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A Greenium for the Next Generation EU Green Bonds

Analysis of a Potential Green Bond Premium and its Drivers

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Isabelle Cathérine Hinsche*°

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Abstract

As part of the Next Generation EU (NGEU) program, the European Commission has pledged to issue up to EUR 250 billion of the NGEU bonds as green bonds, in order to confirm their commitment to sustainable finance and to support the transition towards a greener Europe. Thereby, the EU is not only entering the green bond market, but also set to become one of the biggest green bond issuers. Consequently, financial market participants are eager to know what to expect from the EU as a new green bond issuer and whether a negative green bond premium, a so-called Greenium, can be expected for the NGEU green bonds. This research paper formulates an expectation in regards to a potential Greenium for the NGEU green bonds, by conducting an interview with 15 sustainable finance experts and analyzing the public green bond market from September 2014 until June 2021, with respect to a potential green bond premium and its underlying drivers. The regression results confirm the existence of a significant Greenium (-0.7 bps) in the public green bond market and that the Greenium increases for supranational issuers with AAA rating, such as the EU. Moreover, the green bond premium is influenced by issuer sector and credit rating, but issue size and modified duration have no significant effect. Overall, the evaluated expert interviews and regression analysis lead to an expected Greenium for the NGEU green bonds of up to -4 bps, with the potential to further increase in the secondary market.

JEL Classification: C23, G12, G14, G21, G23, G28, Q56

Keywords: Sustainable Finance, Green Bonds, Greenium, Next Generation EU, EU Bonds, Environmental, Social and Governance (ESG), Sustainable Investing, Green Finance

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1. Introduction

On 21 July 2020, the European Commission adopted the Next Generation EU (NGEU) program, a recovery instrument with the aim to repair immediate economic and social damage caused by the coronavirus pandemic (European Commission, 2021a). Together with the long-term EU budget, the NGEU program is the largest stimulus package financed in Europe so far (European Commission, 2021b). The focus of the funds is to build a more resilient, more digital and greener Europe, which, at the same time, is a much-needed progress to combat climate change. Since the Paris Agreement, with the goal to limit global warming to below 2°C, almost six years have passed (UNFCCC, 2021). However, current efforts are falling short of reaching this target, with estimations based on current policies projecting global warming of 2.9 °C (Climate Action Tracker, 2021). According to the most recent Intergovernmental Panel on Climate Change report (IPCC, 2021), limiting global warming to 1.5 °C or even 2°C will be out of reach, unless the international community takes immediate steps to reduce greenhouse gas emissions on a large scale.

According to the Organization of Economic Co-operation and Development (OECD, 2018), government budgets are insufficient to generate the necessary investments to combat climate change. Supplementary private investments need to be mobilized and redirected into the transition towards a sustainable economy. This approach has been termed Sustainable Finance and entails the process of incorporating environmental, social and governance (ESG) criteria into investment decisions (European Commission, 2021c). To foster sustainable investments within the European Union (EU), the European Commission has developed the European green deal investment plan, which, for example, includes a unified green classification system (EU taxonomy), as well as a sustainability disclosure regulation for asset managers and institutional investors (European Commission, 2021c). Consequently, the field of sustainable finance has gained increasing attention, with, for example, revised risk assessment methods that incorporate ESG criteria, and sustainable finance instruments entering the market.

Among the most prominent sustainable finance instruments are green bonds, which are defined as a bond instrument, for which the proceeds are exclusively used to finance or refinance classified green projects and assets (ICMA, 2021a). The first green bond was issued in July 2007 by the European Investment Bank (EIB) as a Climate Awareness Bond (EIB, 2011). Since then, the green bond market has been growing rapidly, with a total

issuance volume of EUR 252 billion in 2020 (Bundesbank, 2021). The interest in green bonds has been particularly driven by the discussion about a potential negative green bond premium, a so-called "Greenium". A potential Greenium would mean that investors are willing to accept a lower return for green bonds compared to conventional bonds, due to a green bond's exclusively green investments. The literature is divided, whether and in what magnitude such a Greenium exists. On the one hand, evidence for a Greenium in the primary and secondary market has been found (Preclaw & Bakshi, 2015; Ehlers & Packer, 2017; Gianfrate & Peri, 2019), as well as that it varies, for instance, with issuer sector, rating and currency (Bachelet et al., 2019; Zerbib, 2019; Fatica et al., 2021, Kapraun et al., 2021). On the other hand, some research papers find no significant Greenium (Hachenberg & Schiereck, 2018; Larcker & Watts, 2020; Hyun et al., 2020), or even a partly positive green bond premium (Karpf & Mandel, 2018). The most recent evidence in favor of a Greenium are the three green German Federal Government bonds, which were issued as twins to conventional bonds and are all trading at a negative green bond premium in the secondary market of around -4 basis points (bps) to -7 bps as of 11.08.2021.

Encouraged by the opportunity to confirm their commitment to sustainable finance, as well as to widen their investor base and to support green bond market growth, the European Commission has decided to use green bonds as part of their diversified funding strategy for the Next Generation EU (NGEU) program (European Commission, 2021a). With the pledge to issue at least 30% or up to EUR 250 billion of the NGEU bonds as green bonds, the EU is not only entering the green bond market, but also set to become the biggest green bond issuer as of now (Krautzberger, 2020). Consequently, financial market participants are eager to know what to expect from the NGEU (green) bond issuances and the EU as a new green bond issuer.

Motivated to develop an in-depth understanding of the green bond market and how the NGEU green bonds will be received by market participants, this research paper provides an analysis of the anticipated NGEU green bond issuances, answering the following research questions:

(1) Can we expect a Greenium for the Next Generation EU green bonds?

(2) What are the underlying drivers that might affect a potential Greenium?

In order to gain an overview of the current developments in the green bond market and of the expectations for the NGEU green bond issuances, an interview with 15 sustainable

finance and green bond market experts, including rating agencies, issuers, asset managers and bank representatives, is conducted. Moreover, the public green bond market from September 2014 until June 2021 is analyzed with respect to a potential Greenium and its underlying drivers, to formulate a well-founded expectation for a potential NGEU green bond Greenium. The applied methodology involves a matching method for green and conventional bonds, based on their respective maturities. For each matched pair, a green bond premium is derived based on a fixed-effect regression, which models the green bond premium as an individual fixed effect and controls for any persisting liquidity difference. Finally, a cross-sectional regression model analyses the influence of bond characteristics such as issuer sector and credit rating on a potential green bond premium. The quantitative results confirm the existence of a significant Greenium in the public green bond market, as well as that a green bond premium is significantly influenced by issuer sector and credit rating. A negative green bond premium is greater for supranational and AAA rated issuers, such as the EU. Subsequently, the evaluation of the expert interviews and regression estimates leads to the expectation of a significant Greenium of up to -4 bps for the NGEU green bonds, with the potential to increase in the secondary market.

The research paper is structured as follows: the subsequent section gives an overview of the green bond market, explaining green bonds, investor and issuer motivation, current challenges, as well as summarizing the literature on a potential green bond premium. An introduction to the Next Generation EU program is given in the third section, describing the EU's funding strategy, evaluating the EU as a green bond issuer and presenting the sustainable finance expert interview results. In the fourth section, the econometric method for the estimation of a potential green bond premium and its drivers is depicted, clarifying methodology and data selection. Moreover, the respective results are presented and interpreted, followed by the formulation of an expectation for the NGEU green bonds, based on the expert interviews and calculated green bond premium estimates. Finally, all findings are summarized and discussed.

This research contributes to the existing literature by providing an extensive analysis of the public green bond market, establishing a significant Greenium based on a data sample from September 2014 until June 2021. Moreover, it offers an insight into the current developments and challenges of the green bond market from the point of view of green bond market experts and formulates an expectation regarding a potential Greenium for the NGEU green bonds.

2. The Green Bond Universe

2.1 Green Bond Definitions

2.1.1 What are Green Bonds?

Green bonds are a fixed-income instrument with the aim to finance the environmental and sustainable transition towards a low-carbon economy (Deschryver & De Mariz, 2020). In the sustainable finance capital market, green bonds are characterized by their use of proceeds' restriction to only finance or refinance classified green projects and assets. In contrast, social bonds only finance classified social projects, whilst sustainability bond proceeds can be used to finance a combination of both, classified green and social projects (ICMA, 2021b). Moreover, sustainability-linked bonds do not limit the use of proceeds to green or social investments, but their financial or structural conditions, for example the coupon, vary with predefined key performance measures and sustainability performance targets (ICMA, 2021c). Apart from their restricted use of proceeds, green bonds do not differ much from conventional bonds in regards to their characteristics. In fact, even though green bonds finance a specified green project, they are not exposed to the green project's individual risk (Maltais & Nykvist, 2020). Instead, they have recourse to the issuer's entire balance sheet and are therefore exposed to the same firm-specific risk as a conventional bond from the same issuer. However, green bonds have more extensive reporting and verification standards, which is explained in the next section.

2.1.2 What is defined as Green?

For a well-functioning green bond market, a mutual understanding of what is considered as green is needed, in order to avoid greenwashing and to protect the market's integrity (European Commission, 2021d). Several standards, trying to define a bond's greenness, have been developed over the past years. One of the most commonly used standards is the Green Bond Principles (GBP), which were developed by the International Capital Market Association (ICMA) and are a voluntary guideline for issuers. The principles consist of four core aspects (ICMA, 2021a). First, the issuer has to classify investments made, as well as assess and, if possible, quantify the respective environmental benefits. Possible categories of eligible investment projects are renewable energy, energy efficiency, clean transportation and climate change adaptation (see table 1, appendix). Furthermore, the project evaluation and selection process have to be communicated to investors. The standard also requires transparency in the management of green bond proceeds, which can be ensured with the help of an external auditor (ICMA, 2021a). Lastly, the issuer is required to annually report on

allocations and impact, using individually defined performance measures (see table 2, appendix). The relevant information should be summarized in a Green Bond Framework and the principles recommend an external review to assess the green bond's alignment with the GBP. A more extensive standard is the Climate Bond Standard (CBS), developed by the Climate Bond Initiative (CBI, 2019). It requires full alignment with the Green Bond Principles by the ICMA, as well as mandatory reporting. Additionally, the CBS suggests best practices for internal controls, tracking and verification (CBI, 2019).

The most recent efforts to develop an EU taxonomy and EU Green Bond Standard (EUGBS) have been undertaken by the European Commission. The EU taxonomy is a classification system for eligible green investments, which establishes six environmental objectives: climate change mitigation and adaptation, sustainable use of water and resources, circular economy, pollution prevention and a healthy ecosystem (European Commission, 2020). For an investment to classify as green, it has to contribute to at least one of the objectives and must not significantly harm any of the other objectives. Furthermore, the investment has to comply with minimum social safeguards, such as the United Nations guiding principles on business and human rights (United Nations, 2011), as well as with technical screening criteria, which are performance thresholds defined by the EU taxonomy for the classification of economic activities as environmentally sustainable (European Commission, 2020).

The EUGBS requires full alignment with the EU taxonomy, stating that all funds raised by a green bond should be allocated fully to projects that are aligned with the EU taxonomy (European Commission, 2021d). In order to ensure transparency, the issuer has to publish a Green Bond Framework stating the issuer's green bond strategy and alignment with EU taxonomy, as well as describing the green projects, methodology and reporting process. Furthermore, the standard calls for an annual allocation report and an impact report at least once at full allocation or annually (European Commission, 2021d). Additionally, all European green bonds have to be externally reviewed to ensure their compliance with the EUGBS. External reviewers need to be registered and supervised by the European Securities Markets Authority, in order to ensure service quality and reliability. The goal is to establish a new gold standard for green bonds that clearly defines a green investment and thereby addresses concerns of greenwashing and protects market integrity (European Commission, 2021d).

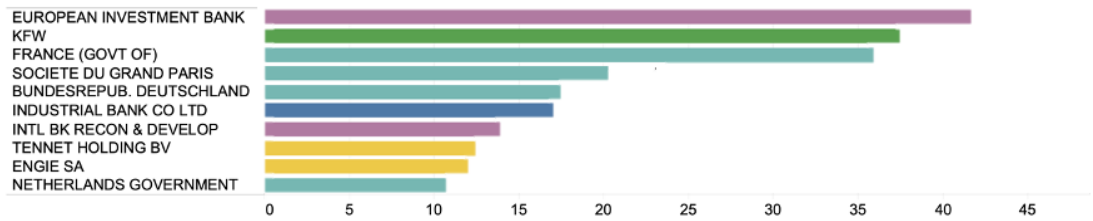
2.2 The Green Bond Market

2.2.1 Market Development

The first bond in the green investment universe was issued by the European Investment Bank (EIB) in July 2007, as a Climate Awareness Bond with an issue size of EUR 600 million, targeting renewable energy and energy efficiency (EIB, 2011). The first labelled green bond was issued by the World Bank in 2008 and the first corporate issue followed in 2013, by Sweden's largest property company Vasakronan and the Scandinavian Individual Bank (Deschryver & De Mariz, 2020). Thus, the green bond market is still very young, but has been growing rapidly, from an issuance volume of around EUR 39 billion in 2015 to EUR 252 billion in 2020 (Bundesbank, 2021). As of May 2021, the outstanding green bonds amount to around 0.8% of the total amount of bonds outstanding. Consequently, green bonds are still a relatively small part of the bond universe, but investor demand is strong and the market continues to expand.

Compared to conventional bonds, which have an average issuance volume of EUR 300 million, green bonds tend to be smaller, with a volume of EUR 225 million (Bundesbank, 2021). Furthermore, green bonds have on average a longer maturity, with an issuance weighted average of 12 years compared to conventional bond's average maturity of 10 years. This is in line with green bonds' goal to finance environmental and energy projects, which tend to be long-term investments (Flammer, 2020). Worldwide, the majority of green bonds is issued in Euros (49%) followed by US-Dollars (25%). The biggest issuers are from the public and financial sector, as well as energy providers. Figure 1 lists the biggest issuers according to total outstanding issuance volume, with the top five issuers being from the public sector.

Figure 1. Top issuers according to total outstanding issuance volume (€ bn)

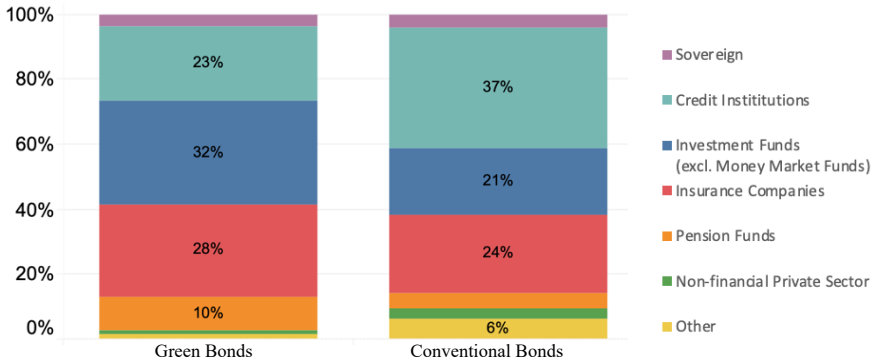


Source: Bundesbank (2021). Green Bond Monitor. Issuance volume is reported in EUR billion.

Among European issuers, the public sector is even more prominent, with top issuers being sovereigns, including agencies (Bundesbank, 2021). The biggest European investors are investment funds, insurance companies, credit institutions and pension funds, with most

investors located in France and Germany. As seen in figure 2, institutional investors tend to hold relatively more green than conventional bonds, which can be attributed to their long-term sustainable investment strategy and their active role in the green bond market development, as explained in section 2.2.2.

Figure 2. Distribution of bonds according to sectors 2020-Q4



Source: Bundesbank (2021). Green Bond Monitor. Issuance volume is reported in EUR billion.

Moreover, another important investor in the green bond market is the European Central Bank (ECB) through its purchasing programs. Bremus, Schütze and Zaklan (2021) find that the asset purchasing program (APP), as well as the pandemic emergency purchasing program (PEPP), have a significant positive effect on green corporate bond's financing conditions. The corporate sector purchasing program (CSPP), which is part of the APP, decreases the yield of eligible green bonds by 18 to 33 basis points (bps) compared to ineligible green bonds, which points out the strong effect of ECB's bond purchases in the green bond market. The PEPP also leads to a decreasing yield of up to 135 bps for eligible green bonds, however, the effect varies depending on issuer sector and currency (Bremus et al., 2021). Furthermore, the ECB will likely increase its investments in the green bond market, as they published their climate change action plan as part of the new monetary policy strategy in July 2021. The action plan states that climate change risks will be explicitly included in CSPP investment decisions (European Central Bank, 2021a). Consequently, even if the temporary PEPP program should be terminated at its earliest in March 2022 (European Central Bank, 2021b), the ECB's green bond purchases are likely to stay high or even increase through the APP, thereby continuing to improve financing conditions for green bond issuers.

2.2.2 Investor and Issuer Motivation

The rapid growth in the green bond market is driven by strong investor demand and growing interest from issuers to participate in the green bond market. In the following, the most prominent drivers for both, green bond investors and issuers, are discussed. From an investor

perspective, traditional financial theory would suggest that green bonds should either have a lower risk or a higher expected return compared to conventional bonds, in order to justify the high demand (Maltais & Nykvist, 2020). According to Deschryver and De Mariz (2020), a potentially higher return could be explained by a more sustainable, long-term financial strategy that is attributed to green bonds. However, they point out that green bonds should not differ in regards to financial risk compared to conventional bonds. Even though green bonds only finance certified green projects, they are not exposed to the green projects' specific risk. Instead, they have recourse to an issuer's full balance sheet and are thus exposed to the same firm-specific risk like conventional bonds, as explained in section 2.1.1. Consequently, fundamental risk factors such as default risk or a liquidity premium should be the same for green and conventional bonds as well (Löffler, Petreski & Stephan, 2021). Nevertheless, Preclaw and Bakshi (2015) argue that green bonds might demonstrate a less volatile behavior, because they particularly attract environmentally conscious, long-term investors. As those investors tend to follow a buy-and-hold strategy, the trading activity could be lower than for conventional bonds, leading to higher price stability.

Aside from potential risk or return benefits, green bonds can offer a diversification benefit to investors, as they tend to show a low correlation with other fixed-income securities (Inderst, Kaminker & Stewart, 2012). This is especially interesting for institutional investors, such as insurances and pensions funds. In fact, European pension funds have been among the first to participate in changing the industry's mindset towards a more sustainable focus, by incorporating climate risk impacts in their decision making and following the request from their shareholders, consumers and stakeholders to improve their portfolio's sustainability (Deschryver & De Mariz, 2020). Generally, for investors with an environmental mandate, such as sovereign wealth funds, investment banks, international organizations and governments, green bonds have become an important asset class (Hyun, Park & Tian, 2020). But, also corporates are interested in green bonds to signal their environmental focus (Deschryver & De Mariz, 2020).

Apart from financial motives, investors might be driven by their preferences to invest in green bonds. According to Ross (2015), churches, charities and environmentally conscious investors were among the first investors in the sustainability market, motivated by the goal to invest socially responsible. Moreover, Martin and Moser (2016) show that investors respond positively to green investment reports, independent of future cash flows, indicating

that investors value the societal benefit of green investments. Indeed, there are several recent studies which support the claim that investors value sustainability and are influenced by non-financial motives in their investment decision. Riedl and Smeets (2017) find that investors are influenced by social preferences and signaling when investing socially responsible, whilst Brodback, Guenster and Mezger (2019) detect a positive relationship between an investor's altruistic values and the decision to invest socially responsible. These findings are reinforced by Bauer, Ruof and Smeets (2021), who find social preferences to be the key driver for sustainable investments. Furthermore, Barber, Morse and Yasuda (2021) discover that investors derive non-financial utility from investing sustainably, even if they have to sacrifice returns.

Next to intrinsic motivation driven by social preferences, investor demand for green bonds can also be motivated by external factors, such as the introduction of regulations to redirect capital flows into sustainable investments. A prominent example is the introduction of the Sustainable Finance Disclosure Regulation, which entered into force in March 2021 (European Commission, 2019). The legislation establishes guidelines for the disclosure of sustainability risks and requires financial market participants, such as investment, pension and insurance funds, as well as financial advisors, to transparently integrate sustainability risk and possible adverse sustainability impacts into their processes (European Commission, 2019). Moreover, they have to provide sustainability-related information for their financial products. Due to the increased awareness regarding sustainability risks and the transparency to investors of any exposure to these risks, institutional investors and asset managers are motivated to improve their portfolios' and products' sustainability and thereby drive up demand for sustainable financial assets.

The high demand for sustainable investment products has created an attractive environment for companies to consider issuing green rather than conventional bonds for eligible projects. Benefits of issuing a green bond include signaling a company's corporate social responsibility policy (Li et al., 2020), as well as improving its environmental reputation (Bachelet, Becchetti & Manfredonia, 2019). Moreover, green bond issuance can both, strengthen the investor relationship and broaden the investor base. Flammer (2020) states that green issuers attract an increased amount of green and long-term investors, leading to a diversification of the investor base. Furthermore, Tang and Zhang (2020) find that increased investor attention can lead to improved stock liquidity. Strong investor demand for green

bonds can also decrease capital availability risk for green bond issuers, thereby improving access to capital, as well as often reducing the cost of capital (Maltais & Nykvist, 2020). In fact, green bond issuers are increasingly motivated by the potential existence of a "Greenium", a negative green bond premium, which offers an attractive pricing advantage compared to conventional bonds, as discussed in section 2.3. Overall, a company's green bond issuance is often used as part of an impact strategy or to boost a company's sustainability image (Deschryver & De Mariz, 2020).

2.2.3 Market Challenges

As the green bond market is still very young and developing, it faces several challenges for both, issuers and investors. Generally, the integrity of the market depends on a sound definition of a green bond, in order to avoid greenwashing and to earn investors' trust. The European Commission's development of a universal EU taxonomy and EU Green Bond Standard establishes a recognized certification system and improves transparency through mandatory reporting and supervision (European Commission, 2021d). However, the classification of green investments proves to be challenging, as depicted by the ongoing discussion on the inclusion of nuclear power and gas in the EU taxonomy. Whilst the CBI standard allows for investments in nuclear power generation and China defines even the manufacture of nuclear energy as eligible (OECD, 2021), the European Commission's technical expert group (TEG) on sustainable finance is still evaluating whether nuclear power and gas can be classified as a green investment under the EU taxonomy.

Furthermore, the EU taxonomy and EUGBS entail mandatory reporting, external reviews and an extensive certification process. This increases costs for issuers, which they might not be willing to bear, unless they can expect a pricing advantage compared to conventional bonds. Apart from issuance costs, Deschryver and De Mariz (2020) report the lack of internal capacity to manage the green bond process and the complex regulations regarding certification and reporting as the biggest barriers to green bond issuance. Additionally, issuers might face difficulties identifying eligible and large enough projects to finance, as they should have a critical size of at least USD 300 to 500 million to ensure liquidity and index inclusion (Cochu et al., 2016; Deschryver & De Mariz, 2020).

From an investor perspective, the green bond market is characterized by the lack of a standardized framework, as well as by limited supply and insufficient liquidity (Deschryver

& De Mariz, 2020). Furthermore, green bond investors face high information costs to assess a green bond's quality in order to avoid investing in greenwashing and risking their reputation. Investors need to review green bond frameworks and often rely on independent verifiers for additional information (Hyun et al., 2020). In order to reduce information costs, issuers tend to rely on a limited number of premium green bond issuers, excluding many green investment project opportunities. The resulting excess demand for premium issuers and green bonds with reliable certification reduces both, return and portfolio diversification for investors with a green or sustainable mandate (Hyun et al., 2020). Consequently, the introduction of an EU Taxonomy and EU Green Bond Standard will improve the green bond market conditions for investors and issuers, by reducing information and issuance costs through a universally accepted label and a standardized process.

2.3 The Green Bond Premium

2.3.1 Existence of a Greenium

Since the green bond market has been growing rapidly and investor interest is strong, the analysis of a potential price difference between green and conventional bonds has been gaining a lot of attention. As long as a green bond has the same characteristics as a conventional bond from the same issuer, and has been exposed to the same market conditions, there should be no significant pricing difference. However, 19 out of 33 green bonds that were issued in the second half of 2020 priced inside the yield curve, thus suggesting a consistently lower yield for green bonds (CBI, 2021). The negative green bond premium that investors might pay for green bonds in the primary or secondary market has been termed "Greenium". It means that investors are accepting a lower yield for green compared to conventional bonds, so that the price difference between a green and conventional bond is negative. An estimation of a potential Greenium has been proven to be difficult, as green and conventional bonds are rarely issued with the same characteristics. An exemption are the green German Federal Government bonds that are issued as twins, with the same maturity and coupon as conventional German Federal Government bonds. The first issuance, a 5-year green bond, had no premium in the primary market, whilst the 10-year and 30-year green bonds were issued with a green bond premium of -1 bps and -3 bps respectively (Deutsche Finanzagentur, 2021). All three bonds are trading at a negative green bond premium (Greenium) in the secondary market, as of 13.08.2021. The literature on green bond pricing differs in its approach to estimate the green bond premium and results vary from detecting a significant Greenium to finding a positive green bond premium. The

following section gives an overview of the green bond premium literature, summarizing different methodologies, estimations and underlying drivers affecting a potential Greenium.

One of the first papers on a potential green bond premium was by Preclaw and Bakshi (2015), who find a significant average green bond premium of around -17 bps, as well as that the Greenium appears to increase over time. Ehlers and Packer (2017), as well as Gianfrate and Peri (2019), derive a significant Greenium in the primary market with a similar magnitude of -18 bps. These estimations are supported by Löffler, Petreski and Stephan (2021), who find a Greenium of on average -15 to -20 bps in the primary and secondary market. Focusing on the US municipal bond market, Karpf and Mandel (2018) detect a positive premium for the time frame from 2010 to 2014 and a negative premium for 2015 and 2016, with an average premium of -23 bps, which further supports a potential Greenium increase over time. Additional research on the US municipal bonds differs greatly in methodology and respective results. Building on the research by Karpf and Mandel (2018), but additionally accounting for federal and state taxation, Baker, Bergstresser, Serafeim and Wurgler (2018) find a premium of -6 bps. In contrast, Larcker and Watts (2020) do not find any significant premium when comparing green US municipal bonds to nearly identical conventional ones and Partridge and Medda (2020), using a matching method, discover a premium of around -5 bps in the secondary market, but no significant Greenium in the primary market. Even beyond the US municipal bond market, several papers find no significant Greenium. For instance, Hachenberg and Schiereck (2018) find no significant Greenium, even though they detect a tendency for green bonds to trade tighter and Hyun et al. (2020) find no significant green bond premium, unless the green bond is certified.

2.3.2 Drivers of a Greenium

A potential Greenium not only appears to change over time, but the following results indicate that it also varies with issuer sector, currency and credit rating. Bachelet et al. (2019) match green and conventional bonds based on their characteristics, limiting their difference in regards to issue size, coupon rate and maturity date. Analyzing 89 matched bond couples over the time frame from January 2013 until December 2017, they show that green bonds from institutional issuers have a small significant Greenium (-0.9 to -1.87 bps), whilst private green bond issuers have a positive premium, which decreases in case the green bond is certified. Zerbib (2019) also uses a matching method to compare 110 matched bond couples from 2013 to 2017, detecting an average green bond premium of -1.76 bps. The Greenium

is higher in case it is a financial sector (-2.5 bps), AA-rated (-2.3 bps) or USD-denominated (-2.3 bps) green bond and is slightly lower for EUR-denominated green bonds (-1.7 bps).

Using an asset pricing model, Fatica, Panzica and Rancan (2021) also find varying significant Greenium estimates for supranational (-80 bps) and non-financial corporate issuers (-22 bps). Further estimates for corporate issuers vary from -21 bps (Gianfrate and Peri, 2019) to around -63 and -70 bps (Nanayakkara and Colombage, 2019; Wulandari, Schäfer, Stephan and Sun, 2018). Moreover, non-corporates tend to have a lower Greenium of on average -15 bps and the overall Greenium decreases in the secondary market to -5 bps (Gianfrate and Peri, 2019). Also studying both, primary and secondary markets, Kapraun, Latino, Scheins and Schlag (2021) find that green bonds trade on average at similar yields, but that (local) government and supranational issuers, as well as euro-denominated bonds, can have a significant Greenium compared to conventional bonds of around -5 to -18 bps.

With regards to issue size and maturity, Hachenberg and Schiereck (2018) find no significant influence on a potential premium, whilst Karpf and Mandel (2018) state that the spread between green and conventional bonds widens with maturity. Moreover, Wulandari et al. (2018) detect that liquidity affects the yield spread of green and conventional bonds, which is supported by the findings of Guntermann (2021) that the outstanding volume of green bonds is negatively related to their spread over conventional peers. A potential Greenium might therefore partly reflect a green bond's poorer liquidity conditions and might decrease in case the green bond's market liquidity improves. Apart from bond characteristics themselves, an external review or green bond certification can have a significant effect on the green bond premium (Bachelet et al., 2019). Hyun et al. (2020) state that a green bond with external review can expect a Greenium of -6 bps whilst a green bond with a Climate Bonds Initiative certificate can get a Greenium of up to -15 bps. Kapraun et al. (2021) also find an effect of green bond certification in the secondary market, more precisely a decrease of a negative green bond premium by -4 bps. Moreover, a high environmental rating of the green bond issuer has a similar effect of -7 to -9 bps. But, according to Fatica et al. (2021), an external review effect is also present in the primary market. The bond yield at issuance decreases by -44 bps in case of external verification and by -36 bps in case of a repeat green bond issuer. Overall, green bond certification and verification, as well as the green bond's characteristics such as issuer sector, credit rating and issue size appear to be important drivers of a potential Greenium.

3. Next Generation EU and the Green Bond Market

3.1 Next Generation EU - Theoretical Background

3.1.1 Next Generation EU Program

The Next Generation EU (NGEU) program is a recovery instrument with the aim to repair immediate economic and social damage caused by the coronavirus pandemic (European Commission, 2021b). The total budget of EUR 806.9 billion will be used to build a greener, more digital and more resilient Europe for potential upcoming challenges. The majority of the budget is attributed to the Recovery and Resilience Facility (RRF), which encompasses a total of EUR 723.8 billion. Part of the funds, EUR 338 billion are distributed as grants and are repaid through the EU budget, whilst the remaining EUR 385.8 billion are given out as loans and have to be repaid by the member states (European Commission, 2021b). Each member state receives their funding according to their developed national recovery and resilience plan, accompanied by the requirement to invest in line with the four core components of the RRF, which are promoting and strengthening the EU's economy, social cohesion, as well as a green and digital transformation (European Commission, 2021b). The remaining NGEU budget of EUR 83.1 billion is distributed to other programs such as REACT-EU, the Just Transition Fund and InvestEU, supporting the goal of a fast recovery after the pandemic and a sustainable transition.

3.1.2 Political Discussion regarding the NGEU Program

Apart from the NGEU program, which was developed as a recovery instrument and response to the coronavirus pandemic, the EU has its regular Multiannual Financial Framework (MFF) from 2021 to 2027, which amounts to EUR 1.211 trillion (European Commission, 2021b). The long-term EU budget, together with the NGEU program, sums to EUR 2.018 trillion and thereby becomes the largest stimulus package financed in Europe so far. The high volume has also raised some critical voices, especially in regards to the increase in EU expenditures. According to Art 310, 4 of the Treaty on Functioning of the European Union, public spending at the EU level is generally not supposed to be financed by debt (Fuest, 2021). Still, the EU has a history of borrowing on capital markets in times of crisis, such as the European Financial Stability Facility (EFSF), which was introduced as temporary support amid the European debt crisis in 2010 (European Commission, 2021e). Most recently, the EU introduced the Support to mitigate Unemployment Risks in an Emergency (SURE) program in May 2020. The instrument has a volume of EUR 100 billion and provides financial assistance to absorb the coronavirus pandemic's impact on the European

job market (European Commission, 2021f). However, the NGEU program of EUR 806.9 billion, which will be financed through debt issuance, is an unprecedented high volume of EU debt. Consequently, the European Commission (2021b) emphasizes that the recovery instrument is only temporary and member states had to agree to the exemption of high volume debt issuance, as well as to a strict repayment plan. Nevertheless, Dorn and Fuest (2021) point out that this exemption has the potential to signal a new direction towards an EU fiscal cooperation and lowers the threshold for a repetitive action in the next economic crisis.

The funds of the NGEU program are redistributed to member states based on an allocation key. Regarding grants, 70% are allocated based on a member state's population, GDP and unemployment measure, whilst 30% are allocated according to population, GDP and economic loss during the pandemic (European Council, 2020). Moreover, loans can be requested based on 2019 Gross National Income. The allocation key is criticized, as it redistributes primarily from member states with high GDP levels to member states with lower GDP levels. Fuest (2021) argues that the NGEU program is therefore an extension of the EU household, rather than targeting economic losses caused by the pandemic. Nevertheless, the recovery program signals solidarity, fosters investment in EU's cohesion and maintains economic stability through a positive effect on expectations. Additionally, the NGEU program offers the opportunity to push national governments towards political priorities, such as sustainable and digital investments (Dorn & Fuest, 2021). Especially in regards to green bonds, the member states are encouraged to increase their investment in eligible green projects. However, because money is fungible, it is difficult to track whether those green projects are initiated due to the NGEU funding or would have been implemented through national government financing regardless.

3.2 Next Generation EU Funding

3.2.1 A Diversified Funding Strategy

In order to finance the NGEU program, the European Commission, on behalf of the EU, borrows funds on international capital markets. Over the past 40 years, the European Commission has become a well-established market participant, having run several lending programs, such as the European Financial Stabilization Mechanism (European Commission, 2021a). Using a diversified funding strategy, the European Commission plans to raise up to EUR 806.9 billion from 2021 to 2027, with an expected annual borrowing volume of around

EUR 150 billion. Thereby, member states can profit from favorable loan terms, due to the EU's high credit rating, an AAA rating by Moody's (European Commission, 2021a). To protect the credit rating and to ensure that commitments can be delivered in the repayment period from 2028 to 2058, the EU increased its budget headroom, which is the difference between the EU's maximum rise of revenue through borrowing and the EU budget (European Commission, 2021b). The headroom is defined by the resource ceiling, which was consequently raised from previous 1.4% to 2%. Moreover, given the high volume, frequency and complexity of the borrowing plan, a new debt management policy was introduced, replicating large sovereign issuers' strategies (European Commission, 2021a). Previous lending programs were financed back-to-back with syndicated bond issuances. The European Commission now employs pool funding as well, will start using auctions as a funding technique in September 2021 and has already established a primary dealer network (European Commission, 2021f). Moreover, next to EU-Bonds, EU-Bills will be introduced in September 2021, giving the EU access to the short-term money market and thereby the opportunity to manage funding needs in a more flexible manner.

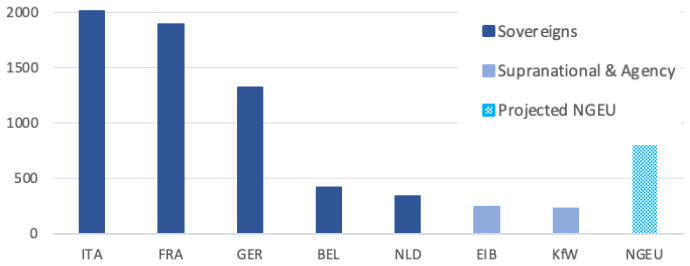
3.2.2 Next Generation EU Bonds

From a technical perspective, NGEU bonds are denominated in Euro and are issued in the European Economic Area. The issuer is the European Commission, a supranational issuer with an AAA rating (European Commission, 2021f). Consequently, NGEU bonds are marketable assets and eligible for the ECB's purchasing programs. NGEU bonds, both conventional and green, can be bought as part of the asset purchasing program (APP). As sovereign bonds, they are part of the public sector purchasing program (PSPP), which makes up 10% of the APP by definition (European Central Bank, 2021c). Furthermore, they can also be bought by the ECB as part of the pandemic emergency purchase program (PEPP), of which also around 10% are invested in the public sector (European Central Bank, 2021d).

In terms of annual issuance volume, the EU is likely to rank alongside the four largest European Government Bond (EGB) issuers Italy, France, Germany and Spain (Krautzberger, 2020). Their average gross issuance volume is around EUR 125 to 250 billion, whilst the EU will issue EUR 80 billion in 2021 and is expected to issue up to EUR 150 billion annually during the upcoming years (European Commission, 2021g). Moreover, the total issuance volume of the NGEU program will make the EU the third-largest top-rated issuer of euro-denominated bonds in the euro area within the next three to five years

(Cazzulani, Dax & Kreipl, 2020). As seen in figure 3, the total NGEU issuance volume of EUR 806.9 billion is larger than that of other supranational issuers, such as the EIB, and even surpasses mid-size sovereign issuers like the Netherlands and Belgium. Already in 2021, the EU will be the largest issuer of euro-denominated bonds in the primary supranational, sub-sovereign and agency (SSA) market, but will remain smaller than the top-rated sovereign issuers Germany and France (Cazzulani et al., 2020). Due to the high issuance volume, investors no longer see the EU as a classic SSA issuer, but not yet as a sovereign issuer either. According to an investor survey by Eichert, Tanguy and Harreau (2021), the crucial aspects for the EU to be considered as a sovereign issuer are volume, index eligibility and additional financial infrastructure, such as EU futures or a derivative market, whilst the temporary nature of the NGEU program is stated to be one of the main obstacles.

Figure 3. Total outstanding green bond volume (€ bn)



Source: Bloomberg (2021)

The EU has already issued EUR 45 billion under the NGEU program, split into three issuances. The first issuance was on June 15th 2021, with an issuance volume of EUR 20 billion and 5-year maturity (European Commission, 2021f). It was the largest ever issuance from a supranational issuer and the bond was more than seven times oversubscribed, demonstrating strong investor demand. The bond was especially targeted at institutional investors, which is reflected in the investor distribution, with the majority of investors being fund managers, central banks, official institutions and bank treasuries (see figure 4). The second issue consisted of a 5-year bond with EUR 9 billion issuance volume and a 30-year bond with EUR 6 billion issuance volume (European Commission, 2021f). Both bonds were highly oversubscribed and the investor distribution was comparable to the first issuance, apart from a higher interest from insurance and pension funds for the 30-year bond, as seen in figure 4. The most recent issuance on the 13th of July 2021was a 20-year bond

Figure 4. NGEU investor distribution by investor type

Type	NGEU	NGEU	NGEU	NGEU	SURE
Tenor	5-year	10-year	30-year	overall	overall
Issuance Date	29.06.2021	15.06.2021	29.06.2021	06/21	10/20 - 05-21
Fund Managers	33%	37%	41%	37%	40%
CB / Official Inst.	30%	23%	15%	23%	20%
Bank Treasuries	21%	25%	19%	23%	24%
Insurance / Pension Funds	10%	12%	18%	13%	9%
Banks	4%	2%	5%	3%	4%
Hedge Funds	2%	1%	2%	1%	2%
Total	100%	100%	100%	100%	100%

Source: Hermann, 2021b. LBBW Research, EU.

with EUR 10 billion issuance volume and almost 10-fold oversubscription (European Commission, 2021h).

Regarding individual bond size, the NGEU issuances so far surpass supranational issuers like the EIB, which has an average issuance volume of EUR 3.4 billion for its benchmark bonds (Hermann, 2021a). With an issuance range from EUR 5 billion to EUR 20 billion thus far, the EU is more comparable with sovereign issuers, however still behind the Bund with an average volume of EUR 17.6 billion for its benchmark bonds. In terms of pricing, all four issuances with 5-, 10-, 20- and 30-year maturities were priced attractively over the respective Bunds. The highest difference at issuance existed for the 20-year NGEU bond, which priced 53.1 bps above the 20-year Bund due in July 2040 (European Commission, 2021h). Overall, the European Commission's goal is to establish regular issuances to satisfy investor demand for all maturities on the EU yield curve and thereby create as liquid NGEU bonds as possible. Consequently, as mentioned above, the EU will also start using auctions to issue taps through their primary dealer network, which currently consists of 30 banks (Hermann, 2021a). The banks will place the NGEU bonds with their investors, thereby making the bonds more attractive and developing a more liquid secondary market trading of NGEU bonds.

3.2.3 Next Generation EU Green Bonds

As part of the NGEU program, the European Commission pledged to issue 30% or up to EUR 250 billion of the bonds as green bonds, which will make the EU the largest global issuer of green bonds as of now (Krautzberger, 2020). The motivation is to gain access to a wider range of investors, to boost the green bond market and to emphasize the European Commission's commitment to sustainable finance (European Commission, 2021a). The green bonds will be primarily relying on the ICMA Green Bond Principles, with the Green Bond Framework currently being reviewed by a second party opinion provider. The publication of the Green Bond Framework and the first green bond issuance are expected for autumn 2021.

The EU has already gained experience in the sustainability market through the issuance of social bonds in the course of the SURE program. As mentioned above, the temporary instrument aims to help EU member states mitigate the negative economic and social consequences of the pandemic and is equipped with a funding volume of up to EUR 100 billion (European Commission, 2021f). The funding relies solely on social bonds, which are

issued as back-to-back loans and compliant with the ICMA's Social Bond Principles. So far, the SURE program has been very successful. The first transaction of EUR 17 billion in October 2020 had total orders in excess of EUR 223 billion and over 500 investors submitting bids (Cazzulani et al., 2020). This underlines the strong investor demand for high-quality fixed-income assets in the sustainability market. As reported by the European Commission (2021f), the EU has already raised EUR 90 billion, with the majority of the investors being fund managers (40%), bank treasuries (24%), central banks and official institutions (20%), as well as insurances and pension funds (9%). Through the successful placement of the SURE social bonds, the EU not only re-positioned itself as a large and frequent issuer, but also gained trust as a prominent issuer in the ESG market. Moreover, the SURE program started the EU's transition towards its diversified funding strategy and helped built a new liquid EU yield curve. Consequently, the upcoming green bond issuances will benefit from both, the EU's experience in the ESG market, as well as the strong placement of the social bonds.

3.3 The Green Bond Market and Next Generation EU – Investor and Issuer Expectations

This section presents an overview of green bond market participant's expectations that goes beyond the factual assessment of the developments in the green bond market and the introduction of the Next Generation EU program. The following summary is based on interviews with a total of 15 ESG and green bond market experts from institutions that issue, analyze, rate or invest in green bonds, as seen in table 3.

Table 3. Overview of interview partners

Group	Interview Partner	Role
Rating Agency	ISS ESG	Green, Transition and Sustainability Bonds
	MSCI	ESG Research
Issuer	EIB	Head of Sustainability Funding
	KfW	Head of Funding
Bank	Commerzbank	Rates and Credit Research
	Crédit Agricole	Head of Covered Bond & SSA Research
	Deutsche Bank	ESG Corporate Bank
	HSBC	Chief Executive Officer HSBC Deutschland
	LBBW	SSA Debt Capital Markets
	Morgan Stanley	Head of ESG Structuring
	UniCredit	ESG Competence Center
Asset Manager	Acatis	Chief Executive Officer Acatis
	Bantleon	Fixed Income Portfoliomanagement
	Bayern Invest	Head of Public Affairs & Sustainability; Investment Strategy & ESG
	Pictet	Head of Group Regulatory Office

Note: A more detailed overview of interview partners and the interview questions can be found in the appendix, section 3.1.

3.3.1 The Green Bond Market

All interviewed experts share the opinion that the green bond market will grow in the upcoming years, driven by strong investor demand. Green bonds are now increasingly represented in performance benchmarks and even gain importance for non-green portfolios, thereby leaving the niche market. According to 50% of interviewed rating agencies and more than 30% of interviewed green bond investors, the recent issuances of green German Federal Government bonds have

encouraged green bond market growth and the NGEU green bond program is expected to support this development through a signaling effect for sovereign and corporate issuers. Moreover, particularly investors can benefit from a growing green bond market, as it allows for more diversified portfolios, as well as for a potential further increase in green investment mandates. However, there is currently still a big difference in the quality of green bonds, emphasizing the importance of a universal standard such as the EU taxonomy and an EU Green Bond Standard. Furthermore, almost 40% of interviewed rating agencies, asset managers and bank representatives expect sustainability as well as sustainability-linked bonds to gain importance in the upcoming years, expanding the sustainability market further.

3.3.2 Green Bond Demand

Green bond market growth is driven by strong investor demand, which has a variety of potential underlying drivers. According to almost 50% of interview partners, sustainable finance regulations, such as the Sustainable Finance Disclosure Regulation, are among the most influential drivers. Moreover, around 40% of interviewed rating agencies and investors agree that green bond issuers and investors are also strongly motivated by reputation considerations, as well as by an overall sustainable finance trend. Only 30% of interviewees think that environmental purpose and societal responsibility play a role for issuers and investors. However, it is pointed out by an interviewed banking representative, that this factor might become stronger due to a generational change in the upcoming years. With younger, more sustainability-conscious investors entering the market, there might be an even heavier shift towards sustainable investments. Further mentioned drivers for green bond investors are an increase in green mandates for asset managers, as well as the pressure for institutional investors to improve their portfolios' sustainability to acknowledge the thread of physical climate risks. Moreover, green bond issuers are said to be motivated by possible cheaper financing conditions, due to a negative green bond premium ("Greenium"), as well as by the opportunity to diversify their investor base. An interviewed asset manager states that a potential Greenium can be crucial for the decision to issue a green bond, as it makes up for the higher costs associated with a green bond issuance, such as reporting and external verification. Finally, two out of seven interviewed banking representatives mention the ECB's asset and pandemic emergency purchasing programs (APP and PEPP) as an additional driver of green bond market growth.

3.3.3 EU Taxonomy and EU Green Bond Standard

All interviewed experts agree that the adaptation of the EU taxonomy and EUGBS is an important next step for the sustainable finance framework. Currently, various market standards exist within Europe and internationally, differing in their definition of green. Interviewed asset managers and bank representatives think that the clear definition of green through technical screening criteria as part of the EU taxonomy is therefore not only beneficial for the European sustainability market, but can also foster an international definition of green. Consequently, the standards are crucial to avoid greenwashing and to increase credibility in the sustainable investment market. However, they are also challenging for market participants to implement. Interviewed issuers, as well as investors, point out that the EU taxonomy is very complex, requiring a lot of additional work and expenditures on, for example, verifications, as well as that the timeline for implementation is very ambitious. Furthermore, in regards to the current discussion on the inclusion of nuclear power and gas as green investments in the EU taxonomy, interviewed asset managers and bank representatives criticize that the taxonomy does not adequately address transformation risks and financing. In fact, more than 50% of interviewed banking representatives state that the inclusion of nuclear power could harm the green bond market's credibility and cause confusion among market participants, in terms of the green classification criteria. Moreover, interviewees argue that it cannot be excluded that nuclear power investments violate any of the EU taxonomy's "do not significant harm" criteria and that the inclusion of gas and nuclear power in the taxonomy would incentivize further investments into these technologies. However, interviewed asset managers and bank representatives also point out that nuclear power is an essential transformation technology, which is needed for the development of a sustainable economy. Consequently, it is suggested that the EU taxonomy should be extended, for example, by including a time limit for investments in transformation activities or, by adding a traffic light system for the classification of transformation activities as orange instead of green, which was proposed by the Platform on Sustainable Finance (2021).

3.3.4 Green Assets and Financial Risk

All interviewees agree that there is insufficient evidence yet, to confirm a lower risk exposure for green assets. However, almost 50% state that they would not attribute a lower risk to green bonds. Because green and conventional bonds have the same issuer and recourse to the full balance sheet, they should not differ in respect to liquidity and financial risk. Still, there is an active discussion on green mortgage loans and potentially lower capital

requirements. Two interviewed banking representatives state that a lower capital requirement for green houses' mortgages could be justified, because demand for sustainable and energy-efficient houses is likely to increase in the future, driven by environmentally conscious investors and, for instance, insulation or heating regulations. However, an interviewed asset manager points out the potential risk of unreasonable lower capital requirements for green assets, as in times of crisis, there might be insufficient capital buffers to compensate for actual default rates. This sentiment is shared by almost 50% of interviewed issuers, asset managers and bank representatives, which are unsure, what role sustainability should play in risk weighting. But even though interview partners differ in their expectations regarding a green asset's potentially lower risk, they agree on the importance of developing a more advanced risk assessment and evaluation process that adequately considers physical climate risks and sustainability considerations. Furthermore, they state that any regulation favoring green assets, for example in terms of a lower equity ratio, would redirect capital flows even more towards sustainable investments.

3.3.5 Existence of a Greenium

When asked about the existence of a negative green bond premium in the market, 80% of interviewed issuers and investors state that there is sufficient proof in favor of a Greenium. Estimates vary around a market average of -2 bps, but are said to be very volatile. For instance, an interviewed issuer and investor state that last year, Greenium estimates for the supranational bond market were around -5 to -7 bps and for the corporate bond market even passed the two-digit mark. However, this year, Greenium estimates decreased towards zero, except for the sovereign green bond market, as, for example, all three outstanding green German Federal Government bonds are currently trading at a Greenium in the secondary market of around -3 to -7 bps. In general, the twin issuance structure used by the German Federal Government to issue green bonds allows for a more precise estimation of a Greenium, which is otherwise difficult to assess. Furthermore, interviewed rating agencies state that even though the Greenium appears to be very volatile, most green bond issuers assume a small negative green bond premium for their issuances by now. This is supported by interviewed bank representatives, from whom 40% explain that they clearly communicate a potential pricing advantage of green bonds in form of a Greenium to bond issuers and that a potential Greenium is often seen as compensation by green bond issuers for their additional costs of certification and external reviews. Amid the evidence for a Greenium, the interview

partners agree that the variation in estimates is caused by various factors, as explained in the next section.

3.3.6 Drivers of a Greenium

According to interviewed issuers, asset managers and bank representatives, a potential Greenium can be attributed to a prevalent excess demand in the green bond market, which is reflected in high oversubscription rates for green bonds. This excess demand is for instance caused by an increase in green investor mandates, additional regulations and the ECB's asset and pandemic emergency purchase programs. Furthermore, a potential Greenium is likely higher for first time green bond issuers, as they offer a diversification benefit to green portfolio investors. But, also for existing green bond issuers, a potential Greenium can vary, as 60% of the interview partners argue that a potential Greenium can increase with an issuer's green credibility. An interviewed bank representative states that an issuer with a better sustainability strategy will likely have a higher Greenium in the long run, as investors value an issuer's credibility and impact of their sustainability strategy. Moreover, with the introduction of the EU taxonomy and EUGBS, the market will become more divided in terms of standard qualities, and a potential Greenium is expected to differ between high and low-quality standards. However, the issuance of a green bond should not increase an issuer's green credibility, because issuers usually issue both, green and conventional bonds, as pointed out by an interviewed asset manager. Finally, interviewed rating agencies, asset managers and bank representatives also view the market environment as an influential factor on a potential Greenium. For instance, an interviewed rating agency observed that green bonds were traded less in secondary markets amid the pandemic and subsequent market uncertainty from March 2020 until June 2020. According to almost 30% of interviewed bank representatives, the subsequent lower volatility of green bonds was caused by green bond investors' predominant buy-and-hold strategy, as well as by the general market demand for liquidity. However, the interview partners point out that the behavior of green bonds during a more severe and longer market downfall is yet to be tested.

3.3.7 The EU as an Issuer

All interviewed experts agree that the NGEU program leads to a more pronounced market presence of the EU, with an impressive issuance volume that is bigger than for most European government bond issuers. However, the fact that the NGEU program is only temporary, that the EU bonds are not part of the sovereign bond index, as well as the lack of

infrastructure, such as derivatives, futures or a repurchase market, are the main reasons why the EU is still considered a supranational issuer by 50% of the interview partners. Still, two out of seven interviewed bank representatives anticipate that the EU might continue issuing debt, even beyond the NGEU program. Consequently, with the introduction of auctions as part of a new funding strategy, as well as the potential of a more permanent bond program, the EU has advanced for the other 50% of interview partners, including issuers and investors, as an "Inbetweener", which is in line with findings by Eichert et al. (2021). Finally, interviewees were divided in their opinion whether the NGEU bonds have the potential to become the new European interest rate benchmark, or whether it is unable to replace the 10-year German government bond as a market benchmark.

3.3.8 EU Green Bonds and their Green Bond Market Influence

The expected high issuance volume of EU green bonds as part of the NGEU program will make the EU one of the largest green bond issuers. Interviewed asset managers and banking representatives argue that it will have a positive signaling effect for sovereign and corporate issuers to enter the green bond market and will thereby further intensify green bond market growth. However, they also state that the EU will face a higher complexity regarding reporting and certification in contrast to other supranational or corporate green bond issuers and that it will be a challenge to ensure transparency and alignment with the EU taxonomy. All interviewed market participants expect strong investor demand for the EU green bonds, as the EU is a reliable issuer, has a good credit quality and offers both high liquidity and additional diversification in regards to existing green bond issuers. In fact, both, the EU social and conventional bond issuances, under the SURE and NGEU program respectively, have been very successful. An interviewed banking representative pointed out that the EU social bond issuances resulted in decreased interest for other similar issuers, such as agency issuers from Benelux which are not as liquid as the EU or other EU programs, like the European Stability Mechanism (ESM). However, the impact decreased after some time. Moreover, an interviewed asset manager mentioned the successful issuances of the NGEU bonds so far, which offer a small yield premium over French and Austrian sovereigns, again due to their high liquidity and AAA rating. Still, the interview partner anticipates that the return will likely decrease over time to levels of other AAA rated issuers. Moreover, three out of eleven interviewees from the asset management and banking sector point out that the EU green bonds will not be interesting for every investor, even if they have a green mandate, as their portfolio focus might be limited to corporate green bonds.

In terms of the NGEU green bond issuances' effect on the excess demand in the green bond market, the interviewed experts agree that the excess demand in the green bond market will not vanish in the near future. Green investor mandates are growing and additional regulations are anticipated, for instance, the introduction of the Corporate Sustainability Reporting Directive, which would extend the scope of mandatory sustainability reports to 49,000 companies compared to currently 11,600 under the Non-Financial Disclosure Directive (European Commission, 2021i). Consequently, investor demand will grow more than supply, which, according to more than 60% of interviewed issuers and investors, will likely keep a potential greenium in place. Furthermore, the high volume of NGEU green bonds will not solve the liquidity problem, as the EU green bonds do not fit in every green investment fund, as some only invest in corporate green bonds. However, an interviewed asset manager anticipates that if demand and supply should be balanced at some point in the future, the greenium were to disappear.

3.3.9 Green Bond Market Challenges and Outlook

One of the most prominent challenges for interviewed rating agencies, asset managers and bank representatives is still the prevention of greenwashing. The adaptation of an EU taxonomy and EUGBS will create a more clear definition, however, the implementation of the taxonomy and standard itself is a challenge for investors, as well as issuers. The lack of data, especially from smaller companies, varying qualities of data and the additional costs are among the primary reasons. Another challenge for green bonds described by interviewed asset managers and bank representatives is the project-focused perspective instead of an issuer perspective, which can be a problem for both, issuers and investors. For instance, according to an interviewed bank representative, companies with smaller projects, which are less utility-focused, such as a consumer goods company, might have trouble defining eligible green projects with a magnitude and credibility compared to a utility company. Instead, sustainability-linked bonds might be a better option. Furthermore, green bond investments likely differ in their impact, but so far there is neither an assessment nor a definition of what investments are most efficient and impactful in terms of moving towards a more sustainable economy. An interviewed asset manager suggests that investments could be assessed in terms of their additional contribution to combating climate change, in order to prevent financing of already existing projects under a green label and to thereby prevent greenwashing. In this regard, also transition financing plays an important role, which,

according to more than 50% of interviewed asset managers and bank representatives, needs to gain attention.

Even though there are several challenges to be overcome, the outlook for the green bond market is seen as positive among all interview partners. The market will further increase in the upcoming years and green bond alignment with the EU taxonomy will likely become a market standard, especially for larger companies. The EUGBS also has great potential, but interviewed asset managers and bank representatives point out that the EU Commission needs to underline their commitment to the standard themselves, for instance as part of the NGEU green bond issuance. Furthermore, almost 50% of interviewed rating agencies, asset managers and bank representatives anticipate a bigger focus on sustainability-linked bonds in the future, as they offer additional product diversification, as well as a more issuer-focused sustainability perspective, in contrast to a green bond's project perspective. In terms of investor demand, the ECB's behavior is crucial, as a potential preferential treatment of green bond purchases would boost demand even further. Finally, interviewed bank representatives are interested to see how green bonds will perform in times of crisis, compared to conventional bonds, as well as whether the difference in green bond standards due to the adaptation of the EUGBS will lead to a pricing difference among green bonds.

4. Identifying a Greenium for the Next Generation EU Green Bonds

In the following section 4.1 and 4.2, the public green bond market is analyzed with respect to a potential Greenium over time, as well as the underlying drivers of a green bond premium, in order to formulate a well-founded expectation regarding a potential Greenium for the NGEU green bonds in section 4.3.

4.1 Data and Methodology

4.1.1 Matching Method: Comparing Green and Conventional Bonds

As explained in section 2.3, different approaches have been employed so far to estimate the green bond premium, a potential price difference between green and conventional bonds due to the green label. The perfect estimation method would be the comparison of two equivalent bonds, which only differ in terms of the green label, in order to eliminate any effect of a difference in credit or market risk (Bachelet et al., 2019). In fact, a comparable method is used for the issuance of the green German Federal Government securities and is termed a

twin issuance. Green securities are issued with the same characteristics as existing conventional securities, thereby creating twin bonds with identical coupons and maturity (Deutsche Finanzagentur, 2021). The bonds only differ in terms of issuance volume and in respect to the green label. Consequently, green and conventional bonds can be more easily compared and a potential green bond premium can be derived in a straightforward manner.

However, as twin issuances are still a new method and have only been used by the German Federal Government so far, another comparison method for green and conventional bonds in the public sector is needed. Instead of comparing two equivalent bonds, a green and conventional bond as similar as possible in terms of characteristics are matched. This approach has already been used in several papers, such as Hachenberg and Schiereck (2018), who use a matching method to estimate and analyze a potential green bond premium. They match green and conventional bonds based on their maturity. In case that no green and conventional bond with the same maturity can be found, they choose a conventional bond with slightly higher and lower maturity for each green bond. The two conventional bonds are then used to build a synthetic conventional bond through linear interpolation, which results in a match of one green and one synthetic conventional bond with the same maturity. Furthermore, Hachenberg and Schiereck (2018) restrict issuance volume to at least USD 150 million to ensure sufficient liquidity and only consider green and conventional matches that have the same issuer, credit rating, currency and bond structure.

Zerbib (2019) employs a similar matching method, but is more restrictive in terms of the matching criteria. For instance, the difference in maturity between a green and conventional bond cannot be larger than ± 2 years. Additionally, he accounts for a remaining difference in liquidity by defining thresholds for the difference in issue amount (± 400%) and issue date (± 6 years) between the paired green and conventional bonds. Apart from the more extensive matching criteria, Zerbib (2019) also uses interpolation to derive a synthetic conventional bond with the same maturity as the matched green bond. In contrast, Bachelet et al. (2019) employ a different matching method, as they only use linear interpolation in case that no conventional bond adheres to the threshold measures. Otherwise, they apply one-to-one matching of green and conventional bonds with the smallest maturity difference. Moreover, they use similar matching criteria to Zerbib (2019), but add a threshold for the difference in the coupon rate (± 0.25%).

In the following analysis, a matching method similar to Hachenberg and Schiereck (2018) and Zerbib (2019) is used. Apart from twin issuance green bonds, every selected green bond is matched with two conventional bonds, based on their maturity. The green and conventional bonds that are considered for matching have the same issuer, currency, credit rating and bond structure. First, for every green bond, two conventional bonds with the closest available maturity dates are chosen. Furthermore, the issuance dates of the matched conventional bonds need to lie before the green bond's issuance date, in order to allow for the longest possible timeline, such that the analysis of a potential green bond's premium runs from its issuance date until today. Once every green bond is matched with two conventional bonds, a synthetic conventional bond is derived through linear interpolation. In case that a green bond could only be matched with two conventional bonds with higher or two with lower maturity than the green bonds, extrapolation is used. To illustrate the derivation of a synthetic conventional bond, table 4 gives an example of a green French Republic Government bond with a maturity of 06/2039 and two conventional bonds from the same issuer with respective maturities of 10/2038 and 04/2041.

Table 4. Example of the matching method

Issuer	Type	Maturity	Yield
French Republic Government	Conventional	10/2038	y^{CB1}
French Republic Government	Green	06/2039	y^{GB}
French Republic Government	Conventional	04/2041	y^{CB2}

Source: EADB Overview (25.05.2021)

In the case at hand, the ask yield for a synthetic conventional bond ($\tilde{y}_{i,t}^{CB}$) is interpolated using the following equation:

$$(1)\ \tilde{y}_{i,t}^{CB} = y_{i,t}^{CB1} + \left(\frac{(y_{i,t}^{CB2} - y_{i,t}^{CB1})}{(2041{,}33 - 2038{,}83)} * (2039{,}5 - 2038{,}83) \right)$$

Overall, the applied matching method, using interpolation and in some cases extrapolation, removes any possible maturity bias between the matched green and conventional bonds. There is no threshold for maturity, issuance date or issuance size, in order to allow for a wider sample. Instead, any remaining liquidity difference between the matched green and conventional bonds will be eliminated through a liquidity control, which is further discussed in the next section.

4.1.2 Yield Difference and Liquidity Control

In order to estimate a potential green bond premium, the yield difference between a green and its matched synthetic conventional bond needs to be calculated. The yield difference for each green bond i to its matched synthetic conventional bond on day t is calculated by subtracting the conventional bond's ask yield from the green bond's ask yield, as seen in equation 2.

(2) $\Delta\tilde{y}_{i,t} = y_{i,t}^{GB} - \tilde{y}_{i,t}^{CB}$

As mentioned above, the estimated yield difference ($\Delta\tilde{y}_{i,t}$) can still be affected by liquidity differences between the matched green and synthetic conventional bonds, caused by, for example, remaining differences in issue size, issue date and unobservable characteristics. To correctly estimate a potential green bond premium, a liquidity control needs to be added, to account for any persisting liquidity differences. The relevant literature proposes several options for a liquidity proxy, which is to be included in the green bond premium estimation. Hotchkiss and Josova (2017) find that issue size and age are among the most important determinants of liquidity. However, as explained in section 4.1.4, the potential green bond premium is estimated using a within fixed-effect regression. Because any time-invariant variable, such as issuance size and age, are cancelled out in a within regression, they are not a feasible choice for a liquidity proxy. Consequently, any liquidity proxy used for the following estimation needs to be time-variant. Moreover, the fact that the green bond estimation uses low-frequency, daily, data instead of high-frequency, intra-day, data, should also be considered when choosing a liquidity proxy (Zerbib, 2019).

Comparing the quality of different liquidity proxies for low-frequency data, Fong, Holden and Trzcinka (2017) find closing percent quoted bid-ask spread to be the best liquidity estimate. In general, the bid-ask spread is difficult to use as a liquidity proxy due to insufficient data availability, especially for corporate bonds (Helwege, Huang & Wang, 2014). However, the focus on the green and conventional bond public sector, for which bid and ask prices are available on a daily basis, allows for the bid-ask spread to be chosen as a liquidity proxy. Therefore, the closing percent bid-ask spread (%) for each green and conventional bond i on day t is calculated based on Chung and Zhang (2014), as seen in equation 3.

(3) $Bid - Ask\ Spread_{i,t} = \frac{Bid\ Price_{i,t} - Ask\ Price_{i,t}}{Mid\ Price_{i,t}} * 100$; $Mid\ Price_{i,t} = \frac{Ask\ Price_{i,t} + Bid\ Price_{i,t}}{2}$

Subsequently, the individual bid-ask spreads for the synthetic conventional bonds are calculated in the same manner as the ask yield, using linear interpolation and in some cases extrapolation. The liquidity difference is estimated as the difference in bid-ask spreads for each matched green and synthetic conventional bond, subtracting the conventional bond's bid-ask spread from the green bond's bid-ask spread, as seen in equation 4.

(4) $\Delta\widetilde{BA}_{i,t} = BA_{i,t}^{GB} - \widetilde{BA}_{i,t}^{CB}$

Considering the distribution of the liquidity control, the derived liquidity difference ($\Delta\widetilde{BA}_{i,t}$) is centered around zero, with a median of 0.005% and a low standard deviation of 0.149% (table 5, appendix). This indicates that the matching method has been successful in significantly reducing the liquidity bias in matched bond pairs.

4.1.3 Data and Sample Selection

The sample of green and conventional bonds is selected based on the European Central Bank's Eligible Database (EADB) of currently outstanding bonds as of 25.05.2021. Furthermore, several restrictions are applied when selecting eligible bonds for the green bond premium estimation and analysis, as seen in table 6. In order to analyze and estimate a potential green bond premium in the public green bond sector, the sample of green and conventional bonds is restricted to euro-denominated, fixed coupon bonds that were issued by sovereigns, government agencies and government development banks, as well as by supranationals. Furthermore, the individual issue amount has to be at least EUR 500 million, in order to ensure sufficient liquidity (Deschryver & De Mariz, 2020). In order to apply the matching method and interpolation of a synthetic bond, as explained above, every issuer has to have issued at least one green and two conventional bonds. This does not apply to green and conventional bonds, which were issued as twins, such as the green German Federal Government Bond, because then no interpolation is needed. Moreover, green bonds need to be classified as such by the Bloomberg green bond label and can neither be additionally labelled as a social nor as a sustainability bond. The green Bloomberg label is assigned to bonds that have a 100%

Table 6. Restriction criteria

Selection Criteria	Definition
Issuers	Public Sector
Currency	€-denominated
Coupon	Fixed
Issuance Size	≥ € 500 million
Outstanding Bonds	min. 1 GB and 2 CBs*
Green Label	Bloomberg Label

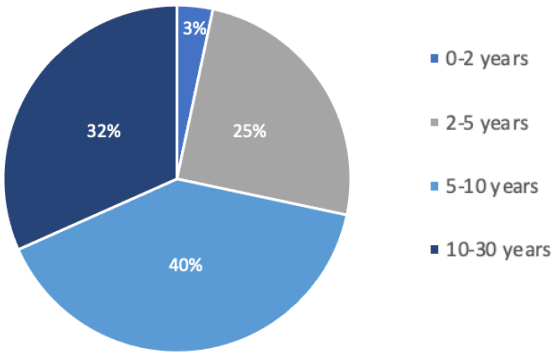
*unless twin issuance of a green and conventional bond

alignment with the Green Bond Principles, but it does not require additional reporting or an external review (ICMA, 2017).

For the following estimation and analysis of a green bond premium, ask price, bid price and ask yield for every green and conventional bond over time are needed. Bloomberg is used as a data source for both, daily pricing data from 10.09.2014 until 07.06.2021 and for fundamental bond-specific data such as maturity, issue date, issue size, modified duration, as well as S&P and Fitch credit ratings as of 23.06.2021. The period under investigation was chosen such as to allow for the longest observation possible when applying the selection criteria to all eligible and currently outstanding green bonds. Thus, the earliest issuance of an eligible and still outstanding green bond was on 10.09.2014. After applying the matching method, as described above, the sample consists of 60 eligible green and 60 matched synthetic conventional bonds, resulting in a 37,420 line unbalanced bond-day panel.

All bonds in the sample have the same bond structure, as they are senior, non-secured and non-covered bonds with fixed coupon rates. The issuers are all placed in Europe, with the majority, 59%, being credit agencies, 23% sovereigns and 18% supranational organizations. The green bond maturities are distributed over a range of up to 30 years, as seen in figure 5, with most of the bonds (40%) having a maturity of 5 to 10 years. The average green bond maturity is 9.98 years, which is slightly lower than the green bond market average of 12 years. In terms of rating, the majority of green bonds in the sample have a AAA rating or AA rating. Only one green bond has an AA- rating and only two green bonds each have an A and BBB rating respectively (table 7, appendix). Moreover, the sampled green bonds have an average issue size of EUR 2,464 million, which is larger than the green bond market average of EUR 225 million. This difference is caused by the applied restriction criteria (table 6) on issue size (> 500 million) and issuer sector (public), and is mostly driven by sovereign issuers with an average issue size of EUR 6,686 million, as seen in table 7 in the appendix. Overall, the sampled green bonds appear to be a well-balanced representation of the green bond market, given the restriction to public green bonds.

Figure 5. Green bonds' maturity distribution



Source: Bloomberg, 07.06.2021

4.1.4 Empirical Methodology

4.1.4.1 Estimating a Potential Green Bond Premium

After applying the matching method and controlling for any persisting liquidity difference, as explained above, the potentially remaining yield difference between a green and conventional bond should only be due to the green label and is therefore considered a green bond premium. Assuming that a potential green bond premium is bond-specific and time-invariant, it is defined as an individual fixed effect. Therefore, a within fixed-effect regression is used to estimate the green bond premium, as seen in equation 5:

(5) $\Delta\tilde{y}_{i,t} = G_i + ß * \Delta\widetilde{BA}_{i,t} + u_{i,t}$ i = 60 bond pairs ; t = 1,759 days

$\Delta\tilde{y}_{i,t}$ is the time-varying and bond-specific yield difference, G_i is the time-invariant, bond-specific green bond premium, $\Delta\widetilde{BA}_{i,t}$ is the time-varying, bond-specific liquidity difference, $\widehat{ß}$ describes the effect of the matched bonds' liquidity difference on the yield difference and $u_{i,t}$ is the error term. For a more detailed explanation of the fixed-effect regression method see section 3.2 in the appendix. Generally, a fixed-effect regression is used to analyze panel data by capturing the effect of time-variant variables, such as the liquidity difference's impact on the yield difference in equation 5, and filtering out any time-invariant heterogeneity, like a green bond's credit rating. Moreover, in contrast to a random effect regression, a within fixed-effect regression allows for the individual fixed effect, in this case the green bond premium (G_i), to be correlated with the included time-varying explanatory variables, in this case the liquidity difference ($\Delta\widetilde{BA}_{i,t}$). This assumption is crucial, as the literature suggests a relationship between a bond's liquidity difference and potential green bond premium. For example, Wulandari et al. (2018) find an effect of liquidity on the yield spread between green and conventional bonds. Furthermore, Guntermann (2021) suggests that a potential negative green bond premium is partly reflecting a green bond's poorer liquidity condition compared to its conventional peers.

As mentioned above, when running a within fixed-effect regression, any time-invariant variable is cancelled out. Consequently, the green bond premium (G_i) needs to be derived separately, after running the regression. The potential bond-specific green bond premia are calculated based on the estimated coefficient $\widehat{ß}$, as well as the individual yield and liquidity difference averages ($\overline{\Delta\tilde{y}_i}$; $\overline{\Delta\widetilde{BA}_i}$), as seen in equation 6:

(6) $\widehat{G}_i = \overline{\Delta\tilde{y}_i} - \widehat{ß} * \overline{\Delta\widetilde{BA}_i}$ i = 60 bond pairs

Using Stata for the empirical analysis, the command "ivreghdfe" based on Baum, Schaffer and Stillman (2020) and Correia (2017) runs the fixed-effect regression and estimates the green bond premium ($\widehat{G}_i$) in one run. As the sample consists of 60 matched bond pairs, running the within fixed-effect regression results in 60 individual, time-invariant green bond premium estimates ($\widehat{G}_i$). To ensure consistency and efficiency of the estimation, several tests are performed. The model is linear in its parameters $\Delta\tilde{y}_{i,t}$ and $\Delta\widetilde{BA}_{i,t}$ (figure 6 in the appendix) and a Woolridge test (Drukker, 2003) and Modified Wald test (Baum, 2001) are performed, to test for serial correlation and heteroskedasticity respectively. For both tests, the null hypothesis is rejected (table 8 and 9 in the appendix), demonstrating that serial correlation and heteroskedasticity are present in the panel data. Consequently, all estimations are run with White-robust standard errors (White, 1980; Hoechle, 2007), accounting for heteroskedasticity, as well as with Newey-West robust standard errors (Newey & West, 1987; Hoechle, 2007) to control for heteroskedasticity and serial correlation.

4.1.4.2 Drivers of a Potential Green Bond Premium

A potential green bond premium could be influenced by green bonds' differing characteristics such as issuer sector, issuer credit rating and modified duration. A linear regression model is used to analyze the relationship between different explanatory variables and the green bond premium estimates ($\widehat{G}_i$). The baseline model is as follows:

(7) $$\widehat{G}_i = a_i + sector_i + rating_i + asset\ type_i + \log(Amount\ Issued_i) + \log(Modified\ Duration_i) + v_i$$

A more detailed explanation and overview of all explanatory variables can be found in table 10 in the appendix. Again, to ensure consistency and efficiency of the estimates, several tests and adjustments are performed. For instance, the logarithm of issue amount and modified duration is used, in order to linearize the respective values (see figure 7 and 8 in the appendix). Moreover, to test for heteroskedasticity in cross-sectional data, a Breusch-Pagan and Cook-Weisberg test (Cook & Weisberg, 1983; Breusch & Pagan, 1979) is used. The null hypothesis of constant variance can be rejected (table 11, appendix), such that White-robust standard errors are used for the linear regression estimation. Finally, to test for multicollinearity among the independent variables, a variance inflation factor (VIF) test is used. With a mean VIF of 1.83, which is well below 10, multicollinearity is not a critical issue in the regression at hand (table 12, appendix).

4.2 Result Analysis

4.2.1 Green Bond Premium Estimates

Running the within fixed-effect regression with White-robust standard errors (table 13, (1)), a significant negative relation between liquidity difference and yield difference is found.

Table 13. Within fixed effect regression with individual fixed effect (G_i)

Dependant Variable: Yield Difference			
Fixed effect regression with White-robust standard errors			
	(1)	(2)	(3)
	FE Regression	FE Regression	FE Regression
Liquidity Difference	-0.014***	0.006	-0.014
	(0.004)	(0.004)	(0.011)
Observations	37,420	37,419	37,420
R^2	0.501	0.575	
Adjusted R^2	0.500	0.553	
F Statistic	11.887***	2.655	1.624
Number of Issuers	60	60	60
Individual FE	YES	YES	YES
Time FE		YES	
HAC-Robust SE BW(12)			YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note. Heteroskedasticity and autocorrelation-consistent (HAC) robust standard errors are used for the third regression. The bandwidth is calculated based on the Bartlett Kernel function and using the approximation: : $T^{\frac{1}{3}} = 1{,}759^{\frac{1}{3}} = 12.07 \approx 12$ (Greene, 2003, p.200).

If liquidity difference increases by 1 basis point, the respective yield difference decreases by 0.014 basis points. A possible explanation could be that, in case of a small liquidity difference between green and conventional bonds, most investors prefer the green bond, because they do not lose in terms of liquidity, but gain the benefits that come with a green label, for instance a positive effect on reputation. Consequently, demand for green bonds is very strong, relative to conventional bonds, leading to an increase in the yield difference. In contrast, if the liquidity difference between green and conventional bonds is high, with most likely the conventional bonds being more liquid, due to green bond investors predominantly following a buy-and-hold strategy (Preclaw & Bakshi 2015), the investor base will be more divided. Investors with a green mandate will still prefer the green bond, whilst traditional investors will probably prefer the conventional bonds, thus leading to a more balanced demand for both assets, and thereby to a decrease in yield difference. The estimated negative relation between liquidity and yield difference is in line with the statement by Guntermann (2021) that a green bond's outstanding volume is negatively related to its spread over conventional peers.

In order to control for any possible time variation and serial correlation, the regression is rerun with a time fixed effect (2) and Newey-West robust standard errors (3) respectively. Both adjustments result in an insignificant effect of liquidity difference on yield difference, as seen in table 13. In fact, when including a year or quarterly time dummy, as seen in table 14 and 15 in the appendix, the relation not only turns insignificant, but all time dummies are highly significant, indicating that a potential green bond premium might change over time. For the year dummy, the yield difference decreases more over the years, compared to the base group of 2014. The same observation can be made for the quarter dummy, with the highest decrease, compared to the 2014 Q3 base, in the year 2020 Q2. According to an interviewed rating agency, see section 3.3.6, this decline was likely caused by the pandemic market environment, which leads to green bonds being traded less in secondary markets from March 2020 until June 2020, thereby decreasing the yield difference between green and conventional bonds.

The distribution of the estimated 60 green bond premia shows a wide range of -13.8 bps to 12.6 bps (see table 16, appendix), with a mean of -0.3 bps. However, as seen in table 17, the mean Greenium is not significantly different from zero, indicating that no mean Greenium exists in the public green bond market from September 2014 until June 2021. Nevertheless, when grouping the mean green bond estimates according to issuer sector and credit rating, a significant Greenium of -1.8 bps for AAA rated green bonds and of -2.4 bps for supranational green bonds can be found. These estimates support the findings by Bachelet et al. (2019), who detect a Greenium for institutional issuers of around -0.9 bps to -1.87 bps, and Zerbib (2019), who finds an overall significant Greenium of -1.76 bps. Moreover, as seen in table 7 in the appendix, all supranational green bonds in the sample have a AAA rating. Consequently, the estimated significant Greenium of -2.4 bps is for AAA rated supranational green bonds, suggesting that being a supranational issuer increases a potential Greenium, as the AAA rated Greenium estimate over all sectors is lower (-1.8 bps). Furthermore, apart from the

Table 17. Green bond premium estimates

		Mean ($\widehat{G}_i$)	#GB
	Total	-0.003	60
Rating	AAA	-0.018***	25
	AA	0.012*	22
	AA-	0.004	1
	A	0.030	2
	A-	-0.019	8
	BBB	0.047	2
Sector	Agency	-0.001	35
	Sovereign	0.009	14
	Supranational	-0.024*	11
Asset Type	Bond	0.003	24
	Medium Term Note	-0.007	36

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note. Mean of green bond premium estimates grouped by rating, sector and asset type. T-test whether the mean estimate is significantly different from zero.

positive green bond premium for AA rated green bonds of 1.2 bps, all other mean green bond premium estimates grouped by ratings are not significantly different from zero. A possible explanation could be the few observation points, as, for example, only one bond in the sample has an AA- rating, as seen in table 17. Regarding mean green bond premium estimates grouped by sector, sovereign green bonds appear to have a small positive mean green bond premium, whilst the agency mean green bond estimate is around zero. However, both mean estimates, as well as the mean estimates grouped by asset type, are not significantly different from zero. Overall, there appears to be a varying effect of issuer rating and sector on a potential green bond premium, which is further analyzed in the next section.

4.2.2 Green Bond Premium Drivers

Constructing the linear regression to analyze the drivers of a green bond premium, issuer sector and issuer credit rating seem to be crucial explanatory variables, as seen above. Furthermore, as seen in table 18 in the appendix, the baseline specification (1) includes asset type, as well as the logarithm of issue amount and modified duration. The baseline regression is rerun for the second specification (2), including an outlier control for issue amount and modified duration. In the third specification (3), asset type and the logarithm of modified duration are dropped, due to insignificance, whilst in the third specification (4) an interaction term of Rating x Sector is added and the logarithm of issue size is dropped. In the final regression (5), only the interaction term Rating x Sector is included to capture the cross effects, as a lot of interaction terms are dropped in the third specification due to collinearity.

As seen in table 18 (1) in the appendix, only the coefficients capturing the effect of credit rating on the green bond premia are significant. Green bonds with the rating A-, AA- and AAA have a significantly lower green bond premium compared to the baseline group of green bonds with an AA rating. The negative effect on a green bond premium is the largest for green bonds with A- rating (-4.6 bps), followed by AAA rating (-2.8 bps) and AA- rating (-2.4 bps), compared to the baseline of AA rating, ceteris paribus. The effect for A and BBB rated bonds is positive, indicating that their green bond premia are higher compared to AA rated bonds, however, the coefficients are not significant. Moreover, sovereign green bonds appear to have a higher green bond premium than agency bonds, whilst supranational bonds indicate to have a slightly lower green bond premium, supporting the findings based on the mean green bond premium estimates. However, both coefficients are insignificant, as well as the coefficients for asset type, issue amount and modified duration. The coefficients'

significance does not change in the case of an outlier control for issue amount and modified duration, as seen in column (2) in table 18 in the appendix.

Furthermore, the significance of estimates does not change for the third specification (3) and the significant effects of credit rating only decrease slightly in their magnitude, as seen in table 18 in the appendix. When adding the interaction term Rating x Sector in the third specification (4), the interaction coefficients are insignificant, but the coefficient of being a sovereign issuer turns significant, such that being a sovereign green bond issuer instead of an agency green bond issuer increases the green bond premium by 2 bps, ceteris paribus. Finally, the regression is rerun (5) only including the interaction term Rating x Sector to capture the cross effects. The subsequent results support earlier findings that the level of green bond premia varies with credit rating and issuer sector. In fact, if an agency bond has an AAA rating, the green bond premium is lower by -2.4 bps compared to the base group of an agency bond with AA rating, ceteris paribus. Moreover, if the green bond not only has an AAA rating, but is also issued by a supranational entity, the effect increases to -3.3 bps compared to the baseline group, ceteris paribus. To conclude, the results of the regression analysis suggest a significant effect of credit rating and issuer sector on a green bond premium, whilst asset type, issue amount and modified duration do not significantly impact the green bond premium. These results support findings by Bachelet et al. (2019), Fatica et al. (2021) and Kapraun et al. (2021), that a potential Greenium is significantly higher for supranational and institutional issuers, as well as that a green bond premium varies with rating (Zerbib, 2019), and that issue size and maturity have no significant influence on a green bond premium (Hachenberg & Schiereck, 2018).

4.2.3 Monthly Green Bond Premium Estimates

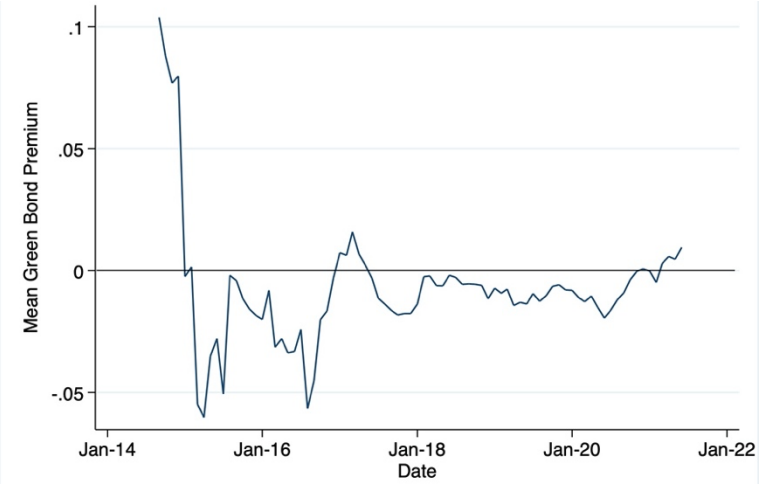
As the within-fixed effect regression results in table 13 suggest, the green bond premium is not only individual-specific, but also changes over time. Consequently, the within fixed effect regression is rerun on a monthly basis, estimating the bond-specific individual fixed effects (G_i) for each month (m) separately, as seen in equation 8 and 9, resulting in 1,801 monthly green bond premium estimates.

(8) For each month (m): $\Delta\tilde{y}_{i,t} = G_i + ß * \Delta\widetilde{BA}_{i,t}$ i=60 bond pairs; t=1,795 days; m=82

(9) $\hat{G}_{i,m} = \Delta\bar{y}_{i,m} - \widehat{ß_m} * \Delta\overline{BA}_{i,m}$ i=60 bond pairs; t=1,795 days

The distribution of the monthly green bond premia has a range of -31.9 bps to 47.6 bps (table 19, appendix). Plotting the monthly mean of the estimated green bond premia over time (figure 9), the majority of green bond premium estimates appear to be negative, suggesting a potential Greenium. Furthermore, the green bond premium is very volatile during the first three observation years (2014-2017), but appears to have stabilized since the beginning of 2018, indicating that the green bond market is maturing and that demand is growing more consistently. In December 2016, the mean green bond premium turns briefly positive, driven by the first sovereign green bond, which was issued by Poland with a positive green bond premium of 4.3 bps. Subsequently, the mean monthly green bond premium turned negative again in June 2017 and stabilized, until it started increasing rapidly in March 2020.

Figure 9. Mean green bond premium over time

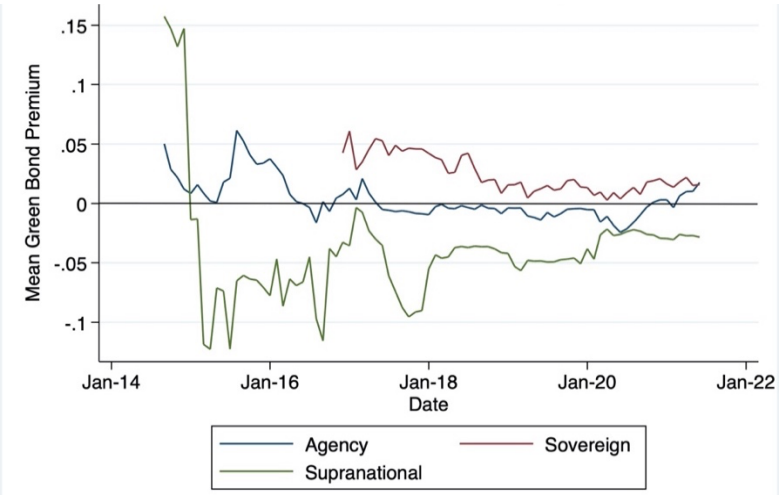


Note. Plot of mean monthly green bond premium estimates over sampled time frame 09/ 2014 until 06/ 2021.

The sharp increase from March 2020 onwards could be due to the economic downfall caused by the pandemic, during which green bonds were traded significantly less (Fatica & Panzica, 2021). A possible explanation is that established green bond investors follow predominantly a buy-and-hold strategy (Preclaw & Bakshi 2015), whilst potentially new green bond investors prefer conventional bonds in times of crisis, because they look for high liquidity (Byrne et al., 2020). This could have decreased investor demand for green bonds, thereby leading to a sharp increase in the mean monthly green bond premium, as seen in figure 9. When looking at the bond level for another potential driver of the sharp increase in the mean green bond premium, a green bond with unusually high volatility in its green bond premium estimates is found (see figure 10, appendix). Once the particular green bond observations are excluded from the sample, the mean green bond premium still depicts a sharp increase starting March 2020, but has stabilized since March 2021 around zero (see figure 11, appendix).

Differentiating between issuer sectors, the estimated monthly green bond premia are consistently more negative for supranational issuers, whilst sovereign issuers register only positive green bond premia, as seen in figure 12. Moreover, agency green bonds appear to have a green bond premium close to zero. Among the first issuers in the green bond market were the EIB (supranational) and KfW (agency). The earliest data points in the sample are from the EIB green bond with maturity 2026 and AFD (agency) green bond with maturity 2024, which were both issued in September 2014. The first sovereign issuance was by Poland in December 2016, as mentioned above.

Figure 12. Mean green bond premium by sector over time



Note. Plot of the mean monthly green bond premium estimates over time, grouped by issuer sector.

Again, the mean green bond premium was more volatile for the respective sectors in the earlier years of the green bond market and has stabilized since early 2018. During the economic downturn by the pandemic, sovereign and supranational green bond premia appear to have stayed fairly stable, whilst the green bond premium for agencies turned positive. However, when excluding the observations from the green bond with abnormally high volatility (see figure 10, appendix), as explained above, the mean agency green bond premium also stays more stable during the pandemic, only increases slightly and levels off at around zero (see figure 13, appendix). Finally, a plot of the mean green bond premia grouped according to credit rating suggests that AAA rated and A- rated green bonds have a significant Greenium over time (see figure 14, appendix).

When calculating the mean across all green bonds and the whole time series, a significant negative green bond premium of -0.7 bps is detected, supporting the existence of a Greenium in the public green bond market (table 20, appendix). Looking at the calculated monthly

green bond premia means, the highest significant Greenium can still be found for AAA rated green bonds (-2.6 bps) and supranational green bonds (-3.8 bps), supporting the previous results and expectations based on the graphs. Moreover, A- rated green bonds (-1.1 bps) and agency green bonds (-0.3 bps) also have a significant mean Greenium over time, as well as medium-term note green bonds (-1.6 bps) (see table 19, appendix). The effect of asset type on a green bond premium could be explained by the fact that MTNs are usually issued as part of a program that allows the issuer to offer several MTNs over a time period. In fact, seven out of nine issuers that offer green MTNs in the sample at hand are repetitive green bond issuers. Moreover, Fatica et al. (2021) find that investors prefer repetitive green bond issuers, because it reduces information costs and the risk of greenwashing. The subsequently higher demand could explain a significant mean Greenium over time. Overall, the monthly green bond premium estimates detect a significant Greenium in the public green bond market and confirm the previous results that issuer sector and credit rating significantly influence a green bond premium, as well as that AAA rated and supranational green bonds record the highest significant Greenium over time.

4.3 A Greenium for the Next Generation EU Green Bonds

In order to formulate a well-founded expectation for a potential Greenium for the NGEU green bonds, the public green bond market regression estimates, as well as the first NGEU bond issuances and green bond market expert insights are evaluated in the following section. First, the regression results confirm the existence of a small significant mean Greenium over time (-0.7 bps) in the public green bond market. Moreover, the significant mean Greenium over time increases to -3.8 bps for supranational green bond issuers with AAA rating, such as the EU. When limiting the observation time to January 2021 until June 2021, to derive a mean green bond premium for the past six months, the estimated mean Greenium for supranational AAA rated green bonds decreases to -2.8 bps. Consequently, the regression results support a potential Greenium of -3 bps to -4 bps for the NGEU green bonds.

Furthermore, the interviewed green bond market experts anticipate a high demand for the NGEU green bonds, as the EU is an attractive issuer with an AAA credit rating and high liquidity. Moreover, as explained in section 3.3, the EU as a first time green bond issuer offers a diversification benefit to green bond investors, which will likely amplify demand. Additionally, high demand for the EU green bonds will be driven by the European Central Bank's purchasing programs, APP and PEPP. As stated in section 2.2.1, the CSPP can

decrease the yield of an eligible corporate green bond by 18 to 33 bps compared to an ineligible green bond. The effect will likely be smaller for the public green bond market, as the APP and PEPP both have only 10% invested in the public sector, as of now, but it emphasizes the possible strong effect of the ECB's bond purchases on a potential Greenium. Consequently, even though the green bond issuance will have a total volume of up to EUR 250 billion, the interviewed experts agree that excess demand, and thereby a potential Greenium in the green bond market, will persist. Regarding the existence of a Greenium, 80% of interviewed issuers and investors consider the green German Federal Government bond twin issuances as a sound confirmation. The green bonds were issued in the primary market with a significant Greenium of up to -3 bps and are trading in the secondary market as of 13.08.2021 with a Greenium of -4 bps to -7 bps (see appendix, table 21). These estimates further support an existing Greenium in the green bond public market, as well as that a potential Greenium is likely to increase in the secondary market.

So far, the EU has already issued four NGEU bonds with 5-year to 30-year maturities. Investor demand was very high for all issuances, with the most recent issuance of a 20-year bond with EUR 10 billion issuance volume in July 2021 being almost 10 times oversubscribed (European Commission, 2021h). Moreover, the EU has already gained experience in the sustainability market through the issuance of social bonds with a total volume of EUR 90 billion for the SURE program, as mentioned in section 3.2.3. The social bond issuances recorded equally high investor demand, as the first transaction in October 2020 had excess orders of EUR 230 billion (Cazzulani et al., 2020). Due to the fact that social bonds are similar to green bonds in terms of the restricted use of proceeds, as explained in section 2.1.1, they offer an opportunity to compare issued EU social bonds and NGEU bonds with the same maturities, as seen in table 22 in the appendix. Comparing the re-offer yield and the yield as of 13.08.2021, a negative yield difference between EU social bonds and NGEU bonds is found. In the primary market, social bonds were priced with a lower yield of -15.3 bps to -41.5 bps and in the secondary market from -1.2 bps to -4.3 bps. These results suggest a potential pricing advantage for green bonds, thereby supporting a potential Greenium for the NGEU green bonds.

Overall, the evaluated arguments and results confirm the expectation of a Greenium for the NGEU green bonds of up to -4 bps, with the potential to further increase in the secondary market.

5. Conclusion

The green bond market has been growing rapidly in recent years and all interviewed green bond experts anticipate green bond market growth to amplify, driven by strong investor demand and growing interest from issuers. Green bond investors are primarily motivated by an increase in green mandates, more extensive disclosure regulations and a potential diversification benefit. In contrast, green bond issuers are driven by the opportunity to broaden their investor base and to receive potentially cheaper financing due to a Greenium. Moreover, green bond market growth is supported by an overall sustainability investment trend and a heightened bond demand caused by the ECB's purchasing programs.

With the adaptation of the EU taxonomy and EU green bond standard, the green bond market will become more transparent, thereby avoiding greenwashing and increasing investor trust and confidence in the green bond market. However, according to interviewed experts, the EU taxonomy and EUGBS are also currently one of the biggest challenges for the green bond market, as they are very complex and market participants are confronted with the lack of necessary data and a costly implementation process. Further challenges include a necessary decision on the potential inclusion of nuclear power and gas in the EU taxonomy, as well as a discussion on the classification and financing of transformation technologies. Moreover, interviewed experts point out the importance of more advanced risk assessment and evaluation processes to appropriately account for climate risks and to assess a potentially lower risk for green assets. Concerning the future of the sustainability market, interviewed experts anticipate that sustainability-linked bonds will receive growing attention, as they offer a more issuer-focused sustainable investment perspective, in contrast to green bonds.

The high volume green bond issuance of up to EUR 250 billion under the NGEU program will likely intensify green bond market growth by signaling to sovereign and corporate issuers to enter the green bond market. Furthermore, due to the high total NGEU issuance volume of EUR 806.9 billion and the anticipation that the EU might continue with its debt issuances even beyond the NGEU program, interviewed experts no longer see the EU as a classical supranational issuer. However, because of the lack of financial infrastructure, as well as the current temporary nature of the NGEU program, the EU is also not considered a sovereign issuer, but rather an "inbetween" issuer. In regards to the NGEU green bond issuances, one of the biggest challenges will be to ensure transparency and alignment with the EU taxonomy, but a successful implementation will be rewarded by strong investor

demand. As mentioned above, the high demand for NGEU green bonds will be driven by the EU's high liquidity, AAA credit rating and the diversification benefit to green bond investors. Consequently, interviewed experts anticipate that the high NGEU green bond issuance volume will not be able to satisfy increasing demand, thereby leading to a persisting excess demand in the public green bond market and keeping a potential Greenium in place.

In order to formulate an expectation regarding a potential Greenium for the NGEU green bonds, an in-depth quantitative analysis of a green bond premium in the public green bond market from September 2014 until June 2021 is performed. Based on a matching method of green and conventional bonds, and a within-fixed effect regression with a liquidity control, a mean significant Greenium of -0.7 bps is estimated for the public green bond markets. This is in line with the existing literature on a potential Greenium, however, estimates are higher when analyzing the whole, instead of the public, green bond market, ranging from -1.76 bps (Zerbib, 2019) up to -18 bps (Preclaw & Bakshi, 2015; Ehlers & Packer, 2017; Gianfrate & Peri, 2019). Furthermore, interviewed experts support the existence of a Greenium, assuming a market average of -1 bps to -2 bps, but pointing out the high volatility and challenging accurate estimation. The green German Federal Government bond twin issuances provide additional evidence for a Greenium, which ranges from 0 to -3 bps in the primary market and from -4 bps to -7 bps in the secondary market. Overall, it can be concluded that a significant Greenium exists in the public green bond market.

The results of the linear regression, which was performed to understand the underlying drivers that might influence a Greenium, show that issuer sector and credit rating have a significant influence on the green bond premia. In contrast, asset type, issue size and modified duration do not have any significant effect. These findings support the existing literature, which states that a Greenium varies with issuer sector and credit rating (Gianfrate & Peri, 2019; Kapraun et al., 2021; Zerbib, 2019; Bachelet et al., 2019), as well as that issue size and maturity have no significant influence (Hachenberg & Schiereck, 2018). Furthermore, grouping the mean green bond estimates according to issuer sector and credit rating, a mean significant Greenium for supranational issuers and green bonds with A- or AAA rating is found. In fact, the mean significant Greenium over time for supranational issuers with AAA rating, such as the EU, is estimated to be -3.8 bps. Consequently, based on an in-depth evaluation in section 4.3, a Greenium of up to -4 bps is expected for the NGEU bonds, with the potential to increase in the secondary market.

To conclude, the findings of this paper support the existence of a Greenium in the public green bond sector and offer an improved understanding of the underlying drivers that influence a potential Greenium. The insights into the green bond market's potential and challenges based on interviews with 15 green bond market experts offer relevant guidance for policymakers in regards to necessary support for the implementation of the EU taxonomy and EUGBS, as well as for a fundamental discussion on transformation technologies, as demanded by interviewed experts. Finally, the results emphasize the green bond market participants' support for the NGEU green bond program and subsequently provide a positive signal to policymakers for future programs in the sustainability market.

Limitations of this study in regards to the Greenium estimation include the varying time series length for sovereign, agency and supranational issuers. Supranational issuers have been active in the green bond market since 2007, whilst sovereign issuers have entered in December 2016, thereby leading to different levels of market maturity and green bond issuances. Moreover, a limited number of public green bond issuers could not be included in the sample, as their issuance sizes are too small or no comparable bonds for the matching method are available, emphasizing that the public green bond market is still very young and developing.

Future research in regards to the green bond market could focus on the effect of green credibility on a green bond premium. Literature in this field has so far been concentrating on the assessment of external review and repetitive issuance as drivers of green credibility (Huyn et al., 2020; Fatica et al., 2021), but an issuer's green reputation is likely to have a crucial impact as well (Kapraun et al., 2021). Furthermore, green bonds can not only differ in terms of the issuer's green credibility, but also in respect to the green bond's environmental impact. Consequently, a green bond premium might be influenced by the green investment's environmental impact, especially once the EU taxonomy improves the transparency and comparability of green bonds. Moreover, the performance of green bonds compared to conventional bonds in times of crisis is still to be evaluated. Finally, the growing sustainability market in terms of social and sustainability-linked bonds offers the opportunity to widen the market analysis to further sustainable finance instruments, thereby improving policy recommendations. To conclude, the field of sustainable finance and, in particular, green bonds offers promising potential for future research and advanced policy proposals.

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Appendix

1. List of Tables

Table 1. Example of eligible investment categories

Environmental objectives					
GBP-project categories	**Climate change mitigation**	**Climate change adaptation**	**Biodiversity**	**Natural resource conservation**	**Pollution prevention and control**
Renewable energy	●●●			●	●
Energy efficiency	●●●				●
Pollution prevention and control				●	●●●
Environmentally sustainable management of living natural resources and land use	●	●●	●●●	●●●	
Terrestrial and aquatic biodiversity conservation		●	●●●	●●●	
Clean transportation	●●●			●	●●●
Sustainable water and wastewater management		●●	●●	●●	●●●
Climate change adaptation		●●●			
Eco-efficient and/or circular economy adapted products, production technologies and processes	●●		●	●●●	●
Green buildings	●●●	●		●●●	●

Contribution to objective:

primary ●●● secondary ●● tertiary ●

Source: ICMA (2019). Mapping of the GBP-project categories to environmental objectives, accessed 4 August 2021.

Table 2. Example of a reporting template for a GBP-project category

Sustainable Water and Wastewater Management

Illustrative Summary Template for Project-by-Project Report:

Sustainable Water Management Projects	Signed Amount a/	Share of Total Project Financing b/	Eligibility for green bonds	Sustainable Water Management component	Allocated Amount c/	Project lifetime d/	#1) Annual absolute (gross) water savings e/		Other Indicators
Project name f/	currency	%	% of signed amount	% of signed amount	currency	in years	in m³/a	in %	~ No. of people with access to clean drinking water (or volume of clean drinking water in m³/a) through infrastructure supporting sustainable and efficient water use ~ Number of people, or enterprises benefitting from measures to mitigate the consequences of floods etc.
e.g. Project 1	XX	XX	XX	XX	XX	XX	XX	XX	

Wastewater Treatment Projects	Signed Amount a/	Share of Total Project Financing b/	Eligibility for green bonds	Sustainable Wastewater Management Component	Allocated Amount c/	Project lifetime d/	#2) Annual absolute (gross) amount of wastewater treated, reused or avoided e/			#3) i) Annual absolute (gross) amount of raw/ untreated sewage sludge that is treated and disposed of e/		#3) ii) Annual absolute (gross) amount of sludge that is reused e/		Other Indicators
Project name f/	currency	%	% of signed amount	% of signed amount	currency	in years	in m³/a	in p.e./a	in %	in tonnes of dry solids p.a.	in %	in tonnes of dry solids p.a.	in %	~ No. of people with access to improved sanitation facilities
e.g. Project 2	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	

Note. Example of a reporting template for the GBP-project category "Sustainable water and wastewater management". Reporting is also possible on portfolio level, with respective templates available. Source: ICMA (2021d). Harmonized framework for impact reporting, accessed 4 August 2021.

Table 5. Distribution of liquidity difference

Liquidity Difference (%)						
Min	**1 st Quart.**	**Median**	**Mean**	**3 rd Quart.**	**Max**	**SD**
-1.151	-0.039	0.005	-0.000	0.037	1.019	0.149

Note. Distribution of the calculated liquidity difference ($\Delta\widetilde{BA}_{i,t}$) based on the full sample of matched green and conventional bonds. Data source: Bloomberg, 23.06.2021.

Table 7. Summary statistics of the green bond sample

	Amount Issued (€mn)	Modified Duration (Years)	Rating					
			AAA	AA	AA-	A	A-	BBB
Agency	1,121	7.308	10	19		2	4	
Sovereign	6,686	13.214	4	3	1		4	2
Supranational	1,364	10.737	11					
Total	2,464	9.315	25	22	1	2	8	2

Note. Average amount issued and modified duration for each sector, as well as the distribution of credit ratings among the issuer sectors. Data source: Bloomberg, 23.06.2021.

Table 8. Fixed effect regression: test for heteroskedasticity

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model
H0: no heteroskedasticity
chi2 (60) = 2.8e+07
Prob>chi2 = 0.0000

Note. Null hypotheses of no heteroskedasticity can be rejected.

Table 9. Fixed effect regression: test for serial correlation

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
F(1, 59) = 134.965
Prob > F = 0.0000

Note. Null hypotheses of no serial correlation can be rejected.

Table 10. Overview of explanatory variables

Variables	Type	Unit	Description
Sector	Qualitative		Issuer sectors: agency, sovereign and supranational. Agency is the basegroup in the regression analysis. Source: EADB list, 25.05.21
Rating	Qualitative		Credit rating of the green bond issuer. Overall six rating categories (A, A-, AA, AA-, AAA, BBB). AA is the basegroup for the regression analysis. Source: Bloomberg, 23.06.21
Asset Type	Qualitative		Asset type of the green bond: bond or medium term note (MTN). Basegroup for the regression is bond. Source: Bloomberg, 07.06.21
Issue Amount	Quantitative	EUR million	Issue amount of the green bond. Source: Bloomberg, 07.06.21
Modified Duration	Quantitative	Years	Modified duration of the green bond. Source: Bloomberg, 07.06.21

Note. Overview of explanatory variables for the OLS-Regression to analyze the underlying drivers of a potential green bond premium.

Table 11. OLS regression: test for heteroscedasticity

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance Variables: fitted values of Greenium chi2(1) = 5.56
Prob > chi2 = 0.0184

Note. The null hypothesis of constant variance can be rejected.

Table 12. OLS regression: test for multicollinearity

Multicollinearity Test (VIF) for Explanatory Variables		
Variable	VIF	1/VIF
A Rating	1.15	0.871384
A- Rating	1.61	0.620959
AA- Rating	1.13	0.881942
AAA Rating	2.55	0.391794
BBB Rating	1.28	0.779329
Sovereign Sector	2.79	0.358966
Supranational Sector	1.62	0.615658
Asset Type MTN	1.78	0.562116
log (Amount Issued)	3.18	0.314906
log (Modified Duration)	1.24	0.804617
Mean VIF	1.83	

Note. Test for multicollinearity with mean VIF < 10: multicollinearity is not a critical issue.

Table 14. Fixed effect regression: year-dummy results

	(1)
VARIABLES	Yield Difference
Liquidity Difference	-0.002
	(0.004)
Year 2015	-0.117***
	(0.011)
Year 2016	-0.142***
	(0.011)
Year 2017	-0.167***
	(0.011)
Year 2018	-0.166***
	(0.011)
Year 2019	-0.172***
	(0.011)
Year 2020	-0.173***
	(0.011)
Year 2021	-0.163***
	(0.011)
Individual FE	YES
Observations	37,420
R^2	0.110
Adjusted R^2	0.109
F Statistic	190.929***

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note. Within-fixed effect regression of liquidity difference on yield difference, controlling for a potential time effect through a year dummy. The baseline dummy is Year 2014.

Table 15. Fixed effect regression: quarterly-dummy results

VARIABLES	(1) Yield Difference
Liquidity Difference	0.003
	(0.004)
2014 Q4	-0.025
	(0.026)
2015 Q1	-0.106***
	(0.025)
2015 Q2	-0.143***
	(0.024)
2015 Q3	-0.148***
	(0.024)
2015 Q4	-0.146***
	(0.024)
2016 Q1	-0.132***
	(0.024)
2016 Q2	-0.160***
	(0.023)
2016 Q3	-0.182***
	(0.024)
2016 Q4	-0.171***
	(0.024)
2017 Q1	-0.170***
	(0.024)
2017 Q2	-0.181***
	(0.023)
2017 Q3	-0.195***
	(0.023)
2017 Q4	-0.201***
	(0.023)
2018 Q1	-0.190***
	(0.023)
2018 Q2	-0.185***
	(0.023)
2018 Q3	-0.186***
	(0.023)
2018 Q4	-0.189***
	(0.023)
2019 Q1	-0.192***
	(0.023)
2019 Q2	-0.197***
	(0.023)
2019 Q3	-0.196***
	(0.023)
2019 Q4	-0.192***
	(0.023)
2020 Q1	-0.195***
	(0.023)
2020 Q2	-0.200***
	(0.023)
2020 Q3	-0.198***
	(0.023)
2020 Q4	-0.189***
	(0.023)
2021 Q1	-0.188***
	(0.023)
2021 Q2	-0.181***
	(0.023)
Individual FE	YES
Observations	37,420
R^2	0.134
Adjusted R^2	0.132
F Statistic	92.71***

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note. Within fixed-effect regression of liquidity difference on yield difference, controlling for a potential time effect through a quarter dummy. The baseline dummy is 2014 Q3.

Table 16. Distribution of the green bond premium estimates

Green Bond Premium Estimates (%)						
Min	**1 st Quart.**	**Median**	**Mean**	**3 rd Quart.**	**Max**	**SD**
-0.138	-0.023	-0.006	-0.003	0.006	0.126	0.039

Note. Green bond premium estimates based on a within fixed-effect regression.

Table 18. OLS regression results

Dependant Variable: Estimated Green Bond Premia					
Linear Regression with White Robust Standard Errors					
	(1)	(2)	(3)	(4)	(5)
Constant	0.042	0.042	0.040	0.010	0.010
	(0.062)	(0.062)	(0.052)	(0.008)	(0.008)
Rating A	0.010	0.010	0.017	0.020	
	(0.033)	(0.033)	(0.029)	(0.029)	
Rating A-	-0.046***	-0.046***	-0.041***	-0.044***	
	(0.014)	(0.014)	(0.014)	(0.013)	
Rating AA-	-0.024**	-0.024**	-0.021**	-0.026***	
	(0.011)	(0.011)	(0.010)	(0.007)	
Rating AAA	-0.028**	-0.028**	-0.026***	-0.024***	
	(0.011)	(0.011)	(0.009)	(0.009)	
Rating BBB	0.023	0.023	0.020	0.017	
	(0.058)	(0.058)	(0.059)	(0.061)	
Sector Sovereign	0.026	0.026	0.023	0.020*	
	(0.017)	(0.017)	(0.018)	(0.010)	
Sector Supranational	-0.003	-0.003	-0.006	-0.009	
	(0.016)	(0.016)	(0.014)	(0.014)	
log(Amount Issued)	-0.002		-0.004		
	(0.008)		(0.008)		
log(Amount Issued) O.C.		-0.002			
		(0.008)			
log(Modified Duration)	-0.011				
	(0.008)				
log(Modified Duration) O.C.		-0.011			
		(0.008)			
Asset Type MTN	0.003	0.003			
	(0.012)	(0.012)			
A- x Sovereign				0.010	-0.013
				(0.025)	(0.022)
AAA x Sovereign				-0.018	-0.022
				(0.022)	(0.021)
A x Agency					0.020
					(0.029)
A- x Agency					-0.044***
					(0.013)
AA x Sovereign					0.020*
					(0.010)
AA- x Sovereign					-0.006
					(0.008)
AAA x Agency					-0.024***
					(0.009)
AAA x Supranational					-0.033**
					(0.015)
BBB x Sovereign					0.037
					(0.062)
Outlier Control (1st, 99th)		YES			
Observations	60	60	60	60	60
R^2	0.309	0.309	0.265	0.271	0.271
Adjusted R^2	0.168	0.168	0.150	0.140	0.140
Robust standard errors in parentheses					
*** p<0.01, ** p<0.05, * p<0.1					

Note. This table gives the results of the cross-sectional OLS regression, explaining the green bond premium with varying bond characteristics, as seen in specification (1) to (5). In specification (2), amount issued and modified duration are adjusted for outliers, replacing extremely low and high values with the 1st or 99th percentile value, respectively.

Table 19. Distribution of the monthly green bond premium estimates

Monthly Green Bond Premium Estimates (%)						
Min	**1 st Quart.**	**Median**	**Mean**	**3 rd Quart.**	**Max**	**SD**
-0.314	-0.026	-0.003	-0.006	0.016	0.461	0.058

Note. Monthly green bond premium estimates based on a monthly within fixed-effect regression.

Table 20. Monthly green bond premium estimates by rating, sector and asset type

		Mean $(\widehat{G_m})$	#
	Total	-0.007***	1,801
Rating	AAA	-0.026***	719
	AA	0.012***	729
	AA-	0.004***	33
	A	0.016**	23
	A-	-0.011*	285
	BBB	0.072***	12
Sector	Agency	-0.003**	1,074
	Sovereign	0.018***	342
	Supranational	-0.038***	385
Asset Type	Bond	0.007***	715
	Medium Term Note	-0.016***	1,086

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note. Mean monthly green bond estimates grouped by rating, sector and asset type. Clustered standard errors with respect to month (82 clusters) are used, to account for possible within month correlation due to the monthly estimation method.

Table 21. Green German Federal Government bond twin issuances

Maturity	5-Year Bond		10-Year Bond		30-Year Bond	
Twin	Conv.	Green	Conv.	Green	Conv.	Green
Re-offer Yield (%)	-0.83	-0.83	-0.47	-0.48	0.42	0.39
Yield as on 13.08.21 (%)	-0.79	-0.83	-0.54	-0.61	-0.02	-0.06
Yield Difference P.M. (%)	0		-0.01		-0.03	
Yield Difference S.M. (%)	-0.04		-0.07		-0.04	

Note. Primary and secondary market green bond premia are calculated based on the reported yields and the condition that green and conventional bonds are part of a twin issuance. Source: Deutsche Finanzagentur, 2021.

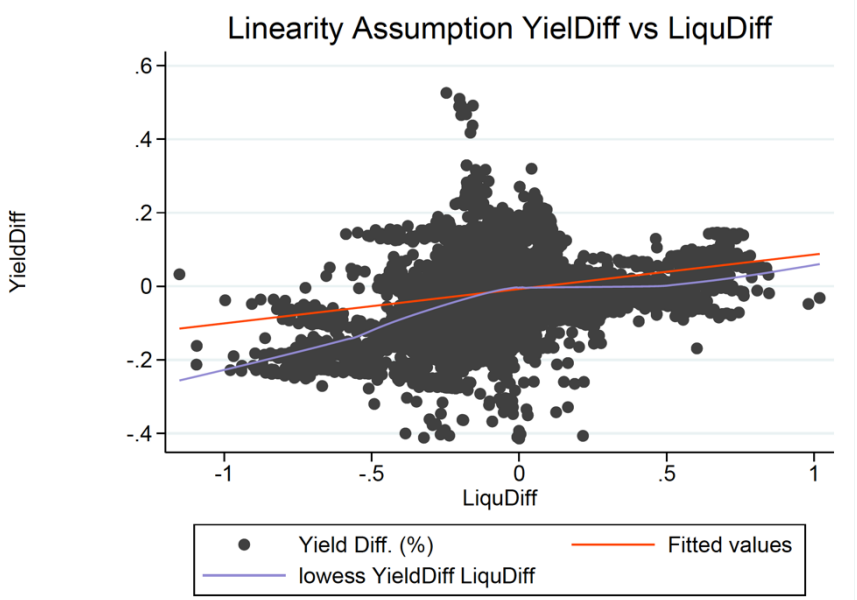
Table 22**.** NGEU bond and SURE social bond issuances

Maturity	5-Year Bond		10-Year Bond		20-Year Bond		30-Year Bond	
Program	NGEU	SURE	NGEU	SURE	NGEU	SURE	NGEU	SURE
Issuance Volume	€ 9bn	€ 8bn	€ 20bn	€ 10bn	€ 10bn	€ 7bn	€ 6bn	€ 10bn
Re-offer Yield (%)	-0.335	-0.488	0.086	-0.238	0.471	0.131	0.732	0.317
Yield as on 13.08.21 (%)	-0.571	-0.583	-0.241	-0.284	0.251	0.227	0.351	0.335
Yield Difference P.M. (%)	-0.153		-0.324		-0.340		-0.415	
Yield Difference S.M. (%)	-0.012		-0.043		-0.024		-0.016	

Note. Primary and secondary market yield differences between issued NGEU bonds and SURE social bonds. The calculations are based only on the reported yields, without accounting for liquidity differences and are therefore only representing the yield difference and not a social bond premium. Source: Financen.Net, 2021.

2. List of Figures

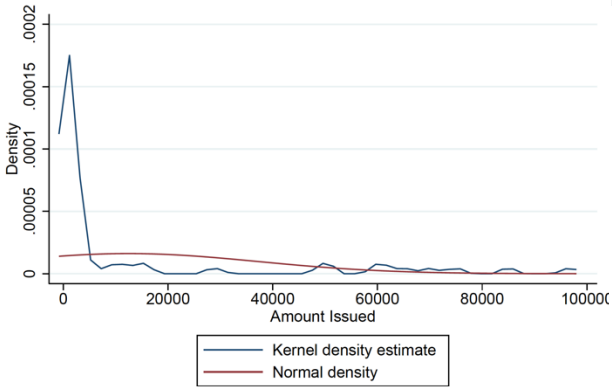
Figure 6. Linearity in parameters



Note. Scatterplot of Liquidity Difference (explanatory variable) on Yield Difference (dependent variable) to test linearity assumption.

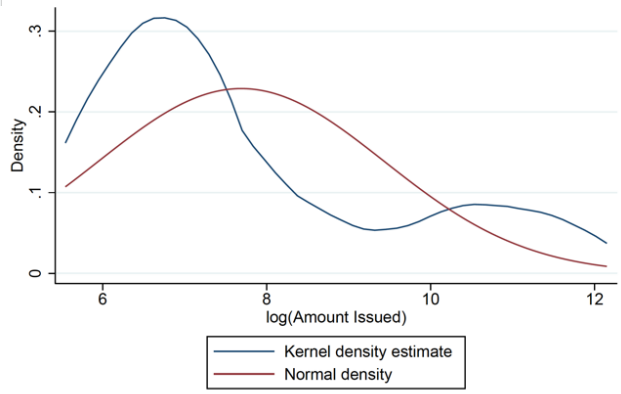
Figure 7. Linearization of Amount Issued

a. Density Amount Issued



Note. Kernel = epanechnikov, bandwidth = 1.3e+03

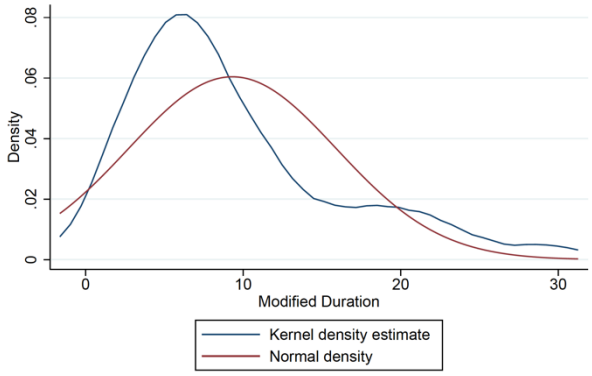
b. Density log(Amount Issued)



Note. Kernel = epanechnikov, bandwidth = 0.6714

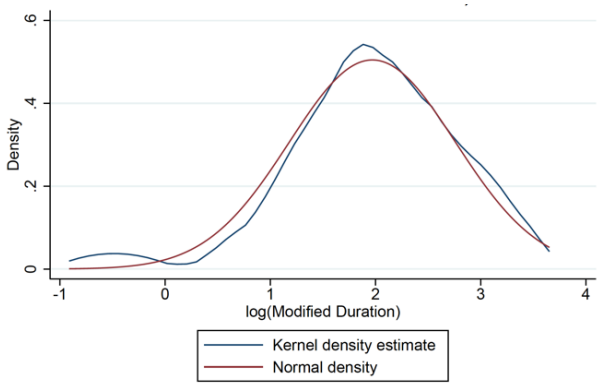
Figure 8. Linearization of Modified Duration

a. Density Modified Duration



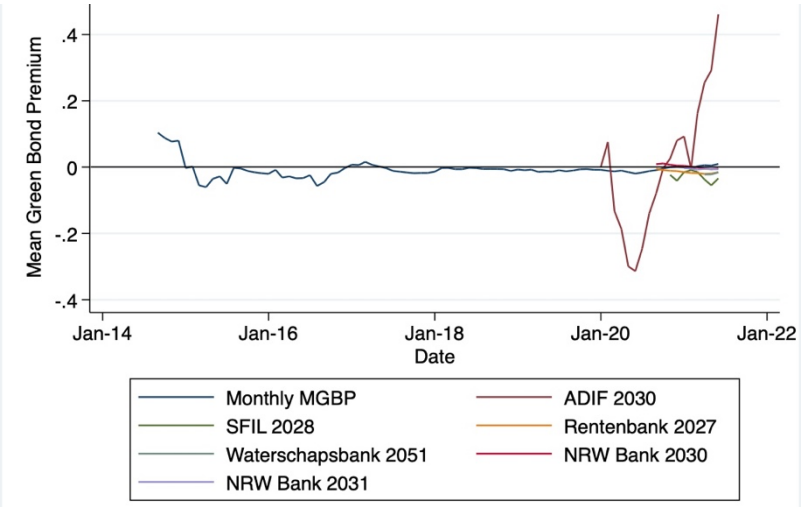
Note. Kernel = epanechnikov, bandwidth = 2.1749

b. Density log(Modified Duration)



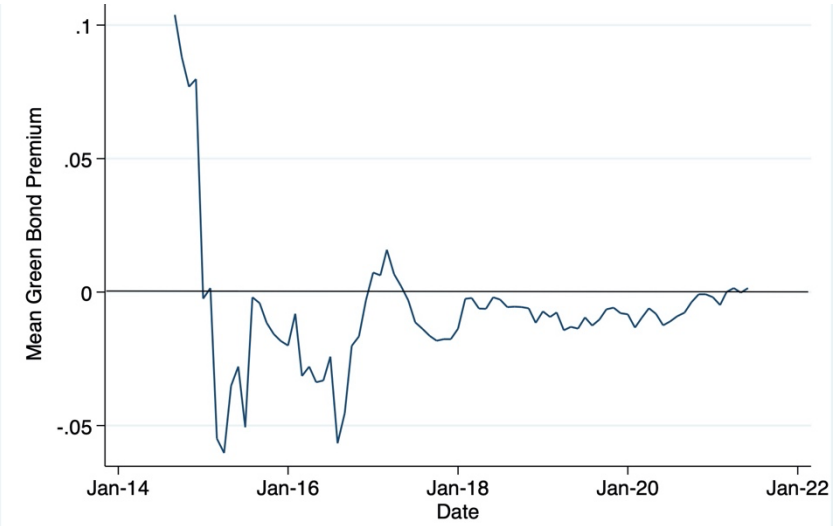
Note. Kernel = epanechnikov, bandwidth = 0.2831

Figure 10. Plot of high volatility agency bond



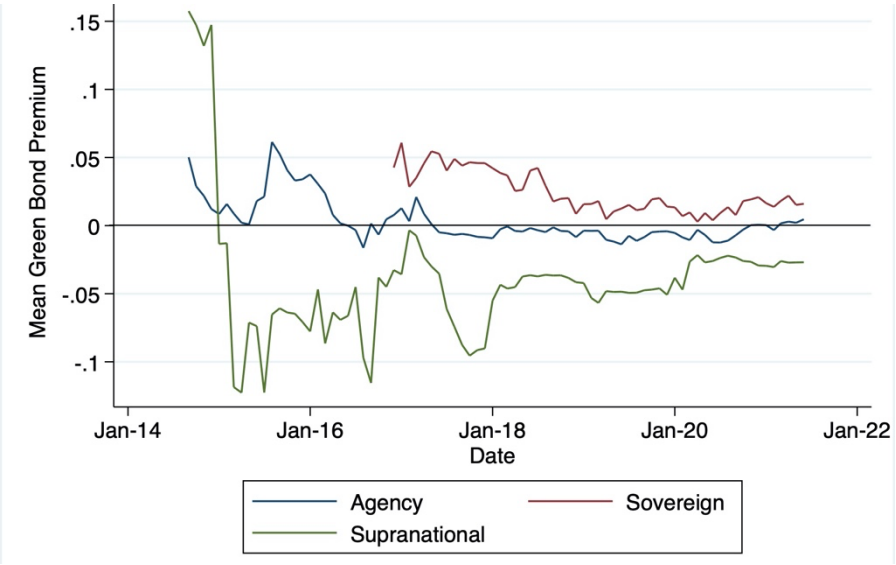
Note. Plot of several agency green bond premia and the mean green bond premium over time. The green bond premium estimates for the ADIF green bond with maturity 2030 show an unusually high volatility.

Figure 11. Mean green bond premium over time without ADIF green bond



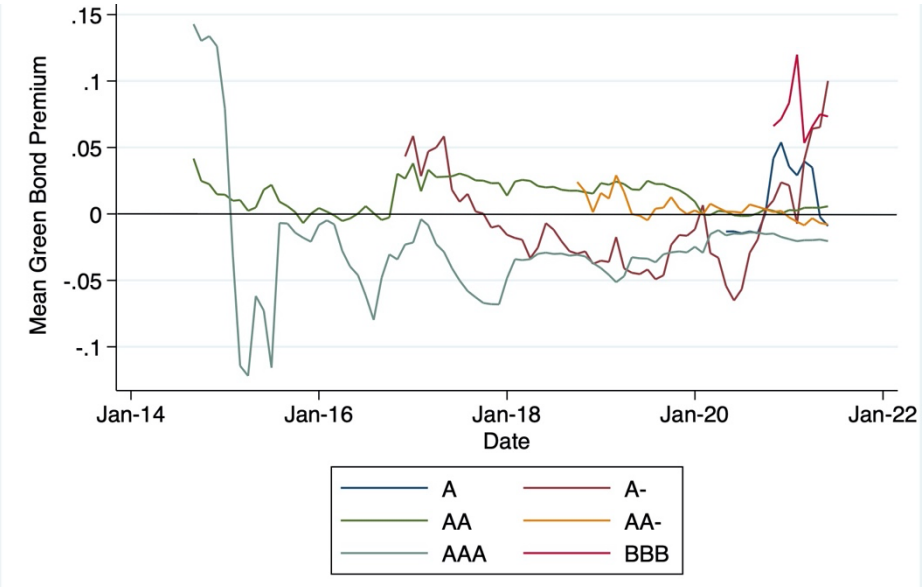
Note. Plot of the mean green bond premium over time, dropping 18 monthly estimates for the ADIF green bond with maturity 2030, due to its unusually high volatility, as seen in figure 10.

Figure 13. Mean green bond premium over time by sector without ADIF green bond



Note. Plot of mean green bond premium by sector, dropping 18 monthly estimates for the ADIF green bond with maturity 2030, due to its unusually high volatility, as seen in figure 10.

Figure 14. Mean green bond premium over time by issuer rating



Note. Plot of mean green bond premium by rating. Both, AAA rated and A- rated green bonds appear to

3. Additional Information

3.1 Interview Partners and Questions

3.2.1 Interview Partners

Group	Company	Role	Interview Partner
Rating Agency	ISS ESG	Green, Transition and Sustainability Bonds	Carman Mak
	MSCI	ESG Research	Matthew Geisler
Issuer	EIB	Head of Sustainability Funding	Aldo Romani
	KfW	Head of Funding	Otto Weyhausen-Brinkmann
Bank	Commerzbank	Rates and Credit Research	Rainer Guntermann
	Crédit Agricole	Head of Covered Bond & SSA Research	Florian Eichert
	Deutsche Bank	ESG Corporate Bank	Kevin Laubach
	HSBC	Chief Executive Officer	Nicolo Salsano
	LBBW	SSA Debt Capital Markets	Iason Ioannidis
	Morgan Stanley	Head of ESG Structuring	Christina Lacaci
	UniCredit	ESG Competence Center	Dr. Josué Manuel Quintana Díaz
Asset Manager	Acatis	Chief Executive Officer	Dr. Hendrik Leber
	Bantleon	Fixed Income Portfoliomanagement	Marcio da Costa
	Bayern Invest	Head of Public Affairs & Sustainability; Investment Strategy & ESG	Wiebke Merbeth; Julia Dissmann
	Pictet	Head of Group Regulatory Office	Yvonne Lenoir Gehl

3.2.1 Interview Questions

Q1. What are your current expectations for the future of the green bond market? Have your expectations changed due to the EU's announcement of high volume green bond issuances in the upcoming years?

Q2. What, in your opinion, drives the high demand for green bonds?

Q3. How do you view the ongoing discussion concerning lower risk being attributed to green assets such as green bonds?

Q4. How do you view the EU as a green bond issuer? As a sovereign or supranational issuer?

Q5. Do you agree / find evidence that green bonds are priced differently due to their green component? (Existence of a Greenium)

Q6. How do you form price expectations for green bonds in your buying decisions? Do you always expect a greenium? What factors do you consider?

Q7. What influencing factors would you suggest that might have an impact on green bond pricing?

Q8. Do you expect that the EU's high green bond issuance volume will ease the excess demand in the green bond market, thereby lowering or even canceling out an existing Greenium?

Q9. Regarding the decisions on the EU Taxonomy: do you expect possible implications of including nuclear energy and gas? Will this have an influence on the green credibility of issuers and the overall credibility of the green bond market?

Q10. What do you see as current challenges or potentials regarding the green bond market?

3.2 Fixed Effect Regression Model

In the following section, the within transformation for the green bond premium estimation in section 4.1.4.1 is explained in detail, following Woolridge (2015). The baseline fixed-effect regression model is as follows:

(1) $\Delta\tilde{y}_{i,t} = G_i + ß * \Delta\widetilde{BA}_{i,t} + u_{i,t}$ i = 60 bond pairs; t = 1,759 days

For each individual bond i, the equation is averaged over time:

(2) $\overline{\Delta\tilde{y}_\iota} = G_i + ß * \overline{\Delta\widetilde{BA}_\iota} + \overline{u_\iota}$ i = 60 bond pairs

Because G_i is a time-invariant individual fixed-effect, it appears in both (1) and (2). In order to perform a within fixed-effect regression, by taking out any time-invariant heterogeneity, equation (2) is subtracted from equation (1), resulting in:

(3) $\Delta\tilde{y}_{i,t} - \overline{\Delta\tilde{y}_\iota} = G_i - G_i + ß * \Delta\widetilde{BA}_{i,t} - \overline{\Delta\widetilde{BA}_\iota} + u_{i,t} - \overline{u_\iota}$

or with a different notation:

(4) $\Delta\ddot{\tilde{y}}_{\iota,t} = ß * \Delta\ddot{\widetilde{BA}}_{\iota,t} + \ddot{u}_{i,t}$ i = 60 bond pairs; t = 1,759 days

$\Delta\ddot{\tilde{y}}_{\iota,t}$, $\Delta\ddot{\widetilde{BA}}_{\iota,t}$ and $\ddot{u}_{i,t}$ are the time-demeaned variables, ß is the within estimator and the individual fixed effect G_i has been cancelled out, because it is fixed over time. Consequently, as explained in section 4.1.4.1, the individual fixed effect has to be estimated subsequently, based on the within estimator ($\hat{ß}$) and the individual time averages ($\overline{\Delta\tilde{y}_\iota}$, $\overline{\Delta\widetilde{BA}_\iota}$), as follows:

(5) $\hat{G}_\iota = \overline{\Delta\tilde{y}_\iota} - \hat{ß} * \overline{\Delta\widetilde{BA}_\iota}$ i = 60 bond pairs

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