigated Covid-19 and financial crises effect on green and conventional bonds to see whether green and conventional bonds are affected differently from these different types of crises. They applied the fractional integration technique to examine market efficiency and volatility persistence of the U.S. green bond market. They stated that green bonds show greater volatility during Covid-19 than during the financial crisis while conventional bonds exhibit a similar level of volatility during both crises.

Umar et al. (2022) made an event study on the Russia-Ukraine war effect on global stock markets for the period between 2021-2022. Their analysis compare how clean energy stocks and conventional energy stocks are affected from this event. They stated that global financial markets had significant losses however green energy firms benefited from the situation. The results of this study exhibited that abnormal returns for clean energy market stocks showed a significant increase compared to conventional companies. They concluded that green nature of business helps companies to protect themselves from crises. Imran and Ahad (2023) examined the U.S. green bond market over the period between 2008 and 2021 to see the effect of Global Financial Crisis and Covid-19 pandemic. They made a cross-quantilogram analysis and argued that green bonds can provide an efficient solution to reduce and diversify the risk under volatile conditions.

Therefore, they concluded that green bonds can provide a hedging opportunity to investors against economic turbulence.

2.6 Hypotheses of the Study

As the literature review suggests empirical studies have produced mixed results, with some supporting the existence of a green premium while others finding no significant difference between green and conventional bonds. These divergent findings underscore the need for further investigation and rigorous empirical analysis to fully comprehend the presence or absence of the green premium. Moreover, the analyses in the literature regarding green bonds' performance are mostly conducted for the US or global market however analysis focusing on the Europe green bond market is needed. Thus, the first hypothesis of this study as follows:

H*1: There is a difference between yields of green bonds and conventional bonds in Europe so a green premium exists in Europe green bond market in normal times. This hypothesis implies that green bonds exhibit a distinct performance advantage compared to conventional bonds in regular market conditions*.

Second important issue is to understand how green premium (if exists) changes during periods of market stress. In this sense, Covid-19 and Russia-Ukraine war are two important periods that might have affected yield spreads. The research about green bonds' performance during turbulent times, especially regarding Russia-Ukraine war, is very limited. Also, Russia-Ukraine war affected the Europe deeply in terms of general economic situation and energy markets. Therefore, it is critical to investigate green premiums in Europe green bond market during these two periods of crisis. This discussion brings the second hypothesis of this paper:

H*2: Green bonds in Europe perform better compared to their conventional counterparts during economic downturns or turbulent times, such as the Covid-19 outbreak and Russian-Ukraine conflict. This assumes the resilience of green bonds when faced with financial crises or market instability.*

Heterogeneity in Europe green bond market is another important issue that needed to be investigated. Several studies in the literature in this field showed that some categories of green bonds may perform in a different way than the others. Sector, size, and issuer country of green bonds might have a moderating effect on green bond performance in Europe. Therefore, the third and last hypothesis of this study is as follows:

H*3: There is heterogeneity in the performance of green bonds, whereby certain categories of green bonds show a different performance than the others compared to conventional bonds. This hypothesis implies the potential variability in performance across different types of green bonds, such as variations based on issue size, sectors or issuer country.*

After reviewing the related literature on the performance and characteristics of green bonds compared to conventional bonds, it is crucial to address these hypotheses. By examining arguments both for and against the green premium and considering the changing performance through different periods or categories, this study aims to contribute to the ongoing discourse and provide empirical evidence to support or refute the presence of a green premium in Europe green bond market, where detailed insights are provided for specific regions/countries or categories of green bonds. This study provides critical insights into the comparative performance, resilience, and heterogeneity of green bonds that contribute to a better understanding of their role in sustainable finance and investment strategies in the Europe green bond market. A profound understanding of the green premium is essential for investors, policymakers, and market participants seeking to explore the opportunities in sustainable finance and make well-informed decisions regarding their green bond investments.

3. Data

3.1 Green Bonds and Conventional Bonds Dataset

In this section, I outline the data compilation process of conventional and green bonds, benchmarks, and the Fama-French factors used to conduct this empirical analysis. Also, the data quality control process is presented in some detail. The research is conducted according to a hold-to-maturity approach as the buyers of the green bonds, mostly, are institutional investors who have a long-term investment approach. In this sense, yield to maturity is taken as a proxy to the return of green and conventional bonds.

Data on yields of both green bonds and conventional bonds have been collected from the Refinitiv-Eikon database alongside information regarding each bond’s qualifications. Each bond's amount issued, maturity, credit rating, issuer, and country of issue are listed in the Refinitiv-Eikon database. The monthly data on conventional yield to maturity and green yield to maturity were gathered from the same database. Most factors used are gathered from Kenneth French’s website. As the analysis demands a large amount of regressions and data management, all data cleaning, calculations, and regressions are conducted in Stata.

A total of 4389 bonds were issued over an eigth-year period from January 2015 to May 2023. The original sample is further cleaned and filtered for potential bias drivers and lack of information. The analysis is done with a novel data set of 4228 Conventional Bonds and 161 Green Bonds. Only investment grade bonds are included in the dataset and the bonds that have observation less than 10 months are excluded. Sample for green bonds is collected using the ‘’Green Bond’’ filter in the Refinitiv-Eikon database. This filter makes sure that all bonds are clearly classified as green and provided with the needed supporting information. The conventional bonds sample is collected from the Thomson Reuter’s Refinitiv fixed income database by using the “Plain Vanilla Fixed Coupon Bonds” tag.

3.2 Risk-free Rate and Dependent Variable

Since the bonds in the dataset are issued in European countries, the German risk-free rate downloaded on a monthly basis by Kenneth French’s website is used to represent the risk-free rate. Dependent variable is yield to maturity of bond (green and conventional) minus German risk-free rate which is taken as representative yield for the Europe bonds market. Also Germany is one of the leading countries in Europe to finance transitions to a greener economy as also suggested by the dataset of this research.

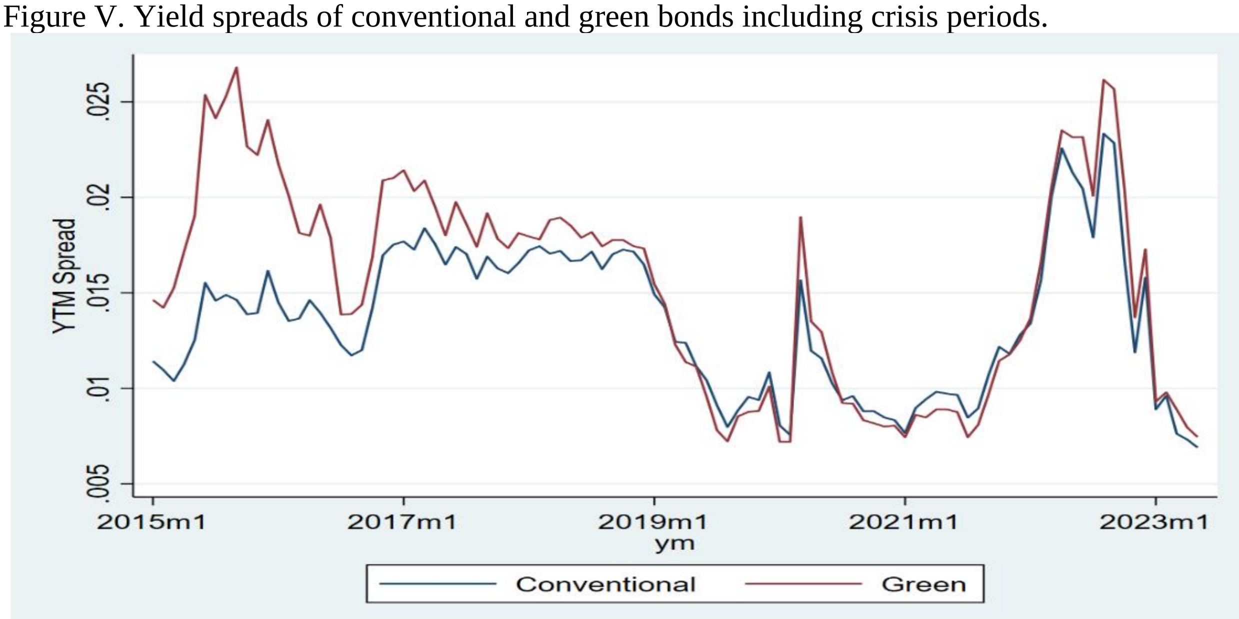
3.3 Fama-French Factors

Data on the Fama-French factors such as the market premium, size (SMB), value (HML), profitability (RMW), and investment (CMA) along with the momentum factor (MOM) are gathered from Kenneth French's website on a monthly format.

3.4 Summary Statistics

Figure V illustrates the yield spread trajectory of green and conventional bonds between 2015 and 2023, covering the pandemic and Russia-Ukraine war. Figure I reveals interesting dynamics as, initially, there was a significant difference in the mean YTM spreads between the two bond types which gradually converged over time. Interestingly, notable divergences in the mean difference were observed during periods of crisis, which are the COVID-19 pandemic and the Russia - Ukraine war. The divergence observed during crisis periods indicates a shift in investor preferences and risk perceptions.

Figure V. Yield spreads of conventional and green bonds including crisis periods.



Note: Figure V shows the yield spreads of conventional and green bonds between Jan. 2015- May 2023.

Table I presents the descriptive statistics for green and conventional bonds used in the analysis. As can be seen on the table, the average yield-to-maturity spread is higher for green bonds. Table II shows the summary statistics for the Fama-French model factors used in the analysis.

Table I

Variable/Statistic	N	Mean	SD	Median	Min	Max
Conventional YTM Spread	185,169	0.0130	0.01	0.01	-0.04	0.12
Amount Issued USD (LN)	185,004	19.1656	1.59	19.43	8.68	22.78
Green YTM Spread	5,464	0.0138	0.01	0.01	-0.01	0.11
Amount Issued USD (LN)	5,464	19.8329	1.08	20.12	16.21	21.43
Total YTM Spread	190,633	0.0131	0.01	0.01	-0.04	0.12
Amount Issued USD (LN)	190,468	19.1848	1.58	19.43	8.68	22.78

Note: The table show summary statistics for both conventional and green bonds examined in this paper. The considered time period is January 2015 and May 2023. The values shown here are calculated using monthly data.

Table II

Variable/Statistic	N	Mean	SD	Median	Min	Max
Mkt-RF	100	0.0054	0.05	0.01	-0.15	0.17
SMB	100	0.0010	0.02	0.00	-0.05	0.05
HML	100	-0.0011	0.03	-0.00	-0.11	0.11
RMW	100	0.0031	0.02	0.00	-0.04	0.04
CMA	100	-0.0016	0.02	-0.00	-0.04	0.03
WML	100	0.0062	0.03	0.01	-0.18	0.09

Note: The table illustrates descriptive statistics for the Fama-French factors, which are market risk premium (Mkt-RF), size premia (SMB), value premia (HML), momentum factor (WML), profitability factor (RMW), investment factor (CMA) used for Fama-Macbeth procedure.

Table III displays an outline of the distribution of green bonds by the issuer countries. As shown on the table, Germany, France, and Switzerland are the countries that have a strong presence in the dataset. Accordingly, analysis in this paper examined these countries considering this strong presence. Table IV illustrates an overview of the issue amounts of green bonds categorized by industry sectors. The TRBCs (The Refinitiv Business Classifications) codes are used to categorize industries. Table IV shows that financials, service, utility, energy, and construction firms are the most important issuers among all sectors.

Table III

Country of Issue	Conventional	Green	Total
Austria	146	4	150
Belgium	81	2	83
Denmark	102	0	102
Finland	22	1	23
France	951	56	1,007
Germany	1,813	48	1,861
Hungary	22	2	24
Italy	60	1	61
Netherlands	71	1	72
Norway	58	8	66
Poland	5	0	5
Portugal	12	0	12
Romania	3	2	5
Slovakia	24	0	24
Spain	76	3	79
Sweden	90	6	96
Switzerland	689	27	716
United Kingdom	3	0	3
Total	4,228	161	4,389

Note: The table provides the number of corporate issues of conventional and green bonds for the period between 2015-2021 by countries in Europe.

Table IV

	Conventional	Green	Total
Sector			
Financial Sector			
Banking	2,705	85	2,790
Leasing	2	0	2
Life Insurance	10	2	12
Mortgage Banking	434	4	438
Property and Casualty Insurance	15	1	16
Real Estate Investment Trust	29	9	38
Securities	6	2	8
Financial - Other	616	18	634
Non-Financial Sector			
Healthcare and Pharmacy	22	0	22
Transportation	15	2	17
Technology and Telecommunications	91	3	94
Automotive Manufacturer	4	0	4
Beverage/Bottling	12	0	12
Building Products	11	1	12
Chemicals	13	2	15
Conglomerate/Diversified Mfg	18	1	19
Consumer Products	15	0	15
Containers	1	0	1
Food Processors	13	0	13
Home Builders	13	5	18
Machinery	5	0	5
Metals/Mining	2	0	2
Oil and Gas	31	10	41
Restaurants	1	0	1
Retail Stores - Food/Drug	8	0	8
Service - Other	98	4	102
Transportation - Other	3	1	4
Utility	32	11	43
Vehicle Parts	3	0	3
Total	4,228	161	4,389

Note: The table provides the number of corporate issues of conventional and green bonds for the period between 2015-2021 by different sectors in two main groups, which are financials and non-financials.

4. Methodology

4.1 Fama-MacBeth Regression

Risk factors are frequently employed in asset pricing research to explain asset returns. A popular technique for examining how multi-factors explain asset returns or portfolios is the Fama-MacBeth two-pass estimation method, developed by Fama and MacBeth in 1973 (Bai & Zhou, 2015). Lin, Wang & Wu (2011) and Bektić et al. (2017) are among the many applying the Fama and MacBeth procedure to test individual bonds. The method comprises of a two-stage procedure that tests the time-series average of estimated risk premiums in cross-sectional regressions.

In the first pass regression, the procedure performs a time-series regression to estimate beta coefficients followed by cross-sectional regressions to estimate risk premia associated with each risk factor (Cochrane, 2009). As a result, the first step involves doing n number of regressions on each of the m factors to determine each factor exposure, denoted by β.

Beginning the first stage, each bond's excess returns in the sample are regressed against the relevant risk factors using Ordinary Least Squares (OLS) (Fama and French, 1992). The regression equation can be expressed as follows:

$$R_{it} – R^f = \alpha_{i1} + \beta_{i1} f_{1t} + \beta_{ik} f_{kt} + \varepsilon_{it}$$

where R_{it} represents the return of bond i at time t, R^f is the risk-free rate at time t, alpha is the intercept, β_{ik} is the time series coefficient of f_{kt} over time, and f_{kt} is the explanatory variable k at time t.

The second step involves running cross-sectional regressions on the returns on a portfolio or asset against the determined factor exposures at each point in time. This generates a time series of risk premium coefficients for each of the model's elements, and the average of these coefficients is then determined for each factor. To be able to quantify the predicted premium for a unit exposure to each risk factor over time, the average risk premium is calculated.

$$R_{it} – R^f = \alpha_{i1} + \beta_{i1}\lambda_{1t} + \ldots + \beta_{ik}\lambda_{kt} + \varepsilon_{it}$$

where λ is the factor coefficient representing factor k, and k denotes the number of cross-sectional regressions of the returns on the first step obtained factor exposures which is denoted by β.

4.2 Fama-French Three-Factor Model

To improve the poor explanatory power of the Capital Asset Pricing Model, Fama and French (1992) introduced a multifactor model, as an extension of CAPM, with two extra factors accounting for size and value. The Fama-French three-factor model captures common risk factors that account for variations in expected returns across different types of assets providing a comprehensive and reliable approximation of expected returns in the considered market, and has been shown to outperform other asset pricing models in empirical studies (Fama and French, 1993).

The SMB factor, which represents the size effect in asset pricing, is constructed on the premise that small firms tend to exhibit higher returns than larger firms, compensating for the increased illiquidity risk associated with small stocks. The size factor is constructed by building three portfolios of small stocks and three portfolios of large stocks, where size is determined by the market equity of the relevant stock. Then, the average return on the three small portfolios minus the average return on the three major portfolios is calculated to build the size factor. The value factor HML is constructed by calculating the average return difference between two value portfolios and two growth portfolios (value portfolios minus growth portfolios), based on the BE/ME ratio.

The Fama-French three-factor model is established as follows:

$$R_{it} – R^f = \alpha_{i1} + \beta_{i,m}(R_{mt} – R_{ft}) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \varepsilon_{it}$$

where $(R_{mt} – R_{ft})$ denotes the market premium, SMB_t is the size premium, HML_t is the value premium, $\beta_{i,m}$ is the coefficient for the market exposure, β_{SMB} measures the small firm impact on the bond return, β_{HML} is the coefficient for the value premium.

In this research, the two factors SMB and HML consist of monthly data for Europe during the period 2015-2022 retrieved from the Kenneth French website. The two factors are calculated by following formulas:

$$SMB_t = 1/3(R_{t,SG} + R_{t,SN} + R_{t,SV}) - 1/3(R_{t,BG} + R_{t,BN} + R_{t,BV})$$

$$HML_t = 1/2(R_{t,SV} + R_{t,BV}) - 1/2(R_{t,SG} + R_{t,BG})$$

where $R_{t,SG}$ represents the return from small growth firms, $R_{t,SN}$ denotes the return from small neutral firms, $R_{t,SV}$ is the return from small value firms, $R_{t,BG}$ is the return from big growth firms, $R_{t,BN}$ is the return from big neutral firms, $R_{t,BV}$ is the return from big value firms. Finally, a dummy variable of green bond is added to the equation to see the additional effect of being green on yield spread following Preclaw and Bakshi (2015) that examined this effect by adding a green dummy to their model and the formula becomes as follows:

$$R_{it} - R^f = \alpha_{i1} + \beta_{i,m}(R_{mt} - R_{ft}) + \beta_{SMB}SMB_t + \beta_{HML}HMLt + \delta_i GreenBond_i + \varepsilon_{it}$$

4.3 Carhart Four-Factor Model

Grinblatt, Titman, and Wermers (1995) found that momentum strategies significantly outperformed investments without a momentum strategy. In order to account for momentum effects, Carhart (1997) adds a fourth element to the original Fama and French three-factor model (1993). Bauer et al. (2004) employ the Carhart model to assess the performance of ethical mutual funds. Carhart four-factor model is set up as follows:

$$R_{it} - R^f = \alpha_{i1} + \beta_{i,m}(R_{mt} - R_{ft}) + \beta_{SMB}SMB_t + \beta_{HML}HMLt + \beta_{MOM}MOM_t + \delta_i GreenBond_i + \varepsilon_{it}$$

where MOM represents the momentum factor capturing the discrepancies between recent underperforming companies and companies that have performed well in terms of market value growth in the last time period. It is calculated using the difference between the returns of a portfolio of high momentum (winner) and a portfolio of low momentum (loser) at time t and β_{MOM} measures the impact of the momentum strategy on the return.

4.4 Fama-French Five-Factor Model

Fama and French (2015) introduced the five-factor model as the three-factor model struggles to account for the cross-sectional variation in expected returns, particularly those connected to investment and profitability, among other anomalies.

Fama and French (2015) use data from July 1963 to December 2013 to examine the efficacy of their five-factor model for the U.S. market. Their findings indicate that a five-factor model outperforms their three-factor model. They also demonstrate that the method used to calculate the factors does not affect the model's performance. However, the five-factor model is unable to account for the low average returns on small stocks with low profitability and high investment. Also, their findings indicate that the value factor (HML) becomes redundant in the five-factor setting.

Fama-French (2015) five-factor model is set up as follows:

$$R_{it} - R^{f} = \alpha_{i1} + \beta_{i,m}(R_{mt} - R_{ft}) + \beta_{SMB}SMB_t + \beta_{HML}HML_t + \beta_{CMA}CMA_t + \beta_{RMW}RMW_t$$

CMA represents the difference between the returns on diversified portfolios of conservative (low) investment and aggressive (high) investment portfolios, and RMW is the difference between the returns on diversified portfolios of robust (high) profitability and weak (low) profitability firms in this equation.

4.5 Def and Term Factors

Fama and French (1993) extended their model with Def and Term factors in order to account for a broader range of effects such as unexpected fluctuations in interest rates and the probability of default which are identified risk factors in bond returns. They used a factor called Term which is the difference in monthly returns between long-term government bonds and one-month treasury bills. Treasury bill acts as a benchmark as it reflects the general level of expected returns of bonds. Therefore, Term factor serves as a proxy for how the long-term bond returns deviate from the expected returns because of a shift in short-term interest rates. In order to construct the

Term factor, this study used Germany's 10-year government bonds and Germany's 1-year government bonds with monthly yields.

On the other hand, the Def factor measures the likelihood of default under changing financial conditions. The Def factor is constructed by computing the return differential between a portfolio of long-term corporate bonds and a portfolio of long-term government bonds. Fama and French (1993) discovered that this factor has a strong explanatory power for pricing the default premium. In this paper, the Def is constructed by using the S&P Eurozone 1+ Year Investment Grade Corporate Bond Index and Germany's 10-year government bonds with monthly yields. Then the model becomes:

$$R_{it} – R^{f} = \alpha_{i1} + \beta_{i,m}(R_{mt} – R_{ft}) + \beta_{SMB}SMB_{t} + \beta_{HML}HMLt + \beta_{CMA}CMA_{t} + \beta_{RMW}RMW_{t} + \beta_{term}TERM_{t} + \beta_{DEF}DEF_{t} + + \delta_{i}GreenBond_{i} + \varepsilon_{it}$$

4.6 Difference in Difference Model (DID)

The methodological framework of this study also employs a Difference-in-Differences (DID) design to determine how the Covid-19 pandemic and the Russia-Ukraine war affected the yield spreads of corporate green bonds compared to their conventional peers. DID model provides a focus to see the effect of events such as pandemic and war on green bonds performance and it eases to explore this effect for different categories of green bonds. The utilization of the Difference-in-Difference (DID) model effectively mitigates heterogeneity and minimizes the potential impact of endogeneity to a significant degree (Hamilton & Nickerson, 2003). DID approach has frequently been suggested and applied in empirical research to examine the repercussions of the Covid-19 pandemic (Goodman-Bacon (2020), Bartik et al. (2020), Chetty et al. (2020)). The DID model has a green dummy variable as green bond is the treatment group while conventional bond is the control group. Also, Covid*Green and R-U War*Green are the interaction variables between green bonds and regarding event. In order to control for unobservable effects, I have added country, sector, and issuer fixed effects. Also, the logarithmic form of bond size (ln Amount Issued) is added as another explanatory variable. To explore the impact of the pandemic and war effect, I conducted the regression for the duration starting from January 2015 to May 2023 on a monthly basis:

$$R_{it} – R^f = β_0 + β_1Green + β_2Covid + β_3R\text{-}U\ War + β_4Covid*Green + β_5\ R\text{-}U\ War*Green + β_6ln(Amount\ Issued) + β_7Country\ FE + β_8SectorFE + β_9IssuerFE+ ϵ_{i,t}$$

where $R_{it} – R^f$ is the log of monthly yield spread of bond i, Green is a dummy variable that takes the value of one if a bond is green, and zero otherwise. Covid, which is designed to see the effect of Covid shock, is a dummy variable that takes the value of one during March 2020 and zero otherwise, as lockdowns started to take place at the very end of February in Europe. R-U War, to see the effect of Russia-Ukraine war on bond yields, is a dummy variable takes the value of one after the March 2022 (24 February 2022 – Vladimir Putin Announcement) and zero before this date. Covid*Green and R-U War*Green are dummy variables for interaction between green bonds and different periods which are Covid and war periods. Country, sector, and issuer are fixed effects and the ln (Amount Issued) variable is the log of issue amount of the relevant bond.

5. Regressions Results and Analysis

5.1 Fama-French Regressions Results

Table V: Fama-French Model Development

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
GREEN	0.0008***	-0.0006***	-0.0004**	-0.0010***	-0.0018***	-0.0020***
	(2.8906)	(-3.2195)	(-2.1954)	(-6.8834)	(-19.2279)	(-20.5048)
MKTRF	-0.4637***	-0.3560***	-0.3977***	-0.3538***	-0.2558***	-0.2801***
	(-28.6439)	(-30.7486)	(-34.5721)	(-32.7559)	(-30.1124)	(-29.6252)
SMB	-0.0960***	-0.0426***	-0.0360***	-0.0288***	0.0749***	0.0821***
	(-26.1074)	(-15.5691)	(-9.8209)	(-7.9638)	(16.4739)	(17.8162)
HML	-0.0267***	-0.0900***	-0.0402***	-0.0593***	-0.1039***	-0.0882***
	(-3.8141)	(-10.0280)	(-4.8314)	(-6.4622)	(-9.9431)	(-9.7985)
MOM		0.3959***		0.2823***	0.1963***	
		(19.9148)		(22.1254)	(17.5000)	
RMW			-0.0435***	-0.0231***	0.0170***	0.0049
			(-6.9431)	(-3.5067)	(2.7491)	(1.1785)
CMA			0.0811***	0.0568***	-0.0480***	-0.0377***
			(17.0129)	(11.7561)	(-10.5616)	(-8.9734)
TERM					0.0129***	0.0118***
					(22.2991)	(17.7974)
DEF						0.0007
						(1.3896)
N	101	101	101	101	101	101
R2	0.7539	0.7939	0.8064	0.8164	0.8365	0.8407
ADJR2	0.7523	0.7924	0.8051	0.8149	0.8352	0.8393

Notes: t statistics in parentheses

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

The table shows results from Fama MacBeth regressions where in the first step a separate time series regression of bond spread on a list of independent variables is estimated for each of the 4,389 bonds. The coefficient estimates from these regressions are then used in the second step of their procedure. Specifically, in this step Fama MacBeth run cross-sectional regressions for each month separately where the dependent variable is bond yield and the independent variables are coefficient estimates from the first stage. Since each bond is either green or conventional, the green bond dummy is added to the second-stage regression only. The table above reports as N the number of second-stage cross-sectional regressions, equivalent to the number of months in our sample. (Adjusted) R-squared is the mean (adjusted) R-squared from all the second-stage regressions. The coefficients' interpretation: Green for Model 6 = -0.0020 = -20 bp.

Table V compares the different Fama-French models from FF3 (3 Factors) to FF7 (extended to 7 Factors) according to the Fama-Macbeth procedure to compare the financial performance of green bonds and conventional bonds.

The results show that the coefficient for the green bond variable is consistently negative and statistically significant across all models except Model 1. This suggests that green bonds tend to perform better than conventional bonds, even after controlling for other factors in the models. Also, it is important to note that the magnitude of the coefficient for the green bond variable increases as more factors are added, suggesting that there was an omitted variable issue. Also, AdjR2 which is increased from 0.7523 in FF3 model to 0.8393 in FF8 model shows that the explanatory power of the analysis is increased significantly as more variables are added. Therefore, FF7 (Model 6) model is chosen to continue with the rest of the analysis. FF8 results show that green bonds' yield spread is 20 basis points lower than those of conventional bonds. This result contradicts the findings of Bachelet et al. (2019), who reported that green bonds, especially the ones from private issuers, have a wider yield spread than their conventional peers.

In addition to the green bond variable, the general Fama-French factors (market risk, size risk, and value risk) consistently showed significant relationships with bond performance across all models, which is in line with previous research. I also included other variables such as momentum following Grinblatt et al. (1995) and also profitability, and investment factors, which showed varying levels of significance across models.

These findings suggest that green bonds, overall, overperform compared to conventional bonds even after controlling for other factors that may affect bond performance. This result confirms the important role of the green bond market in climate transition as it implies that investors' non-pecuniary motives seem strong enough to accept a lower yield for green bonds.

Table VI: Subperiods

	Pre-Covid	Covid	Russia-Ukraine War
GREEN	-0.0018***	-0.0012***	-0.0008***
	(-14.3953)	(-1.7e+02)	(-9.6391)
MKTRF	0.0265*	-0.4407***	-0.4055***
	(1.8285)	(-14.7282)	(-21.0776)
SMB	0.0265***	-0.0690***	0.0392***
	(3.9066)	(-7.4986)	(7.0340)
HML	0.1073***	-0.2689***	0.0137
	(12.9533)	(-13.3930)	(1.1026)
RMW	-0.0855***	0.0778***	0.0479***
	(-17.7121)	(10.8462)	(4.7807)
CMA	0.0647***	-0.0636***	0.0239***
	(11.1586)	(-9.2276)	(6.2835)
TERM	0.0141***	-0.0016***	0.0087***
	(21.2171)	(-5.9972)	(6.8810)
DEF	0.0010***	0.0115***	0.0050***
	(3.4345)	(9.5099)	(12.6746)
N	77	9	15
R2	0.8675	0.6414	0.7378
ADJR2	0.8660	0.6401	0.7373

Notes: t statistics in parentheses

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

The table shows results from Fama MacBeth regressions where in the first step a separate time series regression of bond spread on a list of independent variables is estimated for each of the 4,389 bonds. The coefficient estimates from these regressions are then used in the second step of their procedure. Specifically, in this step Fama MacBeth run cross-sectional regressions for each month separately where the dependent variable is bond yield and the independent variables are coefficient estimates from the first stage. Since each bond is either green or conventional, the green bond dummy is added to the second-stage regression only. The table above reports as N the number of second-stage cross-sectional regressions, equivalent to the number of months in the three subsamples. (Adjusted) R-squared is the mean (adjusted) R-squared from all the second-stage regressions. The coefficients are in percentage points. The three subperiods are defined as follows: Pre-Covid between January 2015 - February 2020, Covid between March 2020 - October 2020, and Ukraine Crisis between March 2022 – May 2023. The coefficients' interpretation: Green for Covid = -0.0018 = -18 bp.

Table VI shows the results from the Fama-MacBeth regressions indicating that green bonds show a consistently negative and significant impact on the bond yield spread across different periods: Pre-Covid, Covid, and Russia-Ukraine War. The coefficients for the green bond dummy variable (GREEN) are negative and highly significant at the 1% level in all three periods, which suggests that green bonds have a lower yield spread compared to conventional bonds during these times.

It is worth noting that the impact of green bonds on yield spread appears to be the strongest during the Pre-Covid period, with a coefficient of -0.0018. However, this coefficient decreased after pandemic begins and decreased further after the beginning of Ukraine crisis. This indicates that green bonds’ financial performance compared to conventional bonds worsened after the pandemic begins and the decline in their performance continued after the Ukraine crisis. Results show that economic downturns had a more substantial effect on green bonds' performance relative to conventional bonds, which is compatible with Keliuotytė-Staniulėnienė and Daunaravičiūtė (2021) who found a negative impact of pandemic on the S&P Green Bond Index.

When it comes to other factors, we can see that the coefficients on the market factor (MKTRF) were positive and statistically significant before the crisis but turned negative and statistically significant during Covid and Ukraine crisis. This may suggest that a shift in the relationship between market risk and bond yields due to the crisis and its aftermath, potentially reflecting altered market conditions or preferences for lower-risk investments. We also observe that the coefficient on the value factor (HML) was positive and statistically significant before Covid but turned negative and statistically significant during the Covid crisis before returning to a positive and statistically significant coefficient after the pandemic. This may suggest that value premiums, which tend to have more exposure to traditional industries, were negatively impacted during the Covid crisis but rebounded afterward as the crisis subsided and the economy began to recover.

Table VII: Sector and Issue Size Subsamples

	Financials	Non-financials	Small Issue	Medium Issue	Big Issue
GREEN	-0.0016***	-0.0012***	0.0008***	-0.0025***	0.0005***
	(-15.1664)	(-6.8865)	(6.5252)	(-13.5492)	(5.8932)
MKTRF	-0.2695***	-0.3115***	-0.3798***	-0.2311***	-0.3380***
	(-28.9925)	(-21.2004)	(-30.8977)	(-15.6275)	(-30.7105)
SMB	0.0772***	0.0774***	0.0176***	0.0994***	0.0263***
	(15.0289)	(7.0733)	(2.8971)	(13.9052)	(4.2311)
HML	-0.0883***	-0.0817***	0.0560***	-0.1353***	-0.1525***
	(-9.7191)	(-6.6667)	(5.6063)	(-13.0187)	(-18.3174)
RMW	0.0032	0.0110	-0.0933***	0.0347***	0.0553***
	(0.7667)	(1.1654)	(-9.1175)	(7.6463)	(11.9023)
CMA	-0.0308***	-0.0450***	0.0591***	-0.0718***	-0.0272***
	(-6.9314)	(-8.5751)	(5.7102)	(-12.3861)	(-5.7170)
TERM	0.0119***	0.0118***	0.0092***	0.0129***	0.0094***
	(18.0783)	(9.7017)	(6.7707)	(15.7316)	(11.3202)
DEF	0.0002	0.0012	-0.0037***	-0.0008	0.0012***
	(0.3823)	(1.5469)	(-4.5143)	(-1.0466)	(3.9877)
N	101	101	101	101	101
R2	0.8372	0.8736	0.8806	0.8156	0.9223
ADJR2	0.8357	0.8669	0.8764	0.8101	0.9209

Notes: t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
The table shows results from Fama MacBeth regressions where in the first step a separate time series regression of bond spread on a list of independent variables is estimated for each of the 4,389 bonds. The coefficient estimates from these regressions are then used in the second step of their procedure. Specifically, in this step Fama MacBeth run cross-sectional regressions for each month separately where the dependent variable is bond yield and the independent variables are coefficient estimates from the first stage. Since each bond is either green or conventional, the green bond dummy is added to the second-stage regression only. The table above reports as N the number of second-stage cross-sectional regressions, equivalent to the number of months in the subsamples. (Adjusted) R-squared is the mean (adjusted) R-squared from all the second-stage regressions. The first column reports the results for financials defined as green bonds issued by financial and banking institutions (3938 bonds), and non-financials(451 bonds) as that of other corporate institutions. The three size groups are defined as the three equally sized groups in terms of amount issued. Specifically, the first size group includes bonds with amount issued below the 33rd percentile, the second includes bond with amount issued between the 33th and 67th percentile, and the third group includes bonds with amount issued above the 67th percentile. The coefficients' interpretation: Green for Financials = -0.0016 = -16 bp.

The results in Table VII show the performance of green bonds in different bond categories. The negative and significant coefficients for the green bond dummy in the Financials and Non-Financial categories indicate that green bonds in these categories have lower yield spreads compared to their conventional counterparts. Green bonds issued by financial institutions have a relatively tighter yield spread than that of non-financial organizations as suggested by their yield spreads being -16 bp and -12 bp, consecutively. This might be due to higher liquidity of green bonds issued by financial institutions. These results contradict the findings of Fatica et. Al (2019) that green bonds by financial issuers have no green premium unlike that of non-financial green bonds.

Table VII also presents the impact of issue size on green bond performance across small, medium, and large-sized issues. It must be noted that the Green variable coefficient varies across the size of the issues. For small-sized issues, the coefficient is 0.0008***, indicating a statistically significant underperformance of green bonds relative to their conventional counterparts. The performance drastically changes for medium-sized issues, as evidenced by the Green coefficient of -0.0025, which shows an outperformance for green bonds about 25 basis points. In the case of large-sized issues, the difference in performance between green and conventional bonds is very limited with only 5 basis points.

The results suggest that issue size may have a moderating effect on the performance of green bonds. Smaller green bond issues may face greater yield spreads compared to conventional bonds, possibly due to factors such as liquidity constraints or investor preferences. On the other hand, larger green bond issues exhibit a performance better than or closer to that of conventional bonds, which is possibly due to a more extensive investor base or greater market liquidity. This finding is parallel with Caramichael and Rapp (2022) who found that larger issues of green bonds for their global sample have tighter yield spreads.

In conclusion, our results indicate that the performance of green bonds compared to conventional bonds varies across different categories. The sector and the issue size are significant drivers of the green premium either positive or negative. Green bonds for financial and medium categories perform better than the others. These findings have important implications for both issuers and investors as they should be aware of the varying performance of green bonds across different issue sizes and sectors when making investment decisions in the green bond market. Further research could explore the underlying factors driving the green bond performance.

Table VIII: Country/Region Subsamples

	Core Europe	Mediterranean	Nordic	France	Germany	Switzerland
GREEN	-0.0018***	0.0002	-0.0011***	-0.0023***	-0.0019***	0.0001
	(-15.02)	(1.06)	(-4.52)	(-12.55)	(-14.41)	(-0.62)
MKTRF	-0.2907***	-0.3303***	-0.4233***	-0.2817***	-0.2916***	-0.3317***
	(-29.58)	(-17.33)	(-14.70)	(-19.37)	(-30.33)	(-22.68)
SMB	0.1493***	0.0625***	-0.2266***	0.1045***	0.1278***	0.0198***
	(17.17)	(6.49)	(-13.56)	(12.83)	(14.14)	(3.3132)
HML	-0.0714***	-0.0750***	0.2250***	-0.1218***	-0.0632***	-0.1797***
	(-7.52)	(-6.41)	(5.63)	(-11.16)	(-6.24)	(-14.62)
RMW	-0.0288***	0.0077	-0.1396***	0.0142***	-0.0336	0.0749***
	(-7.28)	(1.04)	(-7.77)	(2.90)	(-8.75)	(9.48)
CMA	-0.0434***	-0.0269***	0.1039***	-0.0590***	-0.0244***	-0.0472***
	(-7.51)	(-3.62)	(8.16)	(-10.07)	(-4.26)	(-8.15)
TERM	0.0063***	0.0068***	0.0113***	0.0084***	0.0075***	0.0106***
	(7.35)	(5.73)	(9.00)	(10.99)	(8.81)	(10.61)
DEF	0.0027***	-0.0008	-0.0067***	-0.0027***	0.0025***	0.0020***
	(6.00)	(-1.05)	(-9.64)	(-4.82)	(5.76)	(5.90)
N	101	100	77	99	101	101
R2	0.884	0.888	0.903	0.846	0.892	0.895
ADJR2	0.882	0.866	0.896	0.843	0.889	0.891

Notes: t statistics in parentheses
* p < 0.05, ** p < 0.01, *** p < 0.001
The table shows results from Fama MacBeth regressions where in the first step a separate time series regression of bond spread on a list of independent variables is estimated for each of the 4,389 bonds. The coefficient estimates from these regressions are then used in the second step of their procedure. Specifically, in this step Fama MacBeth run cross-sectional regressions for each month separately where the dependent variable is bond yield and the independent variables are coefficient estimates from the first stage. Since each bond is either green or conventional, the green bond dummy is added to the second-stage regression only. The table above reports as N the number of second-stage cross-sectional regressions, equivalent to the number of months in the three subsamples. (Adjusted) R-squared is the mean (adjusted) R-squared from all the second-stage regressions. The five geographical groups represented by the models above are defined as: Core Europe (Germany, Netherlands, and Belgium), Mediterranean (Italy, and Spain), Nordic (Sweden, Norway, and Finland), also Germany, France, and Switzerland are examined separately due to their strong presence in the dataset. The number of bonds for the six groups are 2016, 140, 175, 1861, 1007, and 716 consecutively. The coefficients interpretation: Green for Core Europe = -0.0018 = -18 bp.

The empirical results shown in the Table VIII provide valuable insights into the changing performance of green bonds in various regions. The explanatory power of the model is quite high for each geography where the lowest ADJR2 is 0.843 (France) and the highest is 0.896 (Nordic). In Core Europe, Nordic region, and France, the negative and statistically significant coefficients for the GREEN variable (-0.0018, -0.0011, and -0.0023, respectively) indicate that green bonds exhibit tighter yield spreads, thus overperforming compared to their conventional counterparts. In the Nordic region, as can be seen, this effect is more pronounced with 23 basis points. This finding confirms the general expectation that green bonds would exhibit tighter yield spreads due to their environmentally friendly nature.

In the Switzerland and the Mediterranean region, the coefficient for the GREEN variable is not statistically significant, suggesting that there is no evidence for an inequality between the performances of green and conventional bonds in terms of yield spreads. Finally, regarding the German market, the negative and statistically significant coefficient for the GREEN variable (-0.0019) suggests that green bonds exhibit an overperformance relative to conventional bonds with a 19 basis points lower yield spread.

In conclusion, the regional analysis provides valuable insights into the relative performance of green bonds across different regional contexts. Also, the results imply that different risk factors and macroeconomic conditions may affect yield spreads in different regions. Further research is necessary to better understand the factors driving these differences and explore how local regulations, especially those related to green investments, investor preferences, and market conditions shape green bond performance.

5.2 Difference in Difference Model Results

Table IX: Model development

	(1) No FE	(2) C	(3) C+S	(4) C+S+I
Covid=1	0.34***	0.33***	0.34***	0.34***
	(23.47)	(24.16)	(24.96)	(27.42)
Green=1	0.04***	-0.04***	-0.19***	-0.19***
	(3.25)	(-3.64)	(-16.41)	(-15.57)
Covid=1 # Green=1	0.26***	0.25***	0.24***	0.25***
	(2.79)	(2.90)	(2.77)	(3.09)
R-U War	0.32***	0.30***	0.30***	0.30***
	(95.11)	(93.55)	(95.48)	(100.57)
R-U War*Green	0.04**	0.05***	0.09***	0.06***
	(2.39)	(2.98)	(5.00)	(3.67)
Ln(Amount Issued)	-0.09***	-0.11***	-0.11***	-0.09***
	(-97.04)	(-99.89)	(-97.87)	(-76.92)
Constant	1.79***	2.06***	2.02***	1.73***
	(94.95)	(98.65)	(96.90)	(76.33)
Observations	186009	186009	186009	186009
R^2	0.104	0.179	0.216	0.327

t statistics in parentheses

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

This table shows results from a difference-in-difference estimation model where dependent variable is the log of monthly bond yield. Model 1 represents the basic DID model with variables green, covid as well as their interactions. Model 2 adds country fixed effects. Model 3 adds sector fixed effects. Model 4 adds rating fixed effects. Green dummy is a variable that takes the value of one if a bond is green, and zero otherwise. Covid dummy, which is designed to see the effect Covid shock, is a variable that takes the value of one during March 2020 and zero otherwise. R-U War dummy, to see the effect of Russia-Ukraine war on bond yields, takes the value of one after March 2022 and zero before this date. Covid*Green and R-U War *Green dummy variables are interaction variables between green bonds and different periods which are Covid and war periods. The coefficients' interpretation: Green for C+S+I = -0.19 = -19 bp.

The Table IX shows the model development for comparing the financial performance of green bonds and conventional bonds while controlling for the effects of Covid-19 and Russia-Ukraine war, as well as country, sector, and ratings fixed effects.

In the C+S+I column, all three fixed effects (country, sector, and issuer) are included in the model. This means that the coefficients for the other variables are adjusted for the effects of country, sector, and issuer. Comparing the R-squared values across the columns, we can see that the inclusion of fixed effects leads to a substantial increase in R-squared whereas the C+S+I column having the highest value at 0.327. This suggests that the inclusion of fixed effects has improved the overall fit of the model and has helped to explain more of the variation in the yield spread.

Baseline model provide an explanation of how green bonds performed in three different periods: Pre-Covid, Covid, Russia-Ukraine War. During normal times (Pre-Covid), green bonds have a negative yield spread with a Green coefficient of -0.19, indicating that they outperformed conventional bonds. This finding aligns with my results from the Fama-French model which suggests an outperformance. Also, it is consistent with the literature suggesting that green bonds may benefit from investors' preference for sustainable investments and the perception of lower exposure to environmental risks (Zerbib, 2019). However, the interaction variable Covid*Green is positive and statistically significant showing that green bonds are more negatively affected by the Covid period with an extra effect of 25 basis points on yield spread. Looking at the R-U War variable, we see the increasing effect of Russia-Ukraine war on yield spreads in general also the positive value of R-U War*Green variable suggests that the yield spread for green bonds kept increasing after the war begins.

During the Covid period, the net effect[2] (green variable + related interaction term of the period) on green bonds' yield spread is 6 basis points higher compared to conventional bonds, suggesting a slight underperformance of green bonds. This change in performance might be due to the overall market uncertainty and the change in investor sentiment to cope with the pandemic's effects. This result contradicts the idea that green bonds can act as a safe haven during turbulent times as claimed by Fatica and Panzica (2021), Chopra and Mehta (2023). However, it must be noted that these studies did not examine specifically Europe green bond market.

The Russia-Ukraine war made a slight negative effect on green bonds as suggested by the R-U War*Green coefficient of 0.06 however the net effect[3] on green bonds' yield spread is -13 basis points lower compared to conventional bonds, indicating still an overperformance of green

[2] Net effect for Covid Period = Green Coefficient + Covid*Green Coefficient
[3] Net effect for Russia-Ukraine war = Green Coefficient + R-U War*Green Coefficient

bonds for this period. This change in performance could be attributed to the market readjusting after the conflict, as investors reassess their portfolios and risk exposure regarding geographical proximity. It is also possible that the energy crisis led investors to shift their focus back to brown energy sectors, which could be perceived as more stable investments during economic turbulence. Finally, the coefficient for the Ln (Amount Issued) variable is negative and statistically significant in all four models, suggesting that larger bond issuances are associated with lower yields, which aligns with my findings obtained from the Fama-French model.

In conclusion, the analysis suggests that green bonds outperformed conventional bonds during normal times but underperformed during the Covid period. Also, Russia-Ukraine conflict affected green bonds in a negative way more than conventional bonds. These findings have important implications for both issuers and investors in the green bond market to foresee potential changes in yield spread implications and consider strategies to mitigate the impact of external shocks on financial performance of green bonds across different time periods.

Table X: Sector and Issue Size Subsamples

	(1) Financial	(2) Non-Financial	(3) Small Amount	(4) Medium Amount	(5) Big Amount
Covid	0.32***	0.51***	0.13***	0.48***	0.39***
	(23.07)	(17.26)	(7.07)	(23.33)	(17.19)
Green	-0.20***	-0.17***	-0.32***	-0.10***	-0.15***
	(-13.70)	(-8.45)	(-10.90)	(-5.46)	(-6.84)
Covid*Green	0.34***	-0.00	-	0.11	0.17
	(3.18)	(-0.01)		(0.97)	(1.43)
R-U War	0.32***	0.15***	0.34***	0.33***	0.36***
	(99.33)	(19.07)	(91.89)	(59.28)	(60.10)
R-U War*Green	0.09***	0.11***	-0.04	0.10***	0.10***
	(4.48)	(4.06)	(-1.15)	(3.87)	(3.38)
Ln (Amount Issued)	-0.09***	-0.18***	-0.00	-0.28***	-0.04***
	(-72.97)	(-25.31)	(-0.00)	(-34.26)	(-3.94)
Constant	1.63***	3.92***	0.20***	5.38***	0.59***
	(70.62)	(27.04)	(5.45)	(33.73)	(3.06)
Observations	161151	24858	64880	61899	55603
R^2	0.310	0.398	0.352	0.366	0.308

t statistics in parentheses

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

This table shows results from a difference-in-difference estimation model where dependent variable is the log of monthly bond yield. It represents the DID model with variables Green, Covid as well as their interactions to see the changing effects according to the different sectors being financial and non-financial and different issue sizes of the bonds that are small, medium, and big issues. Green dummy is a variable that takes the value of one if a bond is green, and zero otherwise. Covid dummy, which is designed to see the effect Covid shock, is a variable that takes the value of one during March 2020 and zero otherwise. R-U War dummy, to see the effect of war on bond yields, takes the value of one after the March 2022 and zero before this date. Covid*Green and R-U War*Green dummy variables are interaction variables between green bonds and different periods which are Covid and war periods. Ln (Amount Issued) variable is the log of issue amount of the relevant bond. Note: Covid*Green variable for small size bonds is not available because there is no small green bond in the dataset during this period. The coefficients' interpretation: Green for Financial = -0.20 = -20 bp.

Sector of Bonds

Dividing the results by industry (Financial vs. Non-Financial) acts as a robustness test and also enables us to see the interaction between different periods and heterogeneity in green bonds market as the Covid and War effect on different categories are shown separately.

The subsample analysis presented in the Table X above compares the performance of green bonds and conventional bonds during the Covid-19 pandemic and the war period across different sectors (financial and non-financial) and issue sizes (small, medium, and big). Looking at Green variable, we see that green bonds are having tighter yield spreads in all categories Pre-Covid. The effect is more pronounced for the financial green bonds with a lower yield spread by 20 bp, which contradicts the findings of Sangiorgi and Schopohl (2021) who argued the existence of an unmet excess demand for green bonds issued by non-financial corporates. Similarly to our previous results, Covid had positive and significant values for all categories. The effect of Covid looks more pronounced for financial green bonds, which implies that these categories are seen as riskier during the pandemic. During the Covid period, financial green bonds underperformed conventional bonds, with a 34 basis points wider yield spread. It is not possible to come to a conclusion for the non-financials as the Covid*Green variable is insignificant for this category.

After the war begins, yield spreads for green bonds in both financial and non-financial sectors widened relative to conventional bonds while the effect was slightly larger in the non-financial sector, which might be because of non-financials' stronger link to energy crisis. However, it must be noted that the net effects (-11 bp for Financials, -6 bp for Non-Financials) on green bond yields were still negative suggesting an outperformance for this category. Therefore, green bonds show some resilience during war, possibly due to their alignment with sustainable and socially responsible investment objectives.

Issue Size of Bonds

Table X also shows the regression results divided into three size subsamples: small, medium, and big amount issues. For the Green variable, the coefficients are negative for all issue sizes. This suggests that, other than the pandemic and war effects, green bonds tend to outperform conventional bonds in the medium and big size categories when there is no economic turbulence. Interestingly, the green premium is more pronounced for small bonds, which is in line with the findings of Baker, Bergstresser, Serafeim, and Wurgler (2018) who argued that smaller green bonds tend to have tighter yield spreads due to the higher ownership concentration.

The positive coefficient of the Covid variable shows that pandemic has a similar expansion effect on spreads all bonds of all issue sizes, with the smallest effect observed for bonds with smaller issue sizes. However, Covid*Green interaction terms are inconclusive for specifically green bonds during covid. Additionally, Ln(Amount Issued) variable states that medium size green bonds have an advantage in terms of yield spreads.

Moving on to the War period, the coefficient of the R-U War variable is positive across all sizes, indicating a general widening of bond yield spreads. The magnitude of the coefficient is similar for all sizes, suggesting they are affected equally from the Russia-Ukraine conflict. On the other hand, green bonds' yield spreads for medium and large issues widened more than their conventional counterparts as shown by the R-U War*Green interaction term. The underperformance of green bonds could be due to the increased risk aversion among investors during turbulent times, leading to a preference for safer investments (Vayanos, 2004)

Overall, the findings indicate that the performance of green bonds compared to conventional bonds varies across size categories and different periods. Also, these results confirm the findings of Zerbib (2019), who found that green bond performance varies according to bond characteristics and market conditions.

In conclusion, this subsample analysis suggests that green bonds' performance during the pandemic and war period varies across sectors and bond issue sizes. In general, green bonds are affected negatively by both the Covid and War compared to their conventional counterparts. These findings have important implications for both issuers and investors in the green bond market since they highlight the importance of considering sector and size of issues when evaluating green bond performance.

Table XI: Country/Region Subsamples

	(1) Core Europe	(2) Mediterranean	(3) Nordic	(4) France	(5) Germany	(6) Switzerland
Covid	0.20***	0.28***	0.21***	0.31***	0.18***	0.72***
	(9.54)	(4.97)	(3.76)	(13.48)	(8.45)	(23.25)
Green	-0.19***	0.31***	-0.33***	-0.29***	-0.19***	0.10**
	(-10.13)	(3.41)	(-7.63)	(-15.44)	(-10.19)	(2.31)
Covid*Green	0.45***	0.60	0.27	0.25**	0.46***	0.02
	(3.07)	(1.05)	(0.92)	(2.30)	(3.20)	(0.08)
R-U War	0.34***	0.32***	0.27***	0.19***	0.35***	0.22***
	(80.72)	(21.25)	(19.04)	(33.64)	(80.39)	(22.93)
R-U War*Green	0.09***	-0.11	0.13**	0.12***	0.08***	-0.05
	(3.22)	(-0.98)	(2.29)	(4.67)	(2.91)	(-0.93)
Ln (Amount Issued)	-0.10***	-0.09***	-0.08***	-0.10***	-0.10***	-0.16***
	(-61.16)	(-7.90)	(-13.99)	(-41.71)	(-59.02)	(-16.28)
Constant	1.80***	1.73***	1.80***	2.11***	1.78***	2.93***
	(60.85)	(7.47)	(15.36)	(44.84)	(59.02)	(14.78)
Observations	78402	7604	8005	48804	71037	30472
R^2	0.275	0.194	0.470	0.315	0.268	0.193

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
This table shows results from a difference-in-difference estimation model where the dependent variable is the log of monthly bond yield. It represents the DID model with variables Green, Covid as well as their interactions to see the changing effects according to the different regions or countries, which are Core Europe (Germany, Netherlands, and Belgium), Mediterranean (Italy and Spain), Nordic (Sweden, Norway, and Finland), also Germany, France, and Switzerland are examined separately due to their strong presence in the dataset. Green dummy is a variable that takes the value of one if a bond is green, and zero otherwise. Covid dummy, which is designed to see the effect Covid shock, is a variable that takes the value of one during March 2020 and zero otherwise. R-U War dummy, to see the effect of war on bond yields, takes the value of one after March 2022 and zero before this date. Covid*Green and R-U War*Green dummy variables are interaction variables between green bonds and different periods which are Covid and war periods. Ln (Amount Issued) variable is the log of issue amount of the relevant bond. The coefficients' interpretation: Green for Core Europe = -0.19 = -19 bp.

The analysis of the country subsamples provides insights into how green bonds performed in comparison to conventional bonds in different regions. During normal times, green bonds outperformed in all regions/countries except Mediterranean and Switzerland. In the Core Europe, France, and Germany, green bonds experienced wider yield spreads compared to conventional bonds during the Covid period. In contrast, the Mediterranean and Nordic countries and

Switzerland exhibited no statistically significant difference in the yield spreads of green and conventional bonds during the same period.

When it comes to the Russia-Ukraine conflict, all bonds are affected negatively as the positive R-U War coefficient suggests. Also, R-U War*Green variable suggests that yield spreads of green bonds in all regions increased except Mediterranean and Switzerland during the Russia-Ukraine war. A plausible explanation for the observed variations is the geographical proximity and the varying interconnectedness through energy markets.

It is essential to consider the unique economic characteristics and recovery processes of each region while interpreting these results. Arif et al. (2022) argue that green bonds tend to provide a hedging opportunity and safe haven during economic downturns. However, the results from the current analysis seem to contradict such findings, with varying magnitudes. One possible explanation for this discrepancy could be the heterogeneity in the economic structures and financial markets of the studied regions, which may have influenced the performance of green bonds during the Covid period and subsequent Russia-Ukraine war.

6. Conclusion

This study provides a comprehensive examination of the performance of green bonds relative to conventional bonds across various dimensions, including different time periods, sectors, issuance sizes, and regions. The detailed insights of this study provide a clear picture of the green bond investors' reaction to Covid-19 and Russia-Ukraine war. Also, this study reports the significant heterogeneity in green bond market that some groups of green bonds perform better than the others. Green bonds are expected play a central role in transitioning to a greener economy. Therefore, it is important to understand the current situation and dynamics in this field to be able to have a greener economy.

Utilizing both Fama-French and Difference-in-Difference regression models, this study presents a robust analysis of the factors that potentially influence the yield spreads of green bonds. The explanatory power of Fama-French Seven Factor model was quite high and it provided significant results. On the other hand, the Difference in Difference Model, while providing robustness to the results of Fama-French model, helped to understand how pandemic and war affected each category of green bonds differently in various geographies.

Both of these methodologies showed that green bonds outperformed conventional bonds in normal times for most of the categories. Therefore, Hypothesis 1 is not rejected. On the other hand, Covid and Russia-Ukraine conflict affected green bonds more than conventional bonds in terms of increase in their yield spreads. Also, the results show that Covid affected green bonds more than war in Ukraine. That’s why, green bond performance during crisis times suggests that Hypothesis 2 is rejected. However, categorical and geographical differences stated on regression tables must be considered as there are varying results in details. Moreover, both methodologies revealed significant heterogeneity in the performance of green bonds relative to their conventional counterparts across different regions. The findings indicate that the issue size and sector of green bonds might have a moderating effect on their performance. Green bonds, if they are medium issues or issued by financial institutions, outperformed their conventional counterparts in normal times however economic downturns affected all green bonds, with a more pronounced effect on financial green bonds. Furthermore, geographical differences analysis is another important aspect of this study. Before pandemic, green bonds in Core Europe, Nordic, France, and Germany outperform their conventional counterparts while green bonds in Mediterranean and Switzerland underperform. Moreover, Covid affected green bonds in Core Europe, France, and Germany more than other regions while Russia-Ukraine conflict affected France and Nordic countries most. That’s why, Hypothesis 3 is not rejected.

These findings indicate that crisis times have a critical effect on green bond performance compared to conventional bonds. To summarize, the results in this study show that specific categories of green bonds are affected from economic turbulence more than the others, as investors exhibit a partial shift in their focus towards conventional bonds during times of market stress. Nevertheless, green bond market in Europe seems robust to economic downturn to some extent. The results indicate that, despite the resilience of green bonds, investors were still grappling with the wider implications of the crisis periods. This could be due to the market uncertainty and the reassessment of risk exposures in such economic environment.

The findings of this study have important implications for investors, issuers, formal institutions and society in general since it provides detailed insights to the financial performance of green bonds. Green bonds play a crucial role in funding environmentally friendly projects in transitioning to a greener economy. Understanding the performance of green bonds is critical for decision making and policy development by regulatory bodies, which might bring stability to this market. Also, investors must consider the potential variations in the performance of green bonds. Therefore, the stable performance of green bonds might convince investors to integrate environmental considerations into their investments. On the other hand, enhancing performance of green bonds can help issuers to have a wider investment base and finance their green projects and repay in a more efficient way.

Overall, this study contributes valuable insights into this growing field of research and highlights the need for additional research to understand the factors driving the differences between green and non-green bonds, including local regulations and initiatives, investor preferences, and market conditions. Future studies might help to understand so-called greenium and the factors behind it. For instance, researchers might conduct a study solely focusing on investor sentiment and considerations regarding green bonds. An “interview” approach might be taken in this sense where biggest investors in both green bonds market and fixed-income securities are interviewed. This approach might help to understand the core factors driving possible yield differences between green and conventional bonds from the investors’ point of view as main source. This would help to understand investors’ view on investing in climate sensitive assets and their values and expectations from these markets.

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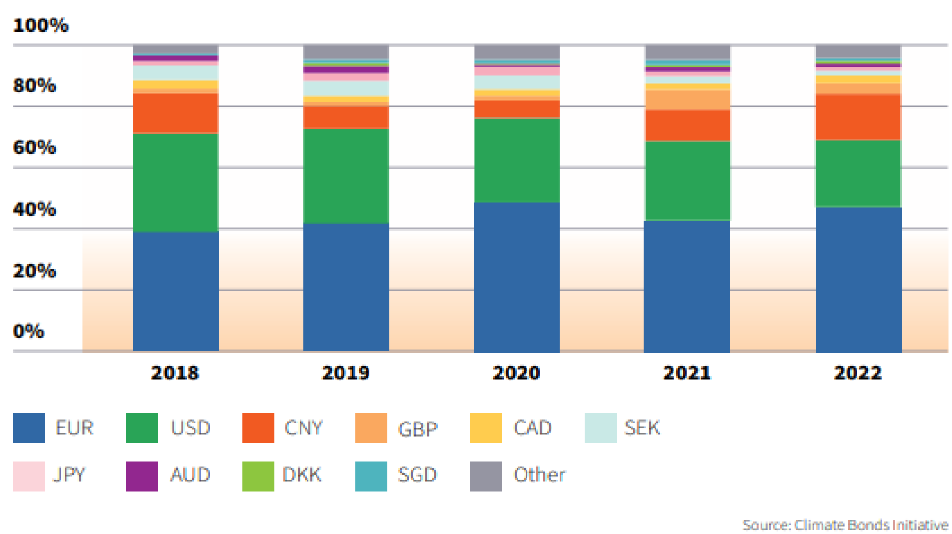
APPENDIX

Figure II

Cumulative regional green bond issuance since 2006				
Region	**Green bond markets**	**Issuers**	**Amount issued (USDbn)**	**Change 2021-2022**
Africa	9	24	4.7	↓
Asia-Pacific	23	973	512.7	↓
Europe	34	647	1,001.9	↓
Supranationals	-	17	168.5	↑
Latin America	16	130	37.5	↓
North America	2	669	434.2	↓

Source: Climate Bonds Initiative (2022)

Figure III



Source: Climate Bonds Initiative (2022)