Can QE speed up the green transition? Evidence on the role of the European corporate bond purchase programme[†]

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Abstract

This study examines the influence of corporate bond purchases by the European Central Bank (ECB) under the Pandemic Emergency Purchase Program (PEPP) on the green bond market. Using a comprehensive bond-based dataset, we investigate the effects of ECB outright purchases on eligible green bonds by focusing on risk premiums, issuances, and the relationship between firms' environmental commitments and green investments. Our results reveal that ECB purchases generate a negative risk premium of 6 basis points for eligible green bonds. Moreover, we observe that the decrease in yields is more pronounced for lower-rated and long-maturity green bonds than for conventional eligible comparable bonds, confirming the effectiveness of the portfolio rebalancing mechanism within the green segment. On the issuance side, the ECB's corporate purchases stimulated the issuance of eligible green bonds, resulting in an increase of € 0.818 billion in the subsequent six quarters. Finally, we assess the connection between a firm's environmental commitment and green investments, and find that the implementation of green policies serves as a credible commitment that notably promotes the issuance of eligible green bonds.

Keywords: green bonds, corporate debt, quantitative easing, green monetary policy, pandemic emergency purchase program

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1. Introduction

To mitigate the escalating rise in global temperatures, 196 countries signed the Paris Agreement (PA) on December 12, 2015. The final goal was to limit the temperature increase to 1.5°C above pre-industrial levels.[1] By ratifying the PA, the European Union (EU), through the Green Deal, has implemented a series of reforms that aim to achieve climate neutrality by 2050. In alignment with the goal set forth by the Green Deal, the ECB has also instated significant structural changes in the structure and functioning of the Asset Purchase Program (APP), with the goal of reducing climate change risk exposure and fostering the transition toward a greener economy.[2] The ECB included the climate change risk within the APP's framework, tilting its asset portfolio and thus changing the assets eligibility criteria by assessing the firms' environmental-related performance and promoting the disclosure of green practices (ECB Climate Agenda, 2022).

Following the increasing academic interest in the role of central banks in the climate challenge (De Grauwe, 2019; Schoenmaker, 2019; Brunnermeier and Landau, 2020) and considering the efforts carried out by the ECB, it remains to be answered whether asset purchase programs have a substantial impact on the economy's green transition. Specifically, we investigate the impact of the ECB's corporate bond purchases on the capital structure of eligible green companies. We analyze the impact of corporate bond purchases performed by the ECB from three perspectives. First, we test the differential impact on yields by comparing eligible green bonds to eligible conventional (or brown) bonds. Second, we analyze whether the expected drop in yields for eligible green bonds increases the issuances of such bonds. And third, we delve into the role of environmental commitment as a potential driver to foster the use of green market financing.

In this study, we focus on the effects of the Pandemic Emergency Purchase Program (PEPP) in the European green bond market, delving into the impact generated in corporate bond

[1] The Paris Agreement, adopted on December 12, 2015, by 196 parties during the UN Climate Change Conference (COP21) in Paris, France, is a legally binding international treaty concerning climate change. It became effective on November 4, 2016. Its primary objective is to limit "the rise in the global average temperature to below 2°C above pre-industrial levels" while striving to cap the temperature increase at 1.5°C above pre-industrial levels.

[2] The ECB's asset purchase programme (APP) started as part of a package of non-standard monetary policy measures that also included targeted longer-term refinancing operations, and which was initiated in mid-2014 to support the monetary policy transmission mechanism and provided the amount of policy accommodation needed to ensure price stability. The APP consists of the: corporate sector purchase programme (CSPP), public sector purchase programme (PSPP), asset-backed securities purchase programme (ABSPP), and third covered bond purchase programme (CBPP3).

segments. This program expanded the existing APP initiated in 2014 in the aftermath of the great financial crisis. The rationale to focus on the PEPP is twofold. On the one hand, announced and performed in March 2020 by the ECB to counteract the economic downturn during the Covid-19 pandemic, the PEPP is the largest purchase program implemented by the ECB to date. With a volume of € 1,850 billion at the end of 2020, this program accounts for approximately 10% of the overall bond market within the Euro area and has led the ECB to hold around 18% of the universe of eligible corporate sector bonds. Besides, it is important to consider the sizable dimension and significant growth experienced by European green bonds in 2020 and 2021. During these two years, the European green bond market experienced a growth rate of 56%, surpassing the average annual growth rate of the past 10 years (50%). As a consequence of this trend, the European market currently constitutes 51% of the global green market in value.[3] Figure 1 depicts the trend of the green bond market.

[Figure 1 here]

Despite the influence of concerns over climate change on current monetary policy strategies, empirical literature is still scant.[4] Building upon the empirical approach put forth by Elliot and Doillet-Maino (2020), we investigate the causal effect of the PEPP on the eligible green bonds. Using an extensive bond dataset obtained from Datastream, including daily bond yields as well as additional bond-level and issuer-level information, we design a difference-in-differences (DiD) strategy to investigate the impact of the program on both yields and issuances of eligible green bonds compared to eligible conventional bonds. Going a step further, we examine whether the disclosure of the implementation of environmental-related policies, as a proxy for green commitments, fosters the issuance of green bonds encouraged by asset purchase programs.

The following key findings emerge from our analysis. Our first finding highlights the impact of the PEPP on the funding cost of eligible green bonds compared with eligible conventional bonds. The empirical results show a drop in the green bond yields of 6.31 bps compared to eligible conventional ones. Furthermore, our results outline the transmission

[3] The market for green bonds has developed rapidly in recent years. The green bond market, both globally and at the EU level, grew by an average of 50% per year from 2015 to 2020. Nevertheless, it represented only 3–3.5% of the overall bond issuance in 2020. The EU is a global leader in green bonds with € 164.2 bn of global issuances in 2020, of which 71% was denominated in euro currency, representing 51% of the global volume of green bonds issued in the EU. Financial and non-financial corporations drive 44% of total green issuance, with yearly growth rates of 143% and 111 %, respectively, in 2021. In detail, the Energy, Buildings, and Transport sectors cover 85%, i.e., € 137 bn., of all issuances in 2020 (De Santis et al., 2018; Climate Bond Initiative, 2020).

[4] Matikainen et al. (2017), De Santis et al. (2018), and Dafaermos et al. (2020) provide a descriptive overview on the central bank's initiatives in terms of climate change focusing on the development of green assets held by central banks over the last decade.

channels through which outright purchases have an effect. Riskier eligible green bonds, that is, bonds close to the eligibility threshold of the program, exhibit a greater reduction in yields upon maturity compared to safer eligible green bonds.

Second, we find statistically significant evidence that PEPP purchases increase the amount of total bonds issued by Eurozone firms. Eligible firms significantly increase the number of eligible green bonds by € 0.818 billion on average and the effect turns out to be significant in the seven quarters following the announcement.

Finally, our empirical evidence suggests that eligible firms that have implemented an environmental policy at least one year before the announcement experience an increase in green bond issuances compared to eligible firms that did not implement such type of policy. The policy impact is not significant for eligible conventional cumulative bond issuances. This result emphasizes the link between the issuance of green bonds and funded green investments. In other words, the adoption of an environmentally targeted policy by companies could stimulate the need to undertake "green" investments funded by the issuance of green bonds.

Our work differs from other related studies, such as those by Bremus et al. (2021) and Eliet-Doillet and Maino (2022), in the following two ways. Unlike Bremus et al. (2021), we examine the impact of the PEPP announcement by specifically concentrating on the eligible bond range, where the influence on yields is more significant in identifying the portfolio choices of the central bank. Furthermore, unlike Eliot-Doillet and Maino (2022), we demonstrate that environmental commitments, such as policies aimed at reducing greenhouse gas (GHG) emissions, prove to be a fundamental channel for the decision to issue eligible green bonds.

We advance the nascent literature by providing new empirical evidence on the effectiveness of European QE in achieving a green transition towards net zero emissions. We demonstrate that green bond issuers benefited more from corporate bond purchases during the implementation of the PEPP, resulting in lower funding costs and an increased reliance on green financing through the issuance of larger volumes of green bonds. Finally, we advance the existing literature on corporate bond purchases in the green bond market by including firms' environmental policy as a key variable that could explain the differential dynamics of eligible green issuances compared to conventional ones.

Our empirical evidence provides clear support for the portfolio rebalancing choices adopted by the ECB. From a backward-looking perspective, the assessment of environmental commitments and disclosure procedures could serve as a significant driver to foster the reduction of emissions and to mitigate climate change risks for ECB portfolio. Considering the recent climate-related regulatory changes in ECB's purchases, this study yields a clear policy

implication. The increased motivation to implement policies aimed at mitigating climate change serves as a catalyst for green bond issuance. Consequently, the ECB's initiative has the potential to trigger a virtuous cycle, guiding businesses toward a more sustainable and environmentally friendly economy altering companies' financing choices.

This paper is organized as follows. Section 2 presents the research hypotheses. Section 3 describes the dataset used in this study. Section 4 introduces the study's empirical model. Section 5 describes and discusses the results. Section 6 concludes.

2. Hypothesis development

The literature has recently started to include environmental topics (climates change, decarbonization process, pollution' reductions) into economic models as the green economy becomes more relevant for both financial institutions and scholars. Annichiarico and Di Dio (2017), Economides and Xepapadeas (2018), Annichiarico and Diluiso (2019), and Chen et al. (2021) studied the implications of climate change on central bank monetary policy.

In this line, nascent literature (Pelizzon et al., 2023; Ferrari and Landi, 2021, 2022; Abiry et al., 2022; Giovanardi et al., 2022) expands the well-established literature on quantitative easing (Curdia and Woodford, 2011; Gertler and Karadi, 2011; Chen et al., 2012; Gertler and Karadi, 2013; Hirstov et al. 2018 and Burlon et al., 2018) by including environmental factors, e.g., green sector and carbon emissions. Therefore, the new strand of research proposes a novel theoretical framework for studying the real implications of green asset purchases, that is, Green Quantitative Easing (Green QE).[5]

Our study is related to the literature that empirically explores the effects of the corporate bond purchase program implemented by the ECB. Several studies have investigated the impact of bond purchases from two main perspectives: drop in bond yields and impact on bond issuances. Previous literature explores the program's impact on the bond market by focusing on the reduction in yields after the announcement of the policy. Regarding the effect of the CSPP on the primary market, Li et al. (2019) found a decrease of 20 basis points in yields for eligible bonds. Focusing also on the primary market, Zaghini (2019) highlights a reduction in the yield spread by 70 basis points during the first two quarters after the policy announcement. Abidi and Miquel-Flores (2018) emphasize a reduction of 15 basis points for eligible bonds in the secondary market. Meanwhile, Todorov (2020) assessed a different magnitude of impact and reported a decrease of 30 basis points in eligible bond yields.

[5] Ferrari and Nispi Landi (2022) define Green QE as a purchase program of green bonds by the central bank, financed with higher reserves.

However, few studies have empirically investigated whether ECB outright purchases are an efficient instrument for mitigating climate change. Descriptive analyses were performed as described by Matikainen et al. (2017), De Santis et al. (2018), and Dafermos et al. (2020), who investigate the composition of ECB corporate bond purchases. For their part, Bremus et al. (2021) and Elliot et al. (2022) focus on the corporate bond purchases impact on the green sector. Bremus et al. (2021) highlight that the announcement of the 2016 and 2020 corporate purchase programs significantly improved the financial conditions for eligible green bonds compared to non-eligible green bonds. Elliot et al. (2022) conduct event-study analysis by focusing on the Monetary Policy Strategy Review's announcement in July 2021 dedicated to climate change. These authors emphasize a twofold enhancing effect, that is, (i) a decrease in the yield of eligible green bonds compared to equivalent conventional bonds, and (ii) an increase in the amount of green bonds issued.

Building on seminal studies on the impact of the corporate bond purchases on bond yields (Zaghini, 2019; Todorov, 2020; De Santis and Zaghini, 2019; Bremus et al., 2021), we focus on the eligible range of bonds. The primary objective is to ascertain whether the PEPP's announcement significantly decrease the yield-to-maturity of eligible green bonds compared to eligible conventional ones.

Hypothesis 1: Corporate bond purchases by the ECB's PEPP improve the financial condition (drop in yields-to-maturity) of green bonds.

Several studies explore the rebalancing portfolio mechanism (Vayanos and Vila, 2009) as the primary channel through which corporate bond purchases occur (Abidi and Miquel-Flores, 2018; Zaghini, 2019; Todorov, 2020; Grosse-Rueschkamp et al., 2019). By creating scarcity in the eligible bond segment and reducing yields for high-rate bonds, outright purchases could incentivize investors to reallocate their holdings to riskier asset classes. This "*search for yield*" behavior prompts investors to favor assets with higher returns, leading to increased demand for low-rated bonds (Vayanos and Vila, 2009; Krishnamurthy and Vissing-Jorgensen, 2011; Fisher et al., 2016). Following an approach similar to Krishnamurty and Vissing-Jorgensen (2011) and Todorov (2020), the sample of eligible bonds can be divided into homogeneous credit risk and maturity classes, as suggested by Abidi and Miquel Flores (2022) and Elliot-Doillet and Maino (2022). We expect that bonds rated close to the eligible threshold, that is, riskier bonds, and those with longer maturities, will experience a more significant decrease in yields compared to conventional eligible bonds.

Hypothesis 2: Long-maturity and low-rated eligible green bonds benefit more from the ECB's PEPP outright purchases.

The CSPP literature widely supports the notion that an increase in bond issuance is a direct implication of the lowered cost of funding for eligible bonds (Abidi and Miquel Flores, 2018; Grosse-Rueschkamp et al., 2019; De Santis and Zaghini, 2021). The seminal contribution of Grosse-Rueschkamp et al. (2019) documents an expansion of bond debt by two percentage points in eligible firms compared with non-eligible firms. Simultaneously, these authors highlight a change in financing decisions for eligible firms, characterized by a significant reduction in loan maturity after the policy announcement. More favorable financing conditions in the market have fostered financial disintermediation for eligible firms, indirectly easing bank balance sheet constraints and enhancing the credit channel. Both Abidi and Miquel-Flores (2018) and Todorov (2020) emphasize the increase in corporate bond issuance as a direct result of the yield reduction after the CSPP's announcement, outlining that eligible firms issued euro-denominated eligible bonds 25% more than comparable firms. Finally, De Santis and Zaghini (2021) find an increase in the likelihood of eligible companies issuing Euro-denominated bonds by 14% compared to non-eligible companies.

Nevertheless, as shown by Abidi and Miquel-Flores (2018), Zaghini (2019), Koijen et al. (2021), and Bremus et al. (2021), investors could adjust their portfolio allocation toward non-eligible segments of green bonds that present comparably elevated Yield-to-Maturity. According to the portfolio rebalancing argument (Vayanos and Vila, 2021), the spillover effects of corporate bond purchases entail a decrease in Yield-to-Maturity for the non-eligible bonds. Consequently, it remains unclear whether the issuance of non-eligible green bonds should be curtailed compared to that of eligible green bonds, considering the heightened incentive to invest in green bonds in the European financial market (regardless of whether they are eligible or not). This study delves into the impact of the PEPP on the issuance of eligible bonds, focusing on eligible green bonds. To achieve this, we assess the policy's differential impact on the dynamics of conventional and green-eligible bonds compared to non-eligible counterfactuals. We expect a significant stimulus provided by the program's announcement of the issuance of eligible bonds.

Hypothesis 3: PEPP corporate bond purchases lead to an increase in eligible green bond issuances.

The literature extensively explores the positive impact of adopting environmental, social, and governance (ESG) criteria practices on firm performance, such as lower interest rates (Menz, 2010; Goss and Roberts, 2011; Chava, 2014) and decreased risk (Stellner et al., 2015), thereby increasing the overall value of firms (Albuquerque et al., 2019). Firms' adoption of environment-related policies serves as a proxy for demonstrating their "green commitment"

(Thang and Zang, 2018; Flammer, 2020; Fatica et al., 2021) for future green investments. Those investments could be funded through the issuance of green bonds. Thang and Zhang (2018) highlight the announcement effect of green bond issuance on firm's performance. Evidence suggests that green issuance is a reliable commitment that can positively impact the stock market, thereby improving companies' environment-related performance. Flammer (2020) conducted a study that revealed a positive relationship between the issuance of green bonds and improvements in the environmental performance of the issuing entities.

We investigate the role of green commitment within the asset purchase framework and explore whether environmental policies can effectively boost the issuance of eligible green bonds. Furthermore, the adoption of environmental commitments could help to mitigate the "greenwashing" phenomenon, emphasizing a meaningful connection between issued green bonds and the underlying real investment, thereby encouraging firms to transition toward a low-emissions economy.

Hypothesis 4: Firms' environmental commitment strengthens the expected positive impact of the ECB's PEPP corporate bond purchases on the issuance of eligible green bonds.

3. Data description

To explore the differential effect of the PEPP on the green European bond market and firms' capital structure, we must combine two different types of data: bonds' financial data and corporate capital structure information. Bond data were collected from the Datastream Thomson Reuters database, encompassing 23 European exchange markets.[6] Our analysis focuses only on bonds issued by firms incorporated in the 19 Eurozone countries.

For each bond, a daily time series of bond yield is obtained, which enables us to investigate the impact of PEPP's announcement. Several metrics of bond yields were collected following the approach of De Santis and Zaghini (2020), Zaghini (2019), Abidi and Miquel-Flores (2018), and Bremus et al. (2020). These metrics include yield-to-maturity (Yield-to-Maturity), yield, spread over the benchmark curve, and spread over the swap curve. We also obtain bid/ask prices to compute the bid/ask spread as a proxy for bond liquidity. The time-series data cover the period from 01/01/2018 to 01/12/2021. Additionally, the dataset includes the issuance value for each bond along with the related date of issuance.

[6] We exclude all types of securities different from corporate bonds. Hence, we drop observation related to asset-backed securities, convertible asset-backed securities, convertible bonds, convertible preference shares, financial preference shares, and industrial preference shares. Moreover, bonds issued by financial firms were excluded based on the program criteria.

To identify bonds that comply with the ECB eligibility criteria for the purchases program, several qualitative variables have been collected from Eikon (Thomson Reuters). Hence, the dataset was enriched including qualitative information related to corporate bonds. More precisely, we collect the following information for each bond: currency denomination, country of incorporation, credit rating, and maturity.[7] According to the ECB's technical requirements for the corporate bond purchases, bonds are eligible when the following criteria are met: they are (i) issued by a European established firm, (ii) euro-denominated, (iii) the credit rating ranges between AAA/BBB- (or equivalent), and (iv) the residual maturity is from 6 months to 30 years (Abidi and Miquel-Flores, 2018; Zaghini, 2019; Todorov, 2020). Appendix A.1 provides a more detailed description of the eligibility criteria.

Furthermore, to be able to differentiate between conventional and green bonds, the identification of bonds that belong to the green sector is crucial. For each bond, we collect data from Datastream (Thomson Reuters) that identify whether a generic bond is labelled as green or not. We construct a dummy variable Green that takes value one if the bond is labelled as green and zero otherwise. Appendix A.2 provides a detailed description of the classification methods concerning the green bond following global major standards.

Table 1 presents the summary statistics for the main bond variables, dividing the sample into the control (eligible conventional bonds) and treated (eligible green bonds) groups in the paper's analysis.

[Table 1 here]

We complement the bond dataset with borrowers' balance sheet data.[8] We collect quarterly balance sheet data from Q1 2018 to Q4 2021, providing an 8-month period before and after the announcement. Specifically, we focus on cumulative bond issuances to evaluate the

[7] The credit ratings used in this paper refer to the rating scale provided by Fitch and Moody's. Concerning the maturity data, Datastream only provides information related to the date of issuance and the expiry date. Hence, we compute the residual maturity.

[8] Inspired by the procedure provided by Abiry and Miquel-Flores (2018) to obtain a matching for bonds and borrower's balance sheet information, we try to improve this procedure combining the LEI (Legal Entity Identifier)-based matching. First, we use a combination of three different LEI codes, i.e., (i) legal identity identifier, (ii) parent legal entity identifier (PLE) and (iii) ultimate parent legal entity identifier (UPLE), to link the two distinct datasets. For bonds issued by non-listed companies that are part of listed companies, a direct link via LEI code is not possible. To overcome the issue, we use the two additional codes, i.e., PLE and UPLE, to achieve a more efficient link between assets and issuers. We match the bond information with firms' dataset starting with the LEI code. Whenever we do not obtain a matching, we re-match the missing value using either of the other two codes, i.e., PLE and UPLE. In this way, we can identify the firms that issue bonds and thus control for the firm's activity for intrinsic qualitative features of bonds. Moreover, to improve the matching procedure, we collect the identification of 3,722 listed firms operating in the Eurozone. We use the historical list of bonds' ISIN for each company obtained from Screener to re-match the two datasets, including part of bonds that were not previously matched.

program's impact on bond issuances, defining three different specifications of cumulative issuances: conventional cumulative bond issuance, green cumulative bond issuance, and total cumulative bond issuance. Table 2 presents summary statistics for the three cumulative issuance variables.

[Table 2 here]

To estimate the impact of the program on cumulative bond issuance, we consider changes in firms' debt demand, including leverage, EBITDA, and total assets. We exclude all firms operating in sectors not eligible for the ECB's corporate bond purchases, dropping those belonging to NAICS Code 52 "Finance and Insurance." After filtering for financial and insurance firms, we obtain 3,177 firms. The eligibility criteria of firms are identified using the credit ratings from Screener. Firms are considered eligible for the program if they exhibit a credit rating that ranges between BBB-/AAA+, with the eligibility condition following the existing CSPP literature (Grosse-Rueschkamp et al., 2019; Arce et al., 2020; Zaghini and De Santis, 2021), which considers Eurozone incorporated firms with credit ratings within the range of BBB- to AAA+ or equivalent as eligible for CSPP purchase. Table B.1 in Appendix B provides the definitions of the variables used in the analyses.

4. Empirical model

4.1. Impact of ECB corporate bond purchases on green bond yields

In this section, we aim to evaluate the distinct differential of PEPP's corporate purchases on the yield-to-maturity of eligible green bonds in comparison to conventional eligible bonds. To explore the effect of the program on eligible bond yields, we initially conducted a matching procedure to address potential biases arising from differences within eligible bonds. We match green bonds with counterfactual conventional bonds on the day prior to the announcement using a nearest-neighborhood procedure. Following the approaches of Abidi and Miquel-Flores (2018) and Giovanardi et al. (2022), the matching procedure considers the following variables: coupon dummy variable, bid-ask spread, year-expressed maturity, residual maturity at the announcement, notional amount issued, and yield spread. Detailed information concerning the econometric models employed for the matching and the related results can be found in Appendix B.2.

To assess the implications of the PEPP on green bonds' yields, we design a difference-in-difference (DiD) approach as follows[9]:

[9] We employ a doubly robust estimation, which combines the propensity score weights from logit model (Appendix B.2) with DiD regression model (Sant'Anna and Zhao, 2020).

$$y_{i,d} = \beta_1 Green + \beta_2 Post + \beta_3 (Green_{i,t} \times Post_t) + \mu_i + \tau_d + \varepsilon_{i,t} \quad (1)$$

Independent variable $y_{i,d}$ is the Yield-to-Maturity for bond *i* at the end of day *d*. The time period is restricted to eight months around the announcement, that is, from January 1, 2020 to August 31, 2020. The sample is restricted to the sub-sample of ECB-eligible bonds according to the requirement settled by the program: Euro-denominated currency bonds, issued by Eurozone incorporated firms, acceptable credit rating ranges between BBB-, AAA+, and residual maturity is between 6 months and 30 years. The *Post* variable is defined as a dummy variable that takes the value of one after the policy announcement on March 18, 2020, and zero otherwise. The green bonds are identified by a Green dummy variable taking the value one if the bond is labelled green by Datastream Thomson Reuters and zero otherwise. The main coefficient of interest is β_3, which measures the policy impact on eligible green bonds' yields compared with eligible conventional bonds. Further, bond fixed effects (μi) and daily fixed effects (rd) are included. Standard errors are clustered at the bond level to account for serial correlations in the outcome (Bertrand et al., 2003). The dependent variable is winsorized at the first and ninety-ninth percentiles to overcome possible influences of outlier values.

The baseline specification of equation 1 is estimated to test Hypothesis 1; that is, to examine the impact of corporate bond purchases on the yield of eligible green bonds compared with conventional eligible bonds. To test Hypothesis 2, we investigate the transmission mechanism of corporate bond purchases; that is, portfolio rebalancing (Vayanos and Vila, 2021; Zaghini, 2019). Consequently, we focus on the two primary channels through which central bank outright purchases exert their effects: the credit channel and the maturity channel (Abidi and Miquel-Flores, 2018, Todorov, 2018; Elliot-Doillet and Maino, 2022). To test the credit risk channel, the sample is clustered into three different subclasses: high-grade bonds (Aa1, Aa2, Aa3, or equivalent), upper-medium grade bonds (A1, A2, A3, or equivalent), and lower-medium grade bonds (Baa1, Baa2, Baa3, or equivalent). Regarding the maturity channel, we classify bonds into three subclasses based on residual maturity: 0-5 years, 6-10 years, and 11-30 years.

Table B.1. in Appendix B provides detailed information on the rating classes belonging to each macro-credit class.

4.2. Impact of PEPP's corporate bond purchases on firms' capital structure

To assess the different impacts of PEPP announcements on green bond issuance (Hypothesis 3), we estimate the following DiD regression:

$$y_{f,q} = \beta_1 Eligible_{i,t} + \beta_2 Post_t + \beta_3 (Eligible_{i,t} \times Post_t) + \theta X_{i,t-1} + \zeta \Delta_{f,c,t} + \mu_i + \tau_m + \delta_{s,m} + \varepsilon_{i,t} \quad (2)$$

We use two different specifications for bond issuance: (i) total cumulative green bond issuance and (ii) total cumulative conventional bond issuance. Cumulative bond issuances are measured as the quarterly sum of the issued bonds for each company. The dependent variables were measured considering the time span from Q1 2018 to Q4 2021. The time break Post variable takes the value one after the PEPP announcement in Q1 2020 and zero otherwise. Following the CSPP literature, the eligibility condition is given by the credit rating of the company. The eligible variable takes a value of one if firms can be classified as eligible according to the PEPP technical requirements for the program; that is, firms have to show a credit rating within the (BBB-, AAA+) range. Two control groups are considered for the evaluation of the PEPP. On the one hand, to explore the impact on eligible green bond issuances, we use the non-eligible green bonds as the counterfactual sample. On the other hand, to test the policy intervention on eligible conventional bonds, non-eligible conventional bonds were used as counterfactual samples. The main coefficient of interest is β_3 given by the interaction between the post dummy variable and the eligible dummy that refers to the issuer. Coefficient β_3 assesses the differential effect of the program on the issuances of eligible green and conventional bonds compared to non-eligible ones. We include firms' control variables that can explain changes in corporate debt demand. X is a set of firm characteristics that determines a firm's demand for debt. We include firm size, measured as the natural logarithm of total assets (Asset), firm profitability, measured as EBITDA over total assets (Norm. Ebitda), and a firm's indebtedness (Leverage), defined as the ratio of total debt to total assets (Grosse-Rueschkamp et al., 2019; De Santis and Zaghini, 2021; Elliot-Doillet and Maino, 2021).

In line with Elliot et al. (2022), the Δ vector includes the market control variables. Our analysis incorporates the quarterly closing price of the European allowance market (*EEX EUA*) and a time trend. We collect quarterly closing prices of carbon emission allowances at country-level from the European Energy Exchange AG (EEX).[10] When the price of carbon emission allowances increases, the higher cost of emitting carbon incentivizes firms to invest more in green projects, consequently stimulating green-bond issuance. Additionally, the bond market time trend (*TimeTrend*) is included as a control variable to capture the effects of market expansion dynamics. Further, firm fixed effects (μi), quarter fixed effects (rd) and sector-

[10] Following Eliet-Doillet and Maino (2023), we use the price allowance permits traded in the EU ETS System for measuring the EU carbon prices (https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en). Auctioning is the basic principle of allocating allowances within the EU emissions trading system (EU ETS). This means that businesses have to buy an increasing proportion of allowances through auctions. In coordination with the European Commission, the EU Member States and the EEA EFTA States auctioning on the common auction platform (CAP3) (https://www.eex.com/en/market-data/environmentals/eu-ets-auctions).

quarter fixed effects are included. To address any potential simultaneity issues with the dependent variable, each control variable, whether firm- or market-related, is lagged by one quarter. Standard errors are clustered at the firm level, which is the treatment level.

4.3. The role of environmental performance on the effect of ECB's corporate bond purchases

To evaluate the effects of firms' green choices on the issuing process (Hypothesis 4), especially when they are eligible for outright purchases, we use a difference-in-difference-in-differences (DDD) approach. This approach has two advantages. First, it allows us to use environmental policy as an exogenous measure of green investment in eligible firms, thus mitigating potentially biased results arising from endogeneity issues. Second, we examine the persistence of the "greenwashing" phenomena that may distort the trend of green issuances. This methodology enables us to capture the differential impact of green-related policies on green-bond issuance within the context of the QE program.

$$y_{i,t,r} = \beta_i(Post \times Treat \times Policy\ Target) + \theta X_{i,t-1} + \zeta \Delta_{f,c,t} + \mu_i + \tau_m + \delta_{s,m} + \varepsilon_{i,t} \quad (3)$$

Conventional cumulative bonds and green cumulative bonds issued are the dependent variables, as described in Section 4.2. The timespan and firm-market control variables are the same as those described in equation 2. The novelty introduced in this subsection relates to the inclusion of the environmental policy variable that captures firms' green commitment. Hence, we include the *Policy Target* variables to account for environmentally friendly policies triggered by firms with the aim of reducing pollution emissions, for example, various forms of emissions to land, air, or water from the company's core activities.[11] The *Policy Target* variable takes a value of one if the firm has implemented policies aimed at increasing or sustaining transactions towards more sustainable activities at least one year before the announcement. If our expectation on the role of environmental commitment is right, in line with Hypothesis 4, the three-way interaction term ($Post \times Treat \times Policy\ Target$) should get a significant and positive coefficient for the issuance of eligible green bonds, whereas the coefficient should be negative in the case of conventional bonds issuances.

[11] We have constructed the *Policy Target* dummy variables using the data provided by Refinitiv Eikon (Thomson Reuters), i.e., Target Emission variable. We delve into whether firm has set the short-term or long-term targets for emission reduction. Target Emission takes value "true" if firms set reduction target whereas sets value "false" otherwise. Consequently, Policy Target takes value 1 when the value of Target Emission is "true" while takes value 0 for the other value of Target Emission. We investigate, therefore, whether eligible firms implement processes or mechanisms, or has programs in place on what the company is doing to reduce emissions in its operations, system or a set of formal, documented processes for controlling emissions and driving continuous improvement.

Further, firm fixed effects (μi), quarter fixed effects (rd), and sector-quarter fixed effects are included. To address any potential simultaneity issues with the dependent variable, each control variable is lagged by one-quarter. The standard errors are clustered at the firm and treatment levels.

5. Results

5.1. The impact of corporate bond purchases on green bond yields

This section discusses the empirical results on the impact of PEPP's announcement on eligible green bonds. First, we depict the average time series of the yield to maturity for both the treated (eligible green bonds) and control (conventional eligible bonds) groups in Figure 2 to ensure that the parallel trend assumption holds. Figure 2 shows that, before the announcement, both subsamples follow a parallel trajectory. However, after the announcement, the trend in the yield to maturity of eligible green bonds shows a more negative slope than that of conventional eligible bonds.

[Figure 2 here]

Table 3 shows the estimation of the impact of PEPP's corporate purchases on bond yields after the PEPP announcement on March 18, 2020. Our results corroborate Hypothesis 1 concerning the positive effects of the ECB program in terms of the negative premium. In column 1, we run a regression without bond and time-fixed effects. In the baseline specification without fixed effects (column 1), we find no significant effect of the PEPP's announcement on the yield-to-maturity of eligible green bonds with respect to the eligible conventional bonds. Columns 2 and 3 show the empirical results obtained by applying the more restricted model described in equation 1. Column 2 shows the estimated coefficients, including bond fixed effects. Finally, column 3 presents the estimate resulting from saturating the model including both bond and daily fixed effects. Controlling for the time-invariant bond features (column 2), the interaction coefficient becomes negative and highly significant: the yield to maturity of eligible green bonds experiences a drop of almost 6.4 bps compared to the control group. In the saturated model with daily-fixed effects, the estimated coefficient β_3 is still negative and significant with a magnitude close to the coefficient obtained in column 2. Our model predicts a statistically significant drop in Yield-to-Maturity for eligible green bonds compared to eligible conventional, which remain stable across the last two specifications.

On average, eligible green bonds show a Yield-to-Maturity 6 bps lower than conventional eligible bonds after the PEPP announcement in the following six months.

[Table 3 here]

In Table 4, we divide the eligible bond sample into four subcategories: three subcategories based on the credit rating (columns 1 through 3) and three others according to maturity (columns 4 through 6); these are the two relevant classification criteria. We want to explore whether the higher drop in Yield-to-Maturity of eligible green bonds compared with eligible brown bonds due to the ECB intervention is different across categories. Hence, we aim to isolate the main transmission channel related to corporate bond purchases (Krishnamurty and Vissing-Jorgensen, 2011; Zaghini, 2019).

The findings reported in Table 4 corroborate Hypothesis 2; that is, the magnitude of the drop in the Yield-to-Maturity of green bonds is negatively related to credit rating. We obtain a more significant coefficient for low-rated eligible bonds than for high-rated bonds. Specifically, our results show a decrease in eligible green bond yield by 9 bps compared to eligible conventional bonds in the next six months after the announcement in the high-grade cluster. Looking at the upper medium-grade cluster, the differential yield drop is equal to 10.54 bps, while the decrease is 14.15 bps for lower medium grade bonds. Our findings indicate that QE's bond purchases reduce the yield for safer bonds less than in the case of riskier bonds.

Regarding the effect of outright purchases on different maturity classes, the empirical evidence is similar to that related to the effect of risk classes. The shortest maturity, i.e., 0-5 years, bonds experience a non-significant decrease in Yield-to-Maturity compared to counterfactual conventional bonds. A significant drop in yields is exhibited for longer maturities, i.e., 5-10 years and 10-30 years. In contrast to the findings on credit rating, the greatest decrease in yield is reported for eligible belonging to the intermediate maturity range of 5-10 years. Bonds whose maturity ranges between 5 and 10 years exhibit a drop in Yield-to-Maturity of 8 bps. We also highlight a decrease in the yield on green bonds for the longest maturity class, that is, 11 to 30 years. Nevertheless, the yield drop in this case is limited to 2.2 bps compared with eligible conventional bonds. Overall, the ECB initiatives, and in particular the PEPP, have significantly decreased the cost of borrowing for the bonds with intermediate and longer maturities, in line with the portfolio rebalancing expectation.

[Table 4 here]

To sum, the PEPP's announcement brought about a significant decrease in Yield-to-Maturity for eligible green bonds compared to eligible brown ones by 6 bps on average. Our results differ from the empirical evidence provided by Bremus et al. (2021). By studying the differential impact of PEPP on eligible green bond versus non-eligible green bonds, the authors outline a greater yield's reduction after the policy. On the contrary, when we focus on the eligible range, we find that the yield reduction is quantitatively lower compared to what is

obtained by comparing eligible vs. non-eligible bonds. Our results are consistent with those obtained by Eliet-Doillet and Maino (2022), who explore the impact of monetary review announcement in July 2021. We highlight that the eligible green and brown bonds exhibit similar behavior in response to the two announcements. PEPP and monetary review generated a similar decrease in cost of funding for eligible green bonds compared to eligible brown ones. Furthermore, by testing several specifications according to different maturities and risk-classes, we prove that the reduction in yield to maturity for the green eligible bonds is due to the rebalancing portfolio triggered by the ECB's programs.

5.1.1. Event study analysis

In this subsection, we explore the persistence of the drop in Yield-to-Maturity for eligible green bonds compared with conventional bonds. The objective of this analysis is to investigate alterations in treatment effects on yields before and after treatment by disaggregating the effects over time to provide a more comprehensive assessment. We employ an event study model to investigate the dynamics of the policy implications over time. In addition, we rely on this analysis to explore the two following patterns. First, the estimation of weekly β coefficients allow us to empirically test the credibility of the parallel trend assumption (before treatment). Second, the estimation of β coefficients after the announcement provide crucial insight concerning the persistency of the ECB's market initiative.

$$y_{i,w} = \sum_{w=-p}^{q} \beta_{i,w}\left(Green_{i,w} \times Post_{w}\right) + \mu_i + \tau_w + \varepsilon_{i,w} \quad (4)$$

The dependent variable y is the Yield-to-Maturity of bond *i* in week *w* so that we can obtain a different coefficient for each week. The *Green* dummy variable takes the value of one if the bond is labelled as green and zero otherwise. In contrast to equation 1, the policy indicator is disaggregated into *p* pre-treatment and *q* post-treatment periods, with the pre-treatment period left out as the baseline period. The *w=0* indicates the start of the post-treatment period. We include bond fixed effects μi and week fixed effects τ_w. Figure 3 provides the empirical evidence by reporting the estimated coefficient for the eight weeks before and after the announcement. We show the persistence of policy interventions on yields of eligible green bonds compared to eligible conventional bonds. Figure 3 exhibits estimated coefficients and 95% confidence bands for the two-way fixed effects model described in equation 4.

[Figure 3 here]

The pre-treatment coefficients exhibit parallel movement compared to the control group, while post-treatment dynamics diverge. The estimated coefficients across the pre-treatment period turn out to be non-significant pointing out that the parallel trends assumption holds in our case. This evidence also corroborates the results provided in the previous section.

The estimated coefficients in the post-treatment period provide crucial insights into the persistence of the treatment effect. The estimated coefficients are significant from one week after the announcement until the end of the estimation period. The estimated treatment effect remains significantly negative throughout large part of the sample-period, pointing out that financing conditions for issuers of eligible green bonds remain favorable due to the PEPP, in comparison to conventional eligible bonds.

5.2. The impact of the PEPP's corporate bond purchases on firms' capital structure

This section analyses the changes in firms' capital structure as a result of QE. Hence, we explore whether the PEPP could have incentivized the increase in bond issuance between green and conventional bonds differently. The intervention of the central bank through substantial corporate bond purchases could facilitate an improvement in companies' capital-raising endeavors. The main purpose of QE is essentially to increase overall investment activity by mitigating the costs associated with the issuance of market debt. The policy would allow firms that were previously unable to receive financing, due to either bad quality or asymmetric information problems, to become eligible for direct financing through the ECB. In other words, bonds issued by these firms could now be sold to the ECB, and the boost in demand by the central bank should incentivize credit-constrained firms to start issuing more euro-denominated bonds that fulfill the CSPP criteria after the QE announcement. Our dataset includes data on the Eurozone firms issuing bonds from Q1 2018 to Q4 2021. The results of the DiD estimation related to the cumulative green and conventional bond issues are reported in Tables 5 and 6, respectively.

In column 1 of Table 5, we run a regression including only firm and quarter fixed effects. Excluding both firm and market control variables, the main coefficient of interest is positive and statistically significant (β_3=1.06). By including firm control variables (column 2), the interaction coefficient remains positive and significant but with different magnitude, i.e., β_3=0.785. In column 3, where we add fixed effects (country-year and sector-year fixed effects), the interaction coefficient is still significant, and the magnitude does not change too much. Finally, column 4 shows the estimate resulting from saturating the model with market control variables. Economically, the empirical evidence in Table 5 highlights a significant increase of eligible green bonds by € 0.818 billion, on average (based on the results in column 4), compared to non-eligible green bonds in the six quarters after the announcement. These findings suggest that the announcement of the ECB's market intervention led to a significative increase in the

issuance of eligible green bond compared to non-eligible green bonds. Besides, the magnitude of the PEPP' s impact remains significant against different specifications of equation 2.

[Table 5 here]

By contrast, if we focus on the conventional cumulative issuances, the results on the role of the PEPP are different, as can be observed in Table 6. Employing the model described in equation 2 and using the conventional bond as a dependent variable, we explore the impact of the PEPP's announcement on the issuance of eligible conventional bonds compared to non-eligible conventional ones. Column 1 exhibits the empirical evidence obtained with the baseline model. Excluding the control variables and the additional fixed effects (country-year and sector-year fixed effects), the interaction coefficient is β_3=1.196. Despite its size, the statistical significance of the coefficient β_3 is relatively low with a p-value higher than the standard threshold of 0.05. The coefficients turn out non-significant when we include firms' control and interacted fixed effects, respectively in column 2 and column 3. Focusing on the saturated model specification with market control variables (column 4), we obtain a coefficient of β_3=1.011; however, the statistical significance is lower than in the case of green bonds.

[Table 6 here]

Our findings point out that the ECB corporate bond intervention stimulated the issuances of eligible bonds in line with the easing funding conditions in financial market. This first set of results sheds light on the ECB's aim to tilt corporate bond portfolio in compliance with the efforts to the transition toward a low-carbon economy. The increase in eligible green bond emissions after the announcement of the PEPP could facilitate the green transition of the bond portfolio held by the ECB. It follows that the greater the volume of qualifying green bonds, the amplified likelihood of the ECB successfully realigning the portfolio in accordance with the newly introduced carbon-free benchmarks.

However, we should also point out that the PEPP also increased the issuance of eligible conventional bonds compared to non-eligible ones. Taking into the account the interaction coefficient estimated with the saturated model, we obtain weaker evidence that ECB's corporate purchases stimulate the issuances of eligible conventional bonds. The diminished significance of the interaction coefficient, as presented in Table 6, prompted us to undertake supplementary tests aimed at delving deeper into the actual impact of the policy within the conventional bond segment.

Therefore, to gain a better understanding of the program' s impact on both segments, we further investigate the dynamic of the central bank's intervention on conventional and green

bond issuances. In the following section, an event study analysis is performed to estimate the dynamic over time of PEPP's announcement on both green and conventional bond markets.

5.2.1. Event study analysis on bond's issuances

To assess the dynamics of the treatment effect on bond emissions, an event study methodology is employed:

$$y_{i,d,r} = \sum_{w=-p}^{q} \beta_{i,t}\left(Eligible_{i,t} \times Post_t\right) + \theta X_{i,t-1} + \zeta \Delta_{f,c,t} + \mu_i + \tau_d + \varepsilon_{i,t} \quad (5)$$

We use the same dependent variables specified in equation 2, i.e., total cumulative issuance of green and conventional bonds. The dependent variables are measured considering the time span between Q1 2018 and Q4 2021. The *Post* dummy variable takes the value of one after the PEPP's announcement in Q1 2020 and zero otherwise. Again, the *Eligible* variable takes the value of one if firms could be classified as eligible according to the CSPP technical requirement, i.e., firms have to show a credit rating in the (BBB-, AAA+) range. The policy indicator is disaggregated into p pre-treatment and q post treatment periods, with the pre-treatment period left out as the baseline period. The $t=0$ indicates the start of the post-treatment period. We use the same set of control variable as in equation 2. Results are shown in Figure 4.

[Figure 4 here]

Figure 4 exhibits point estimates and 95% confidence bands for the two-way fixed effects model for each of the two cumulative issuance variables. The graphs show point estimates and confidence bands up to seven months after the announcement of the PEPP. Pre-treatment trend coefficients move in parallel for all two specifications, while post-treatment dynamics differ.

Panel A of Figure 4 outlines the persistence of ECB's purchase over time for the eligible green bond issuances, whereas Panel B shows the effect on eligible conventional bonds over time. Focusing on the left-hand side of each figure, the evidence shows that the coefficients during the pre-treatment period are statistically insignificant. This emphasizes that both the treated and control groups, namely the eligible and non-eligible groups respectively, followed similar trajectories before the program's announcement. Once we have confirmed the parallel trend assumption in the pre-treatment period, we focus on the right-hand side of the figure and observe different effects of the ECB's announcement on both types of bonds.

By exploring the differential implications for conventional and green cumulative bond issuance, we highlight differences in the persistence of the ECB's purchases. Empirical results (Panel A) reveal that the monetary policy effect generates an increasing and persistent stimulus over time until the last quarter of 2021 in the case of eligible green bonds. The central bank announcement thus stimulates companies to issue more eligible green bonds compared to non-eligible green bonds. This effect is not just limited to the announcement period, but remains

significant throughout the year following the announcement. Conversely, looking at the cumulative issuances of conventional bonds (Panel B), we observe that the coefficients in the right-hand side of Panel B are non-significant for all quarters considered.

The event-study analysis, therefore, provides a useful insight on the effect of PEPP's announcement on the issuance of eligible bonds. The results exhibited in Figure 4 corroborate our research hypothesis on the role of PEPP in the fostering the issuance of green eligible bonds. Moreover, the event-study analysis sheds light on the effect of the program for eligible conventional bonds. Our findings indicate that eligible conventional bonds did not exhibit a significant increase compared to non-eligible ones following the announcement. In summary, the policy announcement triggers a substantial increase exclusively for eligible green bonds, while eligible conventional bonds do not exhibit any difference with their previous dynamics.

5.3. The role of environmental firms' policies in conjunction with the ECB's corporate bond purchase program

We now take a step further and contribute to the existing green-QE literature by exploring the significance of green-related policies adopted by eligible firms before the implementation of the ECB program. Specifically, we aim to assess the differential impact of outright purchases by the ECB for firms that have a pre-existing green commitment in place compared to eligible firms without any environmental policy. Therefore, we test whether the implementation of low-emission targeted policies could enhance the issuance of green bonds. In our analysis of the link between funding for environmental-related investments and the emission of green bonds, the underlying assumption is that companies that issue green bonds should make investments to implement and achieve the "green" objectives defined by their own environmental policies.

Hence, the reference category now is treated firms that put in place several activities aimed at enhancing the transition toward a low carbon economy. If our expectations are true, the coefficients on the three-way interaction term ($Post \times Treat \times Policy\ Target$) should be significant and positive only for the green cumulative issuances due to the link between green bonds and climate-related investments. By contrast, we expect that the interaction term does not affect the issuance of conventional eligibles bonds or the total issuance of bonds.

Table 7 exhibits the results obtained performing the DDD model. Column 1 of Table 7 provides the findings on role of environmental-related policies as driver for the issuance of conventional bonds for eligible companies, whereas column 2 reports the results related to the issuance of eligible green bonds.

[Table 7 Here]

Regarding the main coefficient of interest in equation 3, i.e., $Post \times Treat \times Policy\ Target$, it is worth noting that it remains non-significantly different from zero for the specification reported in column 1. Conversely, the estimated coefficient shows a significant and positive effect in the case of eligible green bond issuance (column 2).

This evidence corroborates our Hypothesis 4 and emphasizes the role of green commitment for the issuance of green bonds. When firms adopt environmentally friendly policies, there is a higher likelihood that they will undertake investments (green investments) to implement these policies. Given the close link between the issuance of green bonds and the underlying green investment, we outline the crucial role of environmental policies as a *boost* for firm's green bond demand. In line with the goal of the PEPP, the reduction in yields of eligible green bonds and the ensuing increase in eligible green bonds issuance appear to facilitate the investment initiatives of qualifying enterprises, particularly investments directed towards environmental projects (Grosse-Rueschkamp et al., 2019; Todorov, 2020; De Santis and Zaghini, 2021). Green-transition related commitments become an integral component of the QE's transmission mechanism, thereby heightening firms' incentives to obtain funds via the issuance of green bonds. Indeed, in the presence of a credible commitment by the firm towards a greener economy, companies that experience a reduction in financing costs, thanks to ECB's corporate bond purchases, seem to finance their green investments by resorting to higher issuance of ECB-eligible green bonds.

By contrast, the adoption of environmental related policies does not stimulate the issuance of conventional bonds for eligible companies. We relate this result to the missing link between environmental-related policies and the undertaking of green investments by the firms in the case of conventional bonds. In other words, when companies do not implement green policies, they do not have an incentive to finance their investment, tangible or intangible, by issuing conventional bonds.

This evidence contributes to the nascent literature on the role of "environmental commitment" of firms in bonds' performance (Thang and Zang, 2018; Fatica and Panzica, 2021; Flammer, 2021). Contrary to Thang and Zang (2018) and Flammer (2021), who explore how the green issuances affect the environmental performance as an increase in green rating or a reduction of carbon emissions, our approach sheds light on how the adoption of environmental commitments positively impacts on the green bond issuances for eligible firms within the outright purchases' framework. Our evidence confirms the importance of environmental commitment as a useful instrument that could enhance the issuances of eligible green bonds and therefore improve the shift toward the greener economy. Given the recent guidelines from

the ECB for rebalancing its portfolio in favor of the green economy, for which information on pollution-reduction policies plays a prominent role (ECB, 2023),[12] we believe that corporate green commitments will increasingly become a fundamental driver for issuing green bonds.

As described in detail in Appendix A.2, the missing constraint of certification by a third party for green bonds settled by the Green Bond Principles (GBP) best-practices may exacerbate the growing trend of greenwashing (Caramichael and Rapp, 2020; Fatica and Panzica, 2021; Fatica et al., 2021; Fammer, 2021). The abuse of the green label is generated when companies purport to engage in green investment to attract impact-oriented investors, while in practice engaging in investment that has little environmental value. Assuming that the implementation of environmental-related policies is a suitable proxy for the will of the firm to undertake green investments, our results should not be driven by the green washing phenomena. In other words, the issuance of eligible green bonds after the PEPP's announcement seems to be driven by the firm's objective to decrease the environmental impact of its activity, and not from the mere will to issue green bonds in a way unrelated to the adoption of specific green policies.

6. Conclusion

The increasing relevance of green bonds, in terms of issues both at global and European levels, led us to wonder whether the massive outright purchases conducted by the ECB to sustain the economy during the pandemic could affect the yield of green bonds compared to conventional or non-green bonds differently. Besides the growth rate of the green segment of the bond market, we also account for the ECB's aim to review the monetary strategy to move the economic system toward a zero-emission scenario.

Building a detailed bond dataset obtained from Datastream Thomson Reuters from January 1, 2018 to December 31, 2021, this paper aims to assess whether the bond purchases, i.e., PEPP, conducted by the ECB in the first quarter of 2020 has had a positive impact on the green bond segment. More precisely, we explore the PEPP's effect on eligible green bond cost of financing and the ensuing increase in green issuances.

First, our results outline the drop in yield-to-maturity for eligible green bonds by 6 bps after the program's announcement. These findings emphasize the existence of a negative risk premium between green and conventional bonds within the set of bonds eligible for ECB

[12] To support the European Union's objective for a climate neutral economy and help foster a better understanding of climate-related risks in the financial sector, the ECB provided the guidelines for the corporate bond tilting portfolio (link to ECB's report: https://www.ecb.europa.eu/pub/pdf/other/ecb.climate_related_financial_disclosures_eurosystem_corporate_sector_holdings_monetary_policy_purposes2023~9eae8df8d9.en.pdf?44e1ca0d64e12148df58cb8acaed6f4a

unconventional programs. Besides, delving into the risk channels (credit risk and maturity channels), we explore the transmission mechanism, i.e., portfolio rebalancing, by which the ECB' intervention impacts on the eligible green bonds. Our evidence shows that the magnitude of the drop in yield-to-maturity is more pronounced for low-rated and long-maturity bonds. The ECB's intervention has a higher positive impact on riskier debt instruments, thus emphasizing that the decrease in bonds' yield is driven by the outright purchases. We can conclude that the ECB's intervention has achieved this goal in the subset of eligible instruments.

Regarding the volume of the issuances, we have observed a noteworthy increase in the issuance of eligible green bonds, which amounts to € 0.818 billion in the seven quarters following the announcement. However, when we focus on conventional bonds, our results suggest that the PEPP did not significantly increase the issuances of conventional eligible bonds compared to the non-eligible counterfactuals. Focusing on the persistency of the impact, the event-study analysis outlines how the PEPP's impact significantly persists in the eight quarters following the announcement for the issuances of eligible green bonds. On the other hand, our results shows that the ECB's intervention does not have a significant impact on the issuance of eligible conventional bonds.

We also advance the existing literature by exploring if firm's environmental commitment could improve the issuance of green bonds. By focusing on the connection between the undertaking of green investments and the issuance of green bonds, we outline that eligible firms that implemented policies with a low-carbon transition as an objective significantly increase the issuance of green bonds. Our results highlight a strong link between firms' green commitment and the issuance of eligible green bonds within ECB's outright purchases.

Our results can be used to assess and develop the future decarbonization strategy of the ECB. The first set of results corroborates the ECB's aim to reduce the climate change-related financial risk in its portfolio. The change in the central bank's preference toward green assets could lead both to a decrease in the environmental risk of the portfolio and to a greater incentive to reduce the cost of financing for more promising enterprises. Our findings also suggest that the ECB is committed to stimulating the transition to a low-carbon economy by reducing the cost of eligible green bonds compared to the cost of conventional bonds. This is a positive development, as it could help to accelerate the green transition and promote the adoption of climate-friendly practices by European firms.

In addition, we emphasize the role of transparency and promotion of best practices to reduce the environmental impact. The disclosure of "green practices" is one of the key points to review, as this could promote the purchase of corporate bonds in the future. This would help

to ensure that the ECB's decarbonization strategy is effective and that it is aligned with the best available practices. The adoption of green policies by eligible companies and the ensuing influence on the green issuance points out the need to stimulate the adoption of climate-related policies by European firms as a driver to enhance the transition to a low-emission economy. This is an important aspect, as it suggests that the ECB's decarbonization strategy could have a positive impact on the broader economy.

Considering these developments, future research should be directed towards evaluating the implications of the monetary strategy review, specifically exploring the impact of environmental performance within the QE's framework on firms' activities. Future research may investigate how and with what timing the intervention of the ECB also impacts the segment of non-eligible green bonds. Such research endeavors are poised to contribute significantly to the broader understanding of the potential interplay between environmental responsibility, monetary policies, and financial markets. Furthermore, investigating the impact of the ECB's disclosure policies on firms' behavior can help to identify whether there is a significant shift in corporate practices and allocation of resources towards more sustainable activities. As the green bond market continues to grow, it is essential to assess how the commitment to sustainability influences firms' financing decisions and whether there is a positive spillover effect to other segments of the financial market.

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Figures

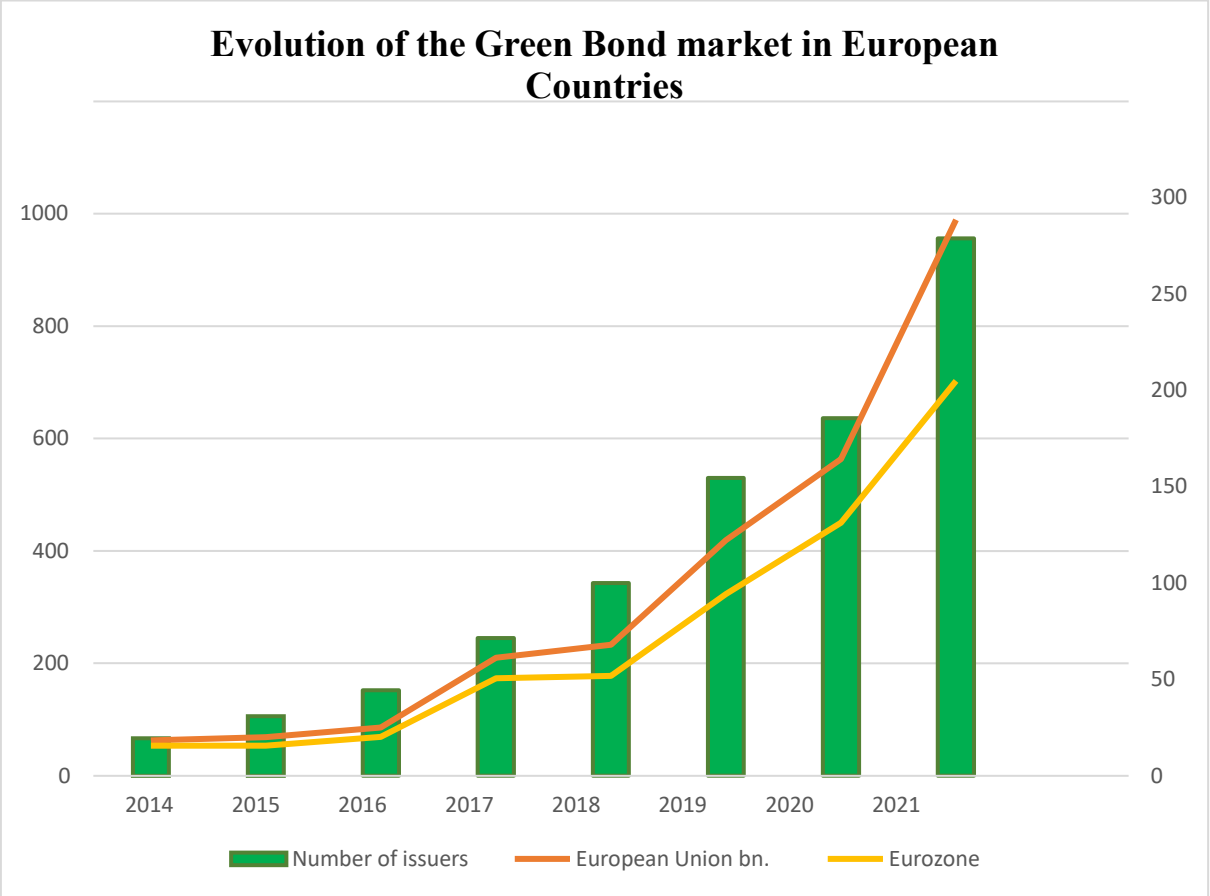

Figure 1. Evolution of the Green Bond market in European Countries. The green vertical bars exhibit the number of green bond issuers within the European Union. The orange line shows the amount in € bn. of green bonds issued by firms operating in European countries. The yellow line showsthe amount in € bn. of green bonds including only bonds issued by firms operating in the Eurozonecountries. *Source*: Climate Bonds (*our own elaboration*)

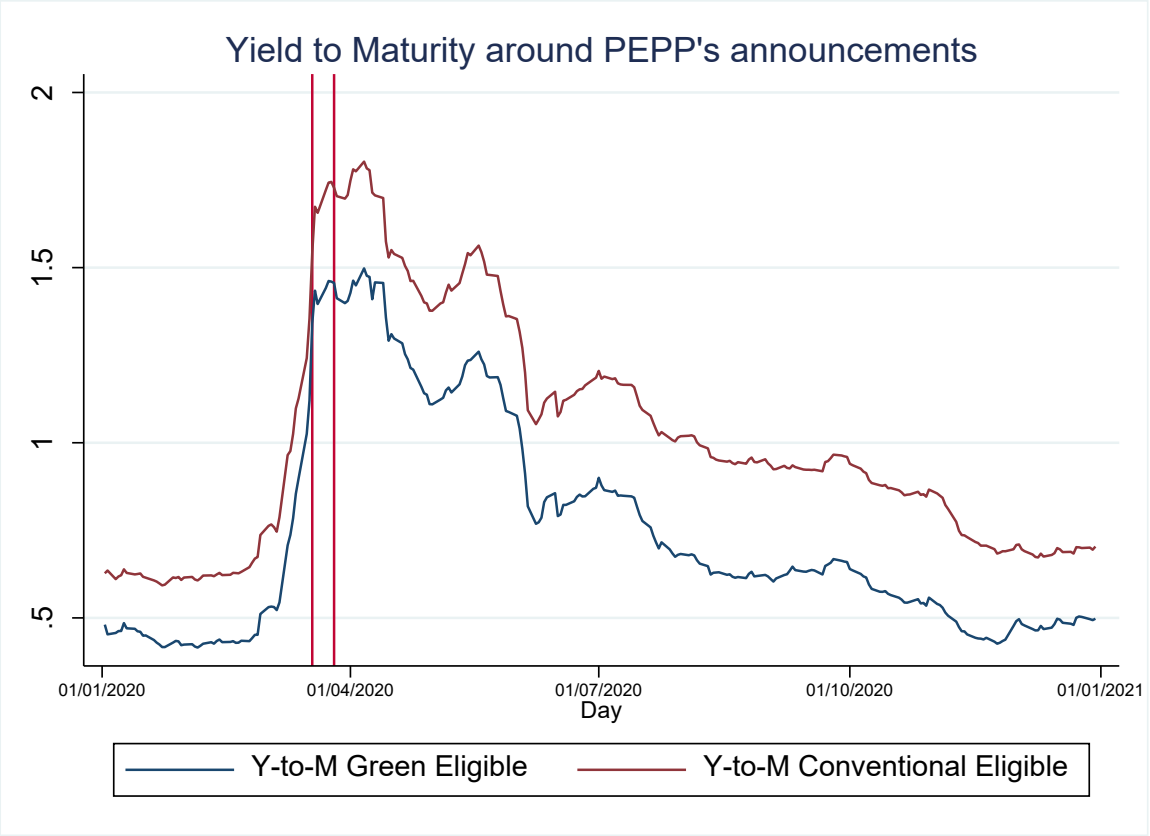

Figure 2. Parallel trend around PEPP's announcement. The blue line captures the yield-to-maturity of eligible green bonds. The red line captures the yield-to-maturity of conventional eligible bonds. The vertical lines exhibit the announcement date (18 March 2020) and the start of purchases (21 March 2020). The y-axis shows the bond's yield to maturity. The x-axis shows the selected timespan. *Source:* own elaboration using data from Datastream Thomson Reuters.

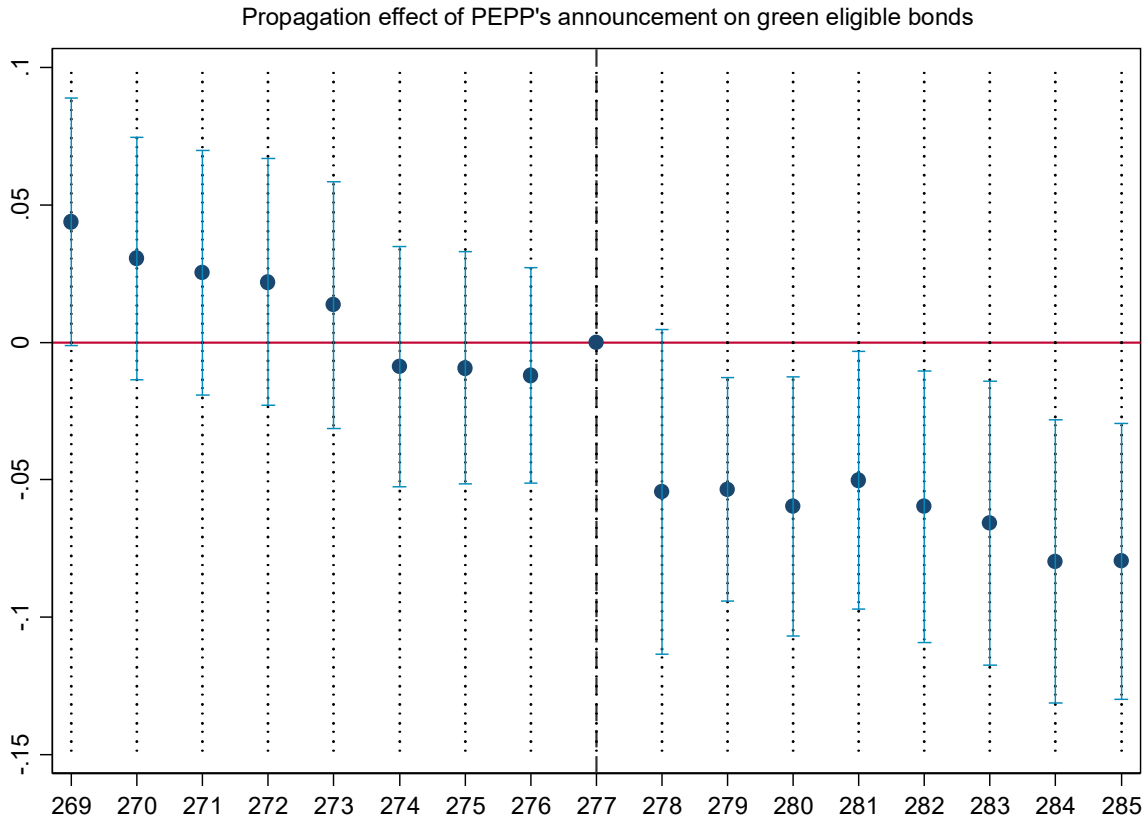

Figure 3. Propagation effect of PEPP's announcement on eligible green bonds. The dotted vertical line shows the announcement date of outright purchases. The horizontal red line is related to value zero of estimated coefficients. The blue dots are the estimated interaction coefficients for each week of time sample considered. The vertical line linked to each blue dots are the 95% confidential interval. The x-axis shows the number of weeks. The y-axis exhibits the coefficient magnitude.

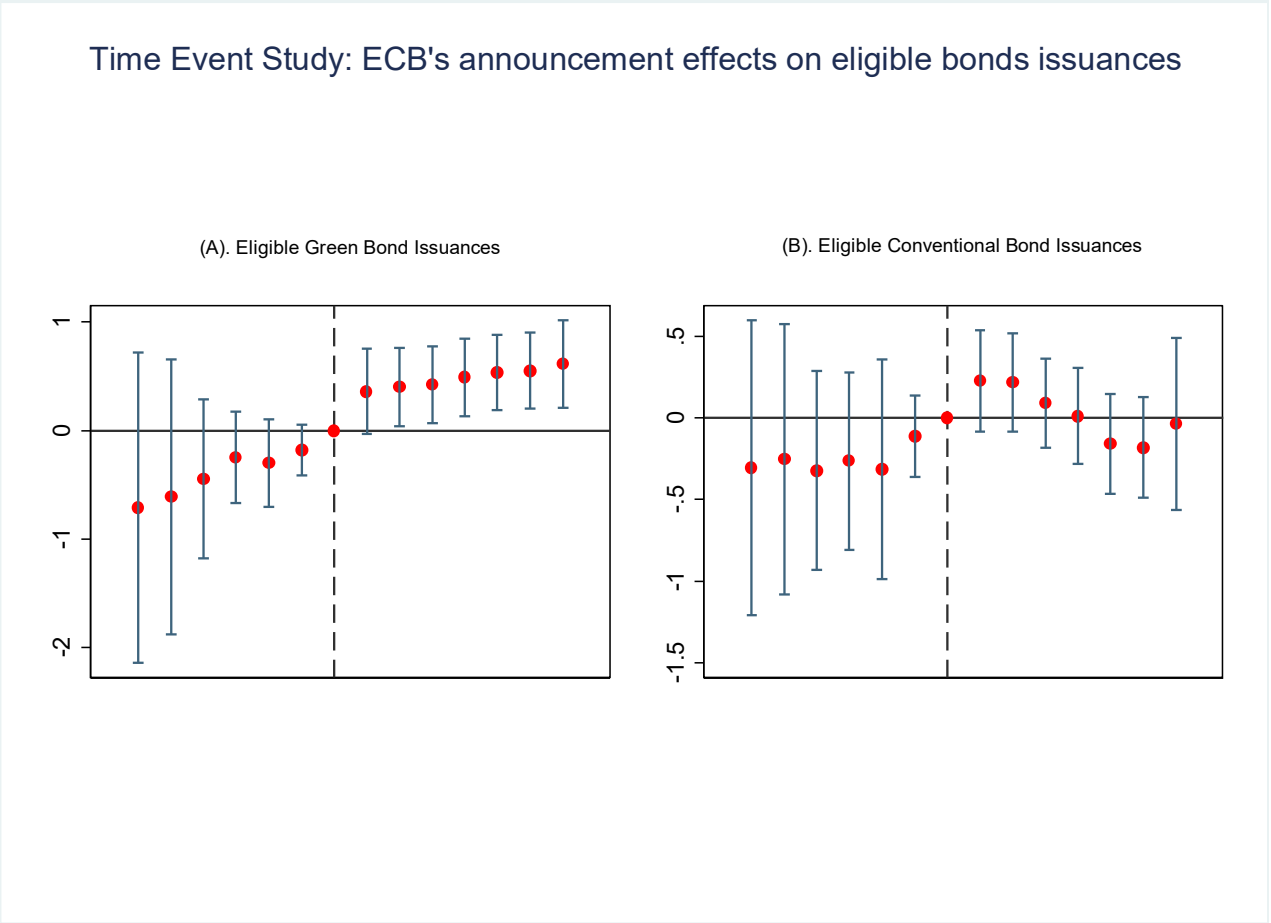

Figure 4. Time event study for green and conventional cumulative bond issuance. For consistency with the PEPP results, 6 pre-treatment period and 7 post-treatment periods are depicted. The graphs depict point estimates and 95% confidence intervals using robust standard errors clustered at the issuer level. Panel A shows the estimated coefficients related to the differential impact on green cumulative eligible bonds compared to total green non-eligible bonds in each quarter. Panel B shows the estimated coefficients related to the differential impact on conventional cumulative eligible bonds compared to total conventional non-eligible bonds in each quarter.

Tables

Table 1. Summary statistics of bond sample

Variable	Obs	Mean	Std. dev.	Min	Max
Panel A - All Bonds					
Yield	146,280	0.0035	0.0029	0.0005	0.0128
Yield to maturity	135,652	0.0003	0.0003	0	0.0012
ASW	135,633	0.0303	0.0330	0.0016	0.1215
Sovereign spread	135,287	0.3367	0.3274	0.0557	1.2379
bid-ask spread	107,680	0.0082	0.0085	0.0007	0.0326
Amount issued	146,200	555,083	1,194,716	0	20,000,000
Panel B - Eligible Conventional Bond (*Control group*)					
Yield	53,550	0.002	0.001	0.001	0.006
Yield to maturity	51,310	0.000	0.000	0.000	0.001
ASW	51,310	0.011	0.009	0.002	0.121
Sovereign spread	51,310	0.152	0.090	0.056	1.238
bid-ask spread	41,541	0.007	0.007	0.001	0.033
Amount issued	53,550	587,856	348,215	15,000	2,500,000
Panel C - Eligible Green Bond (*Treated group*)					
Yield	4,412	0.001	0.001	0.001	0.004
Yield to maturity	3,932	0.000	0.000	0.000	0.000
ASW	3,932	0.010	0.007	0.002	0.040
Sovereign spread	3,932	0.139	0.068	0.056	0.432
bid-ask spread	3,541	0.006	0.005	0.001	0.033
Amount issued	4,412	630,678	294,022	100,000	1,750,000

Note: This table provides the summary statistics of key variables used in the analysis below for the samples of eligible green bonds andconventional eligible bonds. Panel A exhibits the summary statistics for the entire bond sample since January 1, 2020 to July 31, 2020. Panel B and C provide the summary statistics for conventional eligible bonds (control group) and eligible green bonds (treated group).

Table 2. Summary statistics of cumulative issuances

Variable	Obs	Mean	Std. dev.	Min	Max
Panel A - Total sample					
Total cumulative issuance	31,616	482,917.00	4,683,119	0	340,000,000
Green cumulative issuance	31,616	28,146.42	364,648	0	14,300,000
Conventional cumulative issuance	31,616	454,770.60	4,616,922	0	340,000,000
Panel C - Non-eligible firms (*Control group*)					
Total cumulative issuance	28,320	289,775.90	4,652,004	0	340,000,000
Green cumulative issuance	28,320	16,511.95	226,347	0	11,000,000
Conventional cumulative issuance	28,320	273,263.90	4,634,641	0	340,000,000
Panel B - Eligible firms (*Treated group*)					
Total cumulative issuance	3,296	2,142,431.00	4,621,600	0	47,600,000
Green cumulative issuance	3,296	128,112.60	907,922	0	14,300,000
Conventional cumulative issuance	3,296	2,014,318.00	4,146,981	0	33,400,000

Note: This table provides the summary statistics of key variables used in the analysis for the samples of eligible green bonds and conventional eligible bonds. Panel A exhibits the summary statistics for the entire bond sample from Q1 2018 to Q4 2021. Panels B and C provide the summary statistics for eligible green bonds (treated group) and conventional eligible bonds (control group).

Table 3. Green bond yield reaction to the PEPP's announcement

	(1)	(2)	(3)
Variable:	Yield to Mat.	Yield to Mat.	Yield to Mat.
Green x Post	**-0.0141**	**-0.0644*** **	**-0.0631*** **
	(0.0217)	(0.0119)	(0.00989)
Post	0.890***	0.888***	
	(0.0128)	(0.00615)	
Green	-0.148***		
	(0.00957)		
Constant	0.524***	0.461***	0.886***
	(0.00398)	(0.00239)	(0.00218)
Observations	53,966	53,966	53,966
R-squared	0.1	0.547	0.577
Firm FE	No	Yes	Yes
Daily FE	No	No	Yes

Note. The table provides the results of Eq. (2). The dependent variable is the yield to maturity atdaily frequencies. Panel A provides the baseline specification of Eq. (2). In Column 1, model doesnot include the fixed effects. Column 2 includes the firm fixed effects. Column 3 includes the firm and daily fixed effects. The standard errors are clustered by firms and days.

Table 4. Portfolio rebalancing mechanism for eligible green bonds compared to conventional eligible bonds

	(1)	(2)	(3)	(4)	(5)	(6)
	High	Upper Medium	Lower Medium	0-5	5-10	11-30
Variable:	Yield to Mat.	Yield to Mat.	Yield to Mat.	Yield to Mat.	Yield to Mat.	Yield to Mat.
Green x Post	**-0.0976*** **	**-0.1054*** **	**-0.1415*** **	**-0.0338**	**-0.0826*** **	**-0.0226*** **
	(0.0118)	(0.0089)	(0.0114191)	(0.0245)	(0.0827)	(0.0087)
Constant	0.5462***	0.7279***	0.9462***	0.719***	0.8997***	1.2447***
	(0.0039)	(0.0021)	(0.0023298)	(0.005)	(0.002)	(0.002)
Observations	960	11,974	22,400	23,527	21,097	9,342
R-squared	0.9645	0.8911	0.8260	0.427	0.886	0.880
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Daily FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes

Note. The dependent variable in each column is the yield-to-maturity. Column 1 provides results restricting the sample on High eligible bonds (Aa1, Aa2, Aa3 or equivalent). Column 2 exhibit results accounting for Upper Medium credit rating (A1, A2, A3 or equivalent). Column 3 provides empirical resultson Lower Medium credit rating (Baa1, Baa2, Baa3 or equivalent). Column 4 restricts the sample of eligible bonds for bonds' maturity in range 0-5 years. Column 5 restricts the sample of eligible bonds for bonds' maturity in range 5-10 years. Column 6 shows the results related to the bond's maturity in therange 11-30 years. Green dummy variables take value one whether bond is labelled as green. The post takes value one after the PEPP's announcement. All specifications provided include the firm and day fixed effects. Furthermore, we include the sector and country fixed effects to account the heterogeneityin both industry sector and country. The standard errors are clustered by firm and day.

Table 5. Total cumulative green bonds' issuance

Variables	(1) Total Green Cum. Issuance	(2) Total Green Cum. Issuance	(3) Total Green Cum. Issuance	(4) Total Green Cum. Issuance
Treat	0.132	0.424	0.456	0.361
	(0.482)	(0.455)	(0.443)	(0.449)
Post	0.0375***	0.0741***	0.0111	-0.0169
	(0.00829)	(0.0196)	(0.0134)	(0.169)
Treat x Post	**1.060****	**0.785****	**0.716****	**0.818****
	(0.457)	(0.377)	(0.361)	(0.390)
Allowance Price				0.00211*
				(0.00120)
Trend				-0.0493
				(0.0652)
Leverage		-0.0309	0.00354	0.00311
		(0.0354)	(0.0469)	(0.0507)
Norm. Ebitda		-0.0394	-0.00592	-0.0465
		(0.0876)	(0.0959)	(0.118)
Log(Assets)		0.00808	0.0117	0.00780
		(0.0202)	(0.0225)	(0.0219)
Constant	0.0101**	-0.138	-0.168	0.313
	(0.00505)	(0.447)	(0.489)	(0.715)
Observations	39,520	6,698	6,650	6,650
R-squared	0.154	0.223	0.246	0.270
Number of i	1,976	426	423	423
Control Variables	No	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Quarterly FE	Yes	Yes	Yes	Yes
Country X Year FE	No	No	Yes	Yes
Sector X Year	No	No	Yes	Yes

Note. The dependent variable is the total green cumulative issuance of bonds. The time span covers the period from 2018 to the end of 2021. Treat variable takes value 1 whether firms issuePEPP' eligible bonds. The post takes the value 1 after the PEPP's announcement in the first quarter of 2020. Treat x Post is the interaction term and represent the main interest coefficient. Column 1 excludes the control variables. Column 2 provides results controlling for firms' features. Column 3 shows the saturated models including Country x Year fixed effects and the Sector x Year fixed effects. Column 4 shows the results when allowance's price and time trend are included into the analysis. Standard errors are clustered at the firm level.

Table 6. Total conventional bonds cumulative issuance

Variables	(1) Total Conv. Cum. Issuance	(2) Total Conv. Cum. Issuance	(3) Total Conv. Cum. Issuance	(4) Total Conv. Cum. Issuance
Treat	-0.355	-0.457	-0.413	-0.577
	(0.705)	(0.578)	(0.561)	(0.571)
Post	0.544***	1.109***	0.494***	0.0338
	(0.177)	(0.116)	(0.173)	(0.469)
Treat x Post	**1.196***	**0.824**	**0.747**	**1.011***
	(0.662)	(0.596)	(0.575)	(0.596)
Allowance Price				0.00893***
				(0.00240)
Trend				-0.274**
				(0.133)
Leverage		0.100	0.142	0.0862
		(0.342)	(0.356)	(0.370)
Norm. Ebitda		-0.390	-0.495	-0.515
		(0.390)	(0.372)	(0.418)
Log(Assets)		0.0450	0.0807	0.0790
		(0.145)	(0.145)	(0.154)
Constant	0.239***	-0.125	-0.290	2.410
	(0.0795)	(3.120)	(3.101)	(3.495)
Observations	39,520	6,698	6,650	6,650
R-squared	0.003	0.169	0.199	0.243
Number of i	1,976	426	423	423
Control Var.	No	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Quarterly FE	Yes	Yes	Yes	Yes
Country X Year FE	No	No	Yes	Yes
Sector X Year	No	No	Yes	Yes

Note. The dependent variable is the total conventional cumulative issuance of bonds. The time span covers theperiod from 2018 to the end of 2021. Treat variable takes value 1 whether firms issue PEPP' eligible bonds. Post takes value 1 after the PEPP's announcement in the first quarter of 2020. Treat x Post is the interaction term and represent the main interest coefficient. Column 1 excludes the control variables. Column 2 providesresults controlling for firm's features. Column 3 shows the saturated models including Country x Year fixed effects and the Sector x Year fixed effects. Column 4 shows the results when allowance's price and time trendare included into the analysis. Standard errors are clustered at firm level.

Table 7. Role of environmental related policies for eligible issuers

Variable:	(1) Total Cumulative Conv. Issuance	(2) Total Cumulative Green Issuance
Policy	-0.73***	-0.0581*
	(0.1779)	(0.0329)
Post	1.0409***	0.0871
	(0.1879)	(0.0698)
Treat	0.0388	0.8528**
	(0.3255)	(0.3942)
Policy x Post	0.473**	0.0313**
	(0.201)	(0.0155)
Policy x Treat	0.171	-0.412
	(0.482)	(0.593)
Post x Treat	-0.234	-0.276
	(0.266)	(0.243)
Policy x Post x Treat	**0.2861**	**1.3283****
	(0.5584)	(0.6231)
All. Price	0.0112***	0.00293*
	(0.00318)	(0.00158)
Trend	-0.102	-0.0518
	(0.0991)	(0.044)
Leverage	0.661	-0.195*
	(0.654)	(0.104)
Ebitda	-1.630**	-0.0839
	(0.82)	(0.224)
Log(Assets)	0.528	-0.0145
	(0.367)	(0.0487)
Constant	-10.01	0.804
	(8.441)	(1.179)
Observations	4,378	4,378
R-squared	0.265	0.296
Number of i	315	315
Control Variables	Yes	Yes
Firm FE	Yes	Yes
Quarterly FE	Yes	Yes
Country X Year FE	Yes	Yes
Sector X Year	Yes	Yes

Note. The dependent variables are: total cumulative conventional bond issuance (Column 1) and total cumulative green bond (Column 2) the total cumulative issuance of bonds. The timespan covers the period from 2018 to the end of 2021. Treat variables takes value 1 whether firms issue PEPP' eligible bonds. Post takes value 1 after the PEPP's announcement in the first quarter of 2020. Policy takes value 1 if firm take in place a policy targeted to decrease carbon issue or other environmental related policies. Treat x Post x Policy is the interaction term and represent the main interest coefficient. We include the control variables for firms' debt demand (Leverage, Ebitda and Asset) and the market control variable (Allowance Price and Trend) Firmand quarterly fixed effects are included in all specification. We also control for Country x Year fixed effects and including Country x Year fixed effects. Standard errors are clustered at firm level.

APPENDIX

Appendix A. Detailed information

Appendix A.1. CSPP's technical features

In the aftermath of the 2009 financial crisis and the European sovereign debt crisis, the ECB has implemented several packages of unconventional monetary policies to sustain the economy and achieve price stabilization by ensuring the correct functioning of credit markets and low-interest rates in the Eurozone. The Asset Purchase Programmes (APP) includes four sub-programmes featured by different policy target assets: Covered Bond Purchases Programme (CBPP), Asset Backed Securities Purchase Programme (ABSPP), Public Sector Purchase Programme (PSPP) and Corporate Sector Purchase Programme (CSPP).

Announced on 10 March 2016 by the Governing Council of the European Central Bank, the program started in June 2016. The outright purchases of bonds issued by non-bank corporation established in the euro area has been carried out by six Euro system national central banks (NCBs).[13]

The criteria settled by the ECB to be eligible for purchase are the following:

- be denominated in euros;
- have a minimum first-best credit assessment of at least credit quality step 3 (rating or BBB- or equivalent) obtained from an external credit assessment institutions;
- be issued by a corporation established in the euro area, defined as the location of incorporation of the issuer;
- have a minimum remaining maturity of six months and a maximum remaining maturity of 30 years at the time of purchase.

Besides the improvement of firms' financing conditions as results of the CSPP's monetary policy measures, the ECB stimulated the corporate bond issuance as shown in Figure 1 (De Angelis et al., 2018; Zaghini, 2019). The increase in bonds' issuance remained concentrated among major Eurozone countries, i.e., Germany, Spain, France, Italy and the Netherlands. Put differently, in countries where the central banks are actively implementing corporate bond's purchasing, firms are encouraged to increase their market debt exposition.

[13] Nationale Bank van België / Banque Nationale de Belgique, Deutsche Bundesbank, Banco de España, Banque de France, Banca d'Italia, and Suomen Pankki/Finlands Bank.

Appendix A.2. Green bond identification

Investors, scholars and institutions adopt two main strategies to identify green bonds and establish an environmental link with the issued debt. The two main principles that drive the green identification are, i.e., the Green Bond Principle (GBP) and the Climate Bond Standard (CBS). Both sets of principles define as green bond any type of bond instrument whose proceeds are used exclusively to finance or refinance, in whole or in part, new and/or existing environmental projects, and which is aligned with the four core components of the Green Bond Principles or the Green Loan Principles. CBS broadens the definition to include loans and other debt instruments.

Concerning the GBP, they represent the voluntary best practice guidelines established in 2014 by a consortium of investment banks.[14] The ongoing monitoring and development of guidelines activities has been carried out by an independent secretariat hosted by the International Capital Market Association (ICMA), providing a yearly review and updating of the principles for environmental sustainability. The GBP drives issuers with guidance on key components for the issuance of a relevant Green Bond; assist investors by promoting and providing access to information necessary to assess the positive impact of their investments in green bonds; and help securities subscribers by directing the market to disclose useful information to facilitate multiple transactions. The GBP emphasizes the transparency required, the accuracy and the integrity of the information to be communicated and reported by issuers to stakeholders. The GBP have four core components, i.e., Use of Proceeds, Process for Project Evaluation and Selection, Management of Proceeds and Reporting.[15] The Green Bond Principles do not provide details on "green". The green definition is left to the issuer to determine. Broad green project categories suggested by the principles include, e.g., energy, buildings, transport, water management and waste management & pollution control, nature-based assets including land use, agriculture and forestry, industry & energy-intensive commercial and information technology & communications (ICT).

Contrary to GBP, which constitutes a voluntary set of principles for issuers, the Climate Bonds Initiative provides green definitions that are sector specific requested for

[14] The consortium was composed by the following investment banks: Bank of America Merrill Lynch, Citi, Crédit Agricole Corporate and Investment Bank, JPMorgan Chase, BNP Paribas, Daiwa, Deutsche Bank, Goldman Sachs, HSBC, Mizuho Securities, Morgan Stanley, Rabobank and SEB.

[15] For more detailed information, see the ICMA web site (https://www.icmagroup.org/sustainable- finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/) or the GBP (ICMA, 2021)

certification.[16] In order to receive the "Climate Bonds Certified" label, a prospective issuer of a Green or Climate Bond must appoint a third party, i.e., approved verifier, who will provide a verification statement that the bond meets the Climate Bonds Standard.

The CBS allows certification of a bond prior to its issuance, enabling the issuer to use the certification label in marketing efforts and investor roadshows. The CBS board confirms certification once the bond has been issued and the proceeds have been allocated to the projects and assets.

The CBS set a detailed taxonomy to identify what the key investments are that will deliver a low carbon economy. Specifically, the CBS taxonomy identifies the assets and projects needed to deliver a low carbon economy and gives GHG emissions screening criteria consistent with the limit settled by the COP 21 Paris Agreement. The CBS Taxonomy turn out eight different macro classes of investment that may be funded by green bond emissions related to the following sectors: energy, transport, water, buildings, land use & marine sources, industry, waste and ICT.

[16] More detailed information on certification process is provided by CBS board (https://www.climatebonds.net/certification/get-certified).

Appendix B. Further information

Table B.1. List and definition of variables used in the analysis

Variables	Definition	Source
Bond variables		
Yield to Maturity	Yield to maturity	Datastream
ASW	The spread is expressed as difference between yield's bond and the equivalent swap rate	Datastream
Bid-Ask Spread	Defined as the ask-bid price difference over the ask price	Datastream
Coupon	Dummy variable that takes value 1 if the bond allows a periodic payment	Datastream
Maturity	Bond maturity expressed in days	Datastream
Maturity to announcement	Residual bond's maturity according to the PEPP's announcement date	Datastream
Amount Issued	Logarithm of the bond's amount issued expressed in € billion	Datastream
Green	Dummy variable that takes value 1 if bond is labelled as "green" by Thomson Reuters Datastream	Datastream
Post	Dummy variable that takes value 1 after the 18th of March 2020	
Prime	Dummy variable that takes value 1 if credit rating belongs to the range (Aia or equivalent)	
High	Dummy variable that takes value 1 if credit rating belongs to the range (Aa1-Aa3) or equivalent	
Upper	Dummy variable that takes value 1 if credit rating belongs to the range (A1-A3) or equivalent	
Lower	Dummy variable that takes value 1 if credit rating belongs to the range (Baa1-Baa3) or equivalent	
Issuer variables		
Cum. Conventional Issuance	Quarterly cumulative sum for each firm of issued amount related to conventional bond	Screener
Cum. Green Issuance	Quarterly cumulative sum for each firm of issued amount related to green bond	Screener
Tot. cum. issuance	Quarterly cumulative sum for each firm of issued amount related to total bond	Screener
Green Issuer	Dummy variable that takes value 1 if issuer has issued a green bond prior to PEPP's announcement	Screener
Eligible	Dummy variable that takes value 1 if issuer shows a credit rating that complies with the CSPP's requirement	Screener
Post	Dummy variable that takes value 1 from Q1 2020 to Q4 2021	
Policy	Dummy variable that takes value 1 if firm undertakes environmental related policies prior to PEPP's announcement	
Rank A	Dummy variable takes value 1 if the policy rank is equal to (A-, A, A+)	Screener
Rank B	Dummy variable takes value 1 if the policy rank is equal to (B-, B, B+)	Screener
Rank C	Dummy variable takes value 1 if the policy rank is equal to (C-, C, C+)	Screener
Leverage	Total financial debt over total assets	Screener
Ebitda	Logarithm of firms' Ebitda	Screener
Log (Total Assets)	Logarithm of firms' total assets	Screener
Price Allowance	Annual based close price of emission's carbon allowance for each Eurozone country	EEXAG
Time Trend		

Appendix B.2. Matching procedures for bonds' analysis

Following the works by Abidi and Miquel-Flores (2018), Zerbib (2019) and Giovanardi et al. (2022), we address the heterogeneity in the bonds' sample by matching green and conventional bonds at announcement date using a nearest-neighbours procedure. Focusing on the unified framework of green quantitative easing, we follow the matching procedure provided by Giovanardi et al. (2022). The matching procedure involves the following variables, i.e., coupon dummy variables, bid ask spread, maturity (in year), maturity to announcement, notional amountand the yield spreads. Each variable is chosen at one trading day before the PEPP's announcement day. The matching procedure allows us to identify conventional bonds that are close/similar to the green bonds around the announcement. To obtain the propensity weights, a cross-section logit model is estimated. The caliper matching procedure has been used. We set the matching radius as one-fifth of p-scores' standard deviation. The p-score is obtained performing a logit model. We set the number of neighbors used to calculate the matchedoutcome equal to five. The regression is defined as follows:

$$Green_i = \beta_0 + \beta_1 Yield_i + \beta_2 Maturity_i + \beta_3 Amount_i + \beta_4 ASW_i + \varepsilon_i$$

where Green dummy variable takes value one if the bond is identified as "green" and zero otherwise. *Yield* is defined as is defined as the ratio of a coupon of a security to its market price. *Maturity* is calculated as residual maturity after the announcement. Maturity is defined in year. We include the logarithm of issued amount of bonds (*Amount*). *ASW* is the Spread Over Swap Curve estimated as difference between bond's yield and the equivalent swap rate of the currencythe bond is denominated in. All variables are winsorized at the 1st and 99th percentiles. We calculate robust standard errors.

Table B.2. Balancing test for matching procedure

	Unmatched	Mean			%reduct	t-test	
Variables	Matched	Treated	Control	%bias	|bias|	t	p>|t|
Yield	U	0.002	0.004	-71.80		-4.98	0.000
	M	0.002	0.002	0.50	99.30	0.04	0.967
Amount	U	13.025	12.443	51.00		3.63	0.000
	M	12.989	12.947	3.70	92.80	0.23	0.815
Maturity	U	10.014	6.304	33.60		3.63	0.000
	M	6.984	7.171	-1.70	95.00	-0.16	0.874
ASW	U	0.020	0.042	-57.70		-3.42	0.000
	M	0.020	0.020	0.00	100.00	0.00	0.999

Note. Table B.2 provides the balancing test for matching procedure. U is the unmatched sample and M is matched sample. The covariates are: *i*) yield, *ii*) logarithm of amount issued, *iii*) residual maturity, *iv*) assetswap spread. All values are referred to the previous day to the PEPP's announcement, i.e., 17 February 2020.

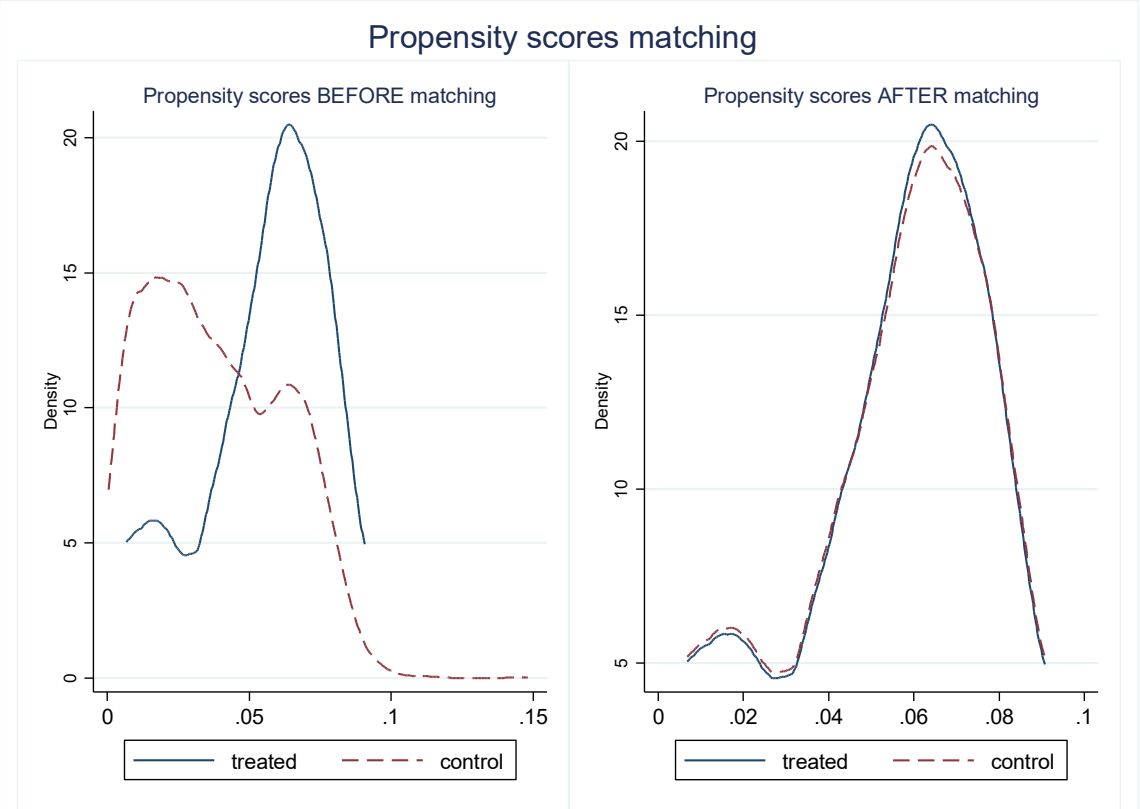

Figure B.1. Plot of propensity score before and after matching procedures. Figures provides the propensity score before and post matching procedure.