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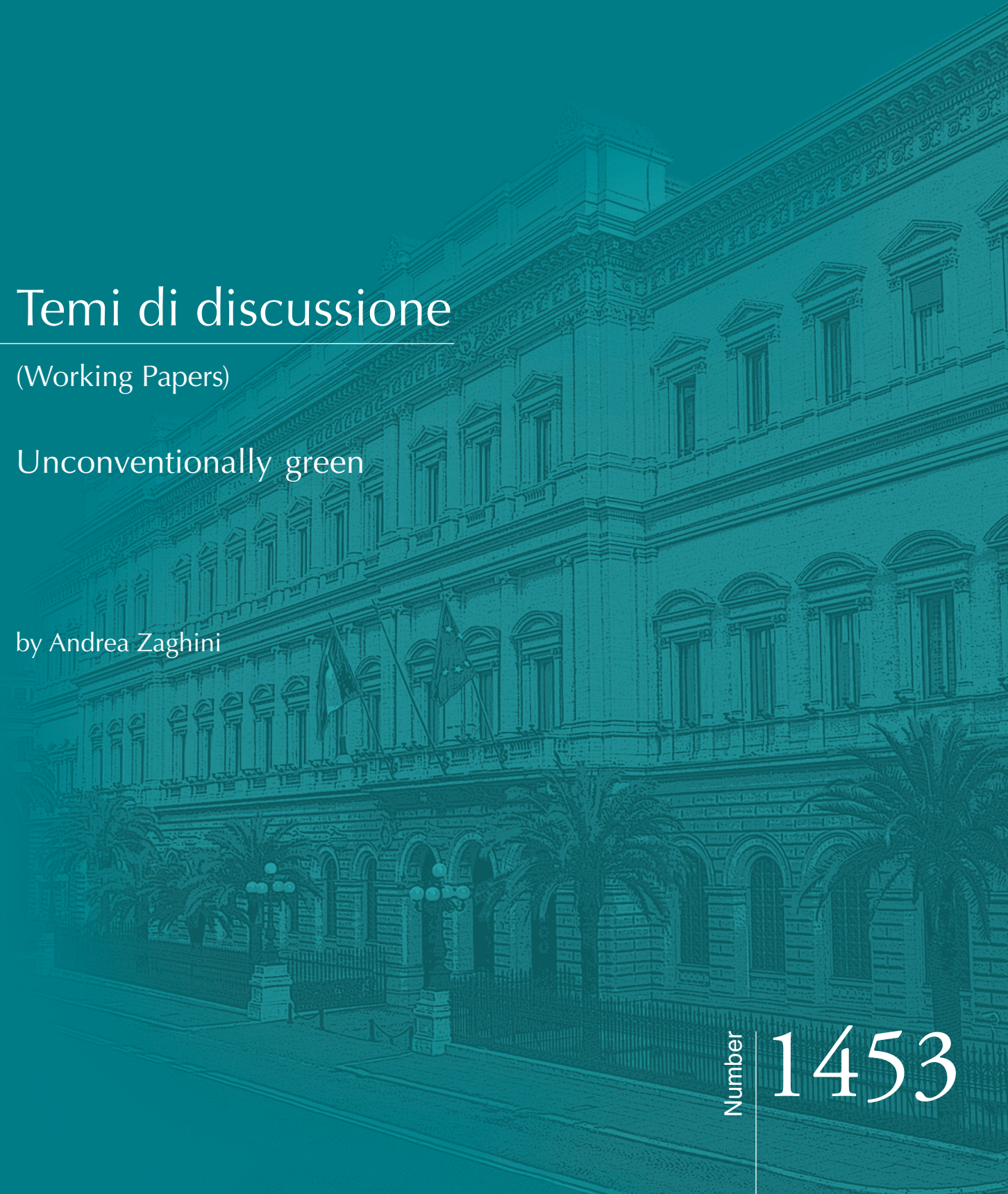
(Working Papers)

Unconventionally green

by Andrea Zaghini



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UNCONVENTIONALLY GREEN

by Andrea Zaghini*

Abstract

We analyse the effects of the Pandemic Emergency Purchase Programme (PEPP) launched by the ECB after the outbreak of the COVID-19 pandemic. The effects of the programme were different from those of the previous asset purchases. The PEPP significantly reduced the yield on bonds that at the same time were eligible for the programme and showed a green label. Via a triple difference estimator, we show that this effect is in addition to the outperformance of green vs non-green bonds that also occurred in the set of non-eligible bonds. All in all, the estimated impact stands at 51 basis points, a value that is also significant from an economic point of view: around 20 per cent of the cost of issuing a bond. From a climate change perspective, this evidence suggests that asset purchase programmes are an effective way of supporting firms financing climate-friendly investments on the bond market. In addition, we find that the issuers that benefited most from the PEPP improved their ESG performance to a larger extent than other issuers.

JEL Classification: G15, G32, E52, C21.

Keywords: corporate quantitative easing, ECB, green bonds, greenium, triple difference estimator.

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1 Introduction[1]

On 18 March, 2020, in the wake of the diffusion of the Covid-19 pandemic, the ECB launched the Pandemic Emergency Purchase Programme (PEPP). The programme was a new private and public sector quantitative easing (QE) of temporary nature and was announced as different from the already existing and running CSPP (Corporate Sector Purchase Programme). The aim of the PEPP was to face the financial markets disruptions and any involuntary tightening of the monetary policy conditions due to the Covid-19 induced crisis. Indeed, while the Covid-19 virus had been spreading since late 2019, market reactions started only after the first significant set of interventions taken from 23 February, 2020. In the following 30 days, stock markets collapsed and volatility surged. The same noticeable development also affected the bond market, in which the yield of both investment grade (IG) and high yield (HY) bonds skyrocketed in the euro area above the peaks reached during the sovereign debt crisis in 2012.

The PEPP shares many features with the CSPP, concerning in particular the bond eligibility. The eligibility is linked to three main characteristics: at least one investment grade assessment from the top rating agencies, the denomination in euro, the incorporation of the issuing institution in a euro-area country. While non-financial corporations (NFCs), insurance corporations and other non-bank financial institutions are allowed to the programme, banks are excluded. However, the PEPP also significantly differs from the CSPP as concerns the programme implementation across asset classes. In particular, purchases were announced to be conducted in a more flexible manner on the basis of the market conditions. Furthermore, the size of the PEPP, at an initial rate of euro 120 billion per month, was much larger than that of the CSPP.

While the literature is abundant regarding the CSPP, it is surprisingly scant concerning the effect of PEPP. We aim at filling this gap by investigating whether the increased size and flexibility of the programme influenced corporate bonds differently across market segments, even within the class of eligible bonds.

We focus on green bonds and we do so for two main reasons. The first concerns the fact that the main mechanism through which security prices in the primary bond market are affected by

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the QE is the portfolio rebalancing channel. This transmission channel hinges on imperfect asset substitutability and preferred-habitat investors. Investors are moved away from the central bank targeted segment and towards non-targeted segments by the large QE purchases. In this way also other segments are able to benefit of an increased demand that, in turn, reduces bond yields across the market. However, when there is strong segmentation in the targets bonds' class, the direct effect experienced by the bonds effectively targeted will be larger than the indirect effect experienced by non-targeted bonds (Bernanke 2012, Vayanos and Vila 2021).[2] Green bonds are among the less substitutable assets in the market, since they represent a still limited share of the market and have a built-in feature that makes them different from all other bonds: their proceeds are univocally committed to the financing of low-carbon, climate-friendly projects. Thus, a stronger effect might be expected on this segment, especially on the sub-segment of eligible green bonds.

The second reason is that eligible green bonds were the most likely target of the increased flexibility of the PEPP. The corporate bond purchases under the previous CSPP programme were committed to maintain the market neutrality, i.e,. they had to be proportional to the market portfolio. While the President of the ECB, Christine Lagarde, has always been recognized as a champion in the fight against climate change, this approach has been strongly criticized and shown to be tilted towards "brown" firms, that represent the vast majority of euro-area issuers (Dafermos et al. 2020; Papoutsi et al. 2021; Schoenmaker 2021).[3]

In order to correctly disentangle the effects of the ECB purchases on the green bond segment, we provide a novel identification strategy. We take into account two layers of difference, the one between green and non-green bonds, and that between eligible and non-eligible bonds. Indeed, there are green bonds eligible to the PEPP and green bonds that are not. The current literature has neglected this issue, but taking into account both layers of difference is of utmost importance in setting the correct econometric approach, since otherwise the identification strategy would not be complete and the estimated effects on green bonds could not be attributed to the ECB monetary

[2] Note that while other channels of transmission – such as the signaling, liquidity and inflation channel – might be at work on secondary market trades (Krishnamurthy and Vissing-Jorgensen 2011), the portfolio rebalancing channel is the most effective in the primary bond market (Zaghini 2019).

[3] At the same time, an increased role of green issuance was expected in the European market due to the idea that a "green recovery" through sustainable energy investments could have helped governments out of the Covid-19 crisis and towards a low carbon environment (Bleischwitz 2020, IEA 2020, IMF 2020, NGFS 2020). As a matter of fact, few months later, the EU announced the NextGenerationEU, a recovery instrument endowed with 750 billion euro, that provides financial support for investments and reforms, with a minimum of 37% of the total amount granted to each member state dedicated to climate change measures.

policy. Consider for instance a traditional difference-in-differences (DID) regression centred on the PEPP announcement that isolate the effect on eligible green bonds with respect to eligible non-green bonds. Also assume that the effect in the period post announcement is estimated at 30 basis points. Can we say that the PEPP effect on (eligible) green bonds is 30 basis points? Not yet, because we do not know what happened to green bonds in the segment of non-eligible bonds. Indeed, suppose that over the same time span green non-eligible bonds outperformed non-green non-eligible bonds by 30 basis points again. This would put the estimated effect of the PEPP in a completely different light, suggesting that it was most likely nil.

We proceed as follows. First, we run two separate DID regressions for the group of eligible bonds only and the group of green bonds only, respectively. We then perform a difference-in difference-in differences regression (or triple difference estimator - DDD) to check whether within the group of bonds eligible to the PEPP, those that were also green benefitted from a different market pricing. The DDD approach provides the ideal econometric framework for the latter goal, since it takes into account the development in two control groups. When estimating the effect of the purchases on eligible green bonds with respect to eligible non-green bonds, it also takes into account the change in the additional control group of non-eligible bonds. Actually, it can be shown that the DDD estimator is the difference between two DID estimators. The one estimating the difference between eligible green bonds and eligible non-green bonds after the PEPP announcement and that estimating the difference between non-eligible green bonds and non-eligible non-green bonds (Olden and Møen 2022).

To preview our results, we find that whole set of green bonds (regardless of the eligibility to the ECB programmes) faced a reduction in the spread at issuance of 28 basis points after the launch of the PEPP. However, this reduction is distributed differently between eligible and non eligible bonds. Non-eligible green bonds benefitted from a yield reduction of slightly more than 20 basis points, while bonds that were at the same time green and eligible benefitted from an additional reduction in the range 30-40 basis points. The evidence gathered suggests that central banks' asset purchase programmes might substantially contribute to the channelling of resources towards green project by lowering their funding cost. In addition, by investigating the company specific development of the ESG scores, we find that the issuers that benefitted most from the PEPP improved their environmental performance to a larger extent than other issuers.

The rest of the paper is as follows. Section 2 places the contributions of the paper within the current literature. Section 3 describes the dataset. Section 4 introduces the empirical model and illustrates the results. Section 5 proposes some robustness checks and looks at companies' ESG performance. Section 6 concludes.

2 Related literature

The contributions of the paper span over two different strands of the current literature. The one analysing the effects of ECB corporate purchases and QEs in general, and that concerning the assessment of a possible (negative) premium on green bonds.

The launch of the CSPP in 2016, the first corporate quantitative easing by the ECB, generated a new wave of interest towards the consequences of unconventional monetary policy measures on market prices and quantities and on non-financial corporations' business developments.

Focusing on secondary trades over a 23-week period around the CSPP announcement, Todorov (2020) finds that the ECB programme substantially increased prices and liquidity of bonds eligible to be purchased. In particular, eligible bond yields dropped on average by 30 basis points after the CSPP announcement. Rischen and Theissen (2021) report a structural change in abnormal returns after the CSPP announcement, especially for eligible bonds that benefitted from a discount of 24 basis points with respect to non eligible bonds. Relying on a novel regression discontinuity design, Li et al. (2021) provide an even smaller estimates in the range 17-22 basis points. Moreover, Pegoraro and Montagna (2021) suggest that the market was very quick in pricing the effect of the CSPP. After accounting for systematic risk exposure and for firm-level risk, they show that eligible bond spreads dropped by more than 10 basis points over the first two days relative to non-eligible bonds.

Over the longer time span of six months after the CSPP announcement, Zaghini (2019) estimates that the effect on new eligible bonds reached the 50-70 basis points range. However, this effect weakened significantly up to disappearing in the following months, suggesting the working of the portfolio rebalancing channel. This effect rests on the circumstance that large QEs are similar to a demand shock that crowds out other investors in the targeted segment (Bernanke 2012, D'Amico and King, 2013, Vayanos and Vila 2021). Thus, the CSPP programme, after six months of robust

purchases and increasing prices, pushed other investors out of the eligible bond segment towards non-eligible bonds, which are imperfect substitutes and usually have higher expected returns. The rebalancing by investors other than the ECB generated an endogenous increase in the demand for non-eligible bonds able to lower their interest rates by an amount statistically comparable to that faced by eligible bonds. This finding is confirmed by Mäkinen et al. (2022) over the whole time span in which the CSPP was operating (2016-2018).

As concerns the effect on the bond issuance, De Santis and Zaghini (2021) isolate the CSPP effects by relying on the key eligibility feature of bond euro denomination. Via a DID approach, they estimate an increase in the issuance of euro denominated bonds relative to other foreign currencies of around 14% for eligible corporations with respect to the control group of non-eligible corporations. Along this line, Galema and Lugo (2021) investigate the capital structure of the issuers whose bonds were actually purchased by the ECB under the CSPP. They find that firms effectively targeted increased their relative use of market debt and the maturity of newly issued bonds more than non-targeted issuers.[4]

Relatively scant is the literature about the PEPP, both concerning the corporate (Bremus et al. 2021; Zaghini 2023) and the sovereign arms (Aymeric and Tripier 2021; Blot et al. 2021; Böninghausen et al. 2022). This is even more surprising given the many contributions about similar policy interventions by the Bank of England and the FED. The Bank of England introduced a new corporate programme (CCFF - COVID Corporate Financing Facility) on 23 March, 2020 to help businesses withstand the COVID 19-related disruption to their cash flows. In addition, it increased the already existing asset purchase programme (APP) to GBP 450 billion. Fatouh et al. (2021) show that these policy measures were timely and effective in easing trading conditions and reducing market volatility. Also the Federal Reserve (FED) responded aggressively expanding for the first time ever its quantitative easing facilities to include also corporate bonds on both the primary (Primary Market Corporate Credit Facility - PMCCF) and secondary market (Secondary Market Corporate Credit Facility - SMCCF). These measures were devised to purchase USD 300 billion of IG corporate bonds (later expanded to USD 850 billion). An increasing recent research has shown that the FED's intervention reduced risk premia, improved liquidity, and led to increased issuance

[4] A related literature investigated a different spillover effect of the CSPP: NFCs eligible to the programme substituted bond debt for bank loans, this in turn allowed banks to increase the lending to the NFCs that did not benefit from the CSPP. See Grosse-Rueschkamp et al. (2019), Arce et al. (2021) and Betz and De Santis (2022).

for both investment-grade and high-yield issuers.[5]

A second strand of the literature to which the paper is related is the one assessing the pricing of green bonds. Green bonds are debt instruments, whose proceeds are committed to the financing of low-carbon, climate-friendly projects. In addition, they are the best candidate to satisfy the appetite of investors attending to environmental concerns (BlackRock 2020). Indeed, both theoretical models and investors' surveys suggest that also non-pecuniary motives, specifically pro-environmental preferences, may motivate the holding of green assets (Krueger et al. 2020, Bolton and Kacperczyk 2021, Giglio et al. 2021, Pastor et al. 2021).

The empirical evidence gathered so far suggests that the pricing of green bonds often include a (negative) premium. For instance, Zerbib (2019) finds that for a set of 110 green bonds priced on global markets between 2013 and 2017 there is a statistically significant negative premium with respect to conventional bonds, even though very limited in magnitude (around 2 basis points). A more recent analysis by Baker et al. (2022) places the premium in a range of 5-9 basis points. Fatica et al. (2021) argue instead that non-financial corporations and especially supranational institutions benefit from a much larger premium (22 and 80 basis points, respectively). At the same time they find that green bonds issued by financial corporations do not enjoy any negative yield differential. Tang and Zhang (2020) reports that stock markets seem to respond positively to the announcement of green bond issuance, whereas Flammer (2021) documents a significant increase in firms' environmental performance after the issuance, that in turn indicates that green bonds are effective in improving companies' environmental footprint. However, both contributions do not find any price difference between green bonds and conventional bonds issued by the same firm.[6]

The only two papers that, to our knowledge, try to link the ECB monetary policy and the pricing of green bonds are Bremus et al. (2021) and Zaghini (2023). The latter proposes an analysis of the pricing development of bonds issued in the market in which the ECB is committed to purchase (labelled Eurosystem market). The econometric approach is based on the pricing model developed

[5] D'Amico et al. (2020), Gilchrist et a. (2020), Kargar et al. (2021), Haddad et al. (2021), Nozawa and Qiu (2021) and O'Hara and Zhou (2021) study the disruptions in the secondary corporate bond market and the improvement in the market functioning following the facilities announcement, Boyarchenko et al. (2022) focus on the primary market.

[6] Following the empirical implications of the model proposed by Pastor et al. (2021), a different branch of the literature looks at the ESG score of the issuers instead of the green label of the bonds. See for instance Halling et al. (2020), Ferriani (2022), Seltzer et al. (2022).

by Sironi (2003) for the primary bond market and covers the CSPP and the early phase of the PEPP. The period studied starts on January 2019 and ends in May 2020, just two months after the PEPP announcement. There are two main findings concerning eligible and green bonds that are of interest for our paper. The ECB asset purchases were not (selectively) effective under the PEPP. While the programme may have avoided a larger deterioration, the worsening in the market conditions that took place after the PEPP announcement was felt by eligible bonds in the same way as all other IG bonds. Over the period from mid-March to end of May 2020 the issuance cost increased by 55 basis points for both the eligible and non-eligible segment. The second finding concerns the set of green bonds: the author reports no evidence of a premium with respect to non-green bonds either up to the PEPP announcement or immediately after. However, he does not take into account the distinction between green eligible and green non-eligible bonds.

The paper by Bremus et al. (2021) looks at the development in the yield to maturity on secondary market trades of green bonds around the PEPP announcement (from January to October 2020). They propose three different DID regressions maintaining the eligible green bonds as the treated group and employing different control samples, that however are always made of green bonds only. In other words, the econometric approach is not suited to disentangle the ECB effect since it focuses on green bond trades only, entirely neglecting the market development of non-green bonds. The estimated effect of the PEPP strongly depends on the control sample used. It ranges from nil, when the control sample is made of green bonds issued by financial corporations, to 135 basis points, when the control sample is made of green bonds issued by non-financial corporations.[7]

With respect to Zaghini (2023), we have a different research question, a different econometric approach and a longer time span. In particular, we center the focus of our investigation on the PEPP, and we allow for windows around the announcement of different length (6, 9 and 12 months), that are always longer than the two-month period considered by the author. This is important since the primary bond market is not a time-continuous trading system. This is due to the fact that new issues occur at discrete points in time and are often agreed upon several days/weeks in advance. Thus, the transmission of monetary policy measures takes longer to show in bond prices than on secondary market trades. From Zaghini (2023), we instead take the methodology about how to

[7] With respect to a third control sample made of green bonds denominated in Swedish crowns the estimated effect is 15 basis points.

construct the market in which the ECB is active.

With Bremus et al. (2021) we have a partially overlapping research question. However, the differences in the econometric approach and the market of bond trades are substantial. First we rely on a more homogeneous sample in order to have a better fit between control and treated samples. We then apply a more refined econometric technique which is better suited for the task of correctly identifying the effect of the PEPP on a particular sub-set of the eligible bonds (i.e., those that are eligible and green at the same time). Finally, we rely on the bond pricing on the primary market, since focusing only on bonds regularly traded on the secondary market significantly reduces the sample size and might introduce a selection bias. In addition, the initial placement of the bond exactly defines the financing cost conditions for the issuer, whereas in secondary market trades the bond just shifts hands reflecting investors assessments at that moment without changing the cost for the original issuer.

3 The Eurosystem corporate market

On April 2016, the ECB set the conditions for eligibility to participate in the CSPP, its first corporate quantitative easing ever. Since then the ECB has only marginally updated them. Even when on March 2020, the ECB introduced more flexibility about procedure and the volume of the purchases within the PEPP, the original eligibility criteria were maintained.

The eligibility criteria are listed below and concern both the bond and the issuer:

- the bond must be eligible as collateral for Eurosystem credit operations;

- the bond must be denominated in euro;

- the bond must have a minimum first-best credit assessment of at least BBB- or equivalent (obtained from an external credit assessment institution);

- the bond must have a minimum (remaining) maturity of six months and a maximum (remaining) maturity of less than 31 years;[8]

- the issuer must be a corporation established in the euro area, defined as the location of

[8] The most relevant change to the eligibility framework concerned the expansion of the purchases to non-financial commercial paper, that was announced together with the PEPP on 18 March, 2020. For further details see the ECB press releases:
www.ecb.europa.eu/press/pr/date/2016/html/pr160421_1.en.html
www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr200318_1~3949d6f266.en.html

incorporation of the issuer;

- the issuer must not be a credit institution nor have any parent undertaking which is a credit institution.

From the eligibility criteria, it turns out that while the ECB targets IG bonds only, not all IG bonds are eligible. Provided that the other criteria are fulfilled, when an IG company that is incorporated in the euro area issues euro-denominated bonds they are eligible. When the same firm issues bonds in currencies other than the euro, they are not eligible. For instance, the German company BMW AG issued bonds in eight different currencies in 2019-2021 but only those denominated in euros were eligible for the ECB purchase. Another interesting case is that of IG extra-euro area companies which issued bonds via a financial vehicle incorporated in the euro area. The Japanese Toyota Corp, for example, cannot issue eligible bonds because of the nationality, but it may do so when the bond is issued via the subsidiary Toyota Motor Finance BV, which is incorporated in the Netherlands.

In order to have access to the universe of bonds placed on the primary market, we rely on one of the most used data provider: DCM Analytics by Dealogic. Taking into account two windows of 12 months around the PEPP announcement (March 2019 to March 2021) and the price availability at issuance, we end up with 23,367 bonds. They are placed all over the world from issuers not belonging to the three industry groups of "Government", "Development Banks and Multilateral Agencies" and "Export Credit Agencies". However, the ECB purchases the eligible bonds in a much smaller sub-set (the Eurosystem market) that includes only the 19 domestic euro-area markets and the generic European market, thus we end up with 7,470 bonds.[9]

Notwithstanding the geographical construction, the Eurosystem market is an open and international market. Since there are no nationality restrictions for the bond issuance in any of the local markets, that means that they also include foreign extra-euro area issuances from both other European countries and the rest of the world. Looking at the parent level, there are 1,676 corporations (which issued through 2,048 issuers) placing at least one bond over the period March 2019 - March 2021, for a total of 3.2 trillions euro (Table 1). While around one third of them shows a euro-area nationality (565 parents, for almost half of the bonds), the parent companies belong to 75 different

[9] We follow the procedure proposed in Zaghini (2023), that looks at the first two letters of the asset identification code (ISIN) of each bond, that univocally identify the market in which the bond is placed.

countries. In particular, there are 351 corporations from China, 160 from the UK and 123 from the US.

Table 1 - The Eurosystem market (March 2019 - March 2021)

Country	Parents	Issuers	Bonds	Value	Value %	Eligible	Green
Australia	19	25	79	24	0.7	0	1
Brazil	19	21	74	37	1.2	0	8
Canada	13	14	79	50	1.6	0	4
China	351	434	1,049	324	10.2	0	45
Euro Area	565	710	3,571	1,581	49.8	748	453
Hong Kong	43	53	140	41	1.3	4	9
Japan	26	34	115	50	1.6	16	6
Norway	15	19	110	47	1.5	11	23
Philippines	17	21	33	11	0.4	0	4
Sweden	41	52	352	88	2.8	34	93
Switzerland	30	37	109	56	1.8	36	19
United Arab Emirates	24	27	114	46	1.4	0	3
United Kingdom	160	190	550	260	8.2	52	17
United States	123	148	529	316	10.0	50	23
Rest of the World	230	263	566	241	7.6	41	38
Total	**1,676**	**2,048**	**7,470**	**3,172**	**100**	**992**	**746**

This Table presents some summary statistics of the Eurosystem bond market by country. Parents, Issuers, Bonds, Eligible (bonds), Green (bonds) are reported in units; Value is the amount placed in the market in billions euro. Value % is the percentage of the amount placed by each country. Sources: DCM Analytics, ECB.

A similar picture applies to the value issued: euro-area companies issued 50% of total value, followed by those from China, the US and the UK (10.2%, 10.0% and 8.2%, respectively). Also important is the role played by Switzerland and the other European countries which together account for another 7% of the total market size. As already explained, the fact that not all eligible bonds are issued by euro-area parents is not surprising: there are 244 bonds issued through euro-area incorporated subsidiaries by parents whose nationality is not from a euro-area country (mainly the UK, the US, Switzerland and Sweden).

Also for the 746 green bonds issued in the Eurosystem market, the euro-area corporations play the largest role with a share of 61%, followed by Sweden at 12.5% and China at 6%. However, if we look at the share of green bonds issued by each country over its own total in the Eurosystem market, we get a different picture: Sweden and Norway show shares above 20%, while the euro area stands at 12.7%, behind Switzerland and barely in front of the Philippines (17.4% and 12.1%,

respectively). This evidence suggests that the Eurosystem market is a favorite market for green bonds' placement.

As for the size of the green bond segment, it amounts to 10.7 per cent of whole market and around 7.4% of the total volume. The number of bonds that at the same time are eligible and green stands at 122 items. They are mainly issued by euro-area corporations (105 vs 17). Around 70% of them (85 bonds) were actually purchased by the ECB, either on the primary or secondary market.

4 The econometric analysis

Before relying on the DID approach to identify the PEPP effects, we refer to the asset pricing model proposed by Sironi (2003) for the primary bond market. This is done in order to isolate the sources of systematic difference across bonds. The bond spread with respect to a risk-free asset is related to the two main sources of risk of bond and issuer features and the market characteristics at the moment of issuance. Analytically:

$$spread_i = \beta_0 + \sum_k \delta_k V_{i,k}^{bond} + \sum_l \delta_l V_{i,l}^{issuer} + \sum_m \delta_m V_{i,m}^{market} + FE_i + \varepsilon_i \tag{1}$$

where $spread_i$ is the yield spread of bond i with respect to a risk-free asset and it represents the cost of issuing bond i. The set of the K variables tracking the bond features is V_k^{bond}, while the set of the L variables characterizing the issuing corporation of bond i is V_l^{issuer}. The additional set of M control variables V_m^{market} takes into account the financial market stress and the macroeconomic conditions. Finally, FE_i are *ad hoc* fixed effects constructed by sets of dummy variables to take into account idiosyncratic shocks.

Note that all variable values are taken at the time of issuance of bond i; therefore, for each bond i, the regressors' value is fixed at the time of placement. Thus, the model is structured as a cross-section and the estimation procedure can be thought of as equivalent to a standard pooled OLS estimation. The issuance date is just another characteristic of bond i and can be taken into account by a set of time dummies. A useful feature of the cross-section approach is that it allows a much larger selection of bonds and issuing institutions than a time series analysis. Indeed, many

bonds, especially from smaller issuers, are not constantly priced and traded in the secondary market and thus can not be used in a time series approach.

Following Imbens and Wooldridge (2007), the expansion of model (1) to a DID framework is straightforward. Focusing on the set of eligible bonds as the treated group, we have:

$$\begin{aligned} ASW_i &= \beta_0 + \beta_1 EB_i + \beta_2 Post_i + \beta_3 Post_i * EB_i + \\ &\sum_{k \cup l} \delta_j W_{i,j} + \sum_m \delta_m V_{i,m}^{market} + FE_i + \varepsilon_i \end{aligned} \tag{2}$$

where the measure of the cost of bond i placement is the asset swap spread (ASW_i), that is the difference between the bond yield and the yield of an asset swap contract of similar characteristics taken as the risk-free benchmark.[10] At the same time, EB is a dummy taking 1 for eligible bonds and 0 otherwise, and $Post$ is a step dummy taking 1 after the PEPP announcement and 0 before. The K+L bond and issuer characteristics are summarized in the W matrix.

As for the selection of the regressors, it is based on the traditional drivers of the risk premium. In particular, as regards the bond features, the variables taken into account are: the time to maturity at origination, the amount issued (single tranche), the currency of denomination, the coupon frequency and the type of deal (fixed, floating or zero-coupon). The variables characterizing the issuer include a measure of the creditworthiness of the corporation, the general industry sector and the business nationality.[11] As for the creditworthiness, we rely on the rating provided by the three most important rating agencies: Moody's, Fitch and Standard&Poors. Given the likely non linear relation between the probability of default and the rating, we use a set of dummy variables, one for each rating grade.[12]

In the set V_m^{market} of variables tracking the financial stress, there are three market indices at

[10] An asset swap contract is a synthetic instrument which allows an investor to swap the payments on a bond (i.e., coupons) to a floating rate payment (risk free rate plus the ASW spread), while maintaining the original credit exposure to the fixed rate bond. In the euro area, it is supposed to perform better than the spread with respect to sovereign bonds, especially in periods of high volatility and when the flight to safety phenomenon pushes the yield of the sovereign benchmarks below the fundamentals. The ASW spread is sourced from Bloomberg.

[11] The 31 sectors provided by DCM Analytics are: Aerospace, Agribusiness, Alcoholic Beverages, Auto/Truck, Banks, Chemicals, Computers & Electronics, Construction/Building, Consumer Products, Defense, Dining & Lodging, Finance other, Food & Beverage, Forestry & Paper, Healthcare, Holding Companies, Insurance companies, Leisure & Recreation, Machinery, Metal & Steel, Mining, Oil & Gas, Professional Services, Publishing, Real Estate/Property, Retail, Telecommunications, Textile, Tobacco, Transportation, Utility & Energy.

[12] The rating of the issuer is first linearized between 1 (CC/Ca) and 20 (AAA/Aaa), so that when the same bond receives more than one assessment from Moody's, Fitch and Standard&Poors they can be averaged. Then the average is transformed into a set of dummy variables.

the daily frequency: (i) the VSTOXX index, which is a measure of the equity market volatility in the euro area (computed relying on both call- and put-implied volatilities from the DJ Euro STOXX 50 index); (ii) the CISS bond index (Composite Indicator of Systemic Stress), which is the systemic stress indicator for the euro-area financial markets proposed by Hollo et al. (2012); (iii) the iTraxx Europe index (the average of 125 equally-weighted single-name European CDS spreads), which should capture market-wide variation in CDS spreads due to changes in fundamental credit risk, liquidity, and CDS market-specific shock (Acharya et al. 2014). In addition, also at the daily frequency, we include: (i) the index of macro news for the US and the euro-area provided by Citi; (ii) the index of economic policy uncertainty (EPU) by Baker et al. (2016) for the US and the UK; (iii) the nominal effective exchange rate of the euro computed by the ECB with respect to the 19 main trading partners of the euro area.

Furthermore, to take into account idiosyncratic shocks hitting at the country level, fixed effects constructed by multiplying quarterly and country dummies are introduced.

As usual in the traditional DID analysis, the coefficient of interest is β_3, that quantifies the differential behavior of the treated group with respect to the control group in the treatment period (with respect to the previous period). In other words, given the cross-sectional framework employed, β_3 estimates how different is the ASW on the eligible bonds placed in the *Post* period with respect to the non-eligible bonds placed in same period, taking into account the ASW spread difference between the two sets of bonds placed in the pre-PEPP period.

In order to be a valid control sample for the set of eligible bonds, we need the set of non-eligible bonds to trend in the same way as the eligible set before the PEPP: the so called parallel trend assumption (Imbens and Wooldridge 2007). Figure 1 shows the estimated difference between the ASW spread in the two samples over time. In particular, the coefficients are obtained from a regression of the ASW spread over quarterly time dummies and the quarterly dummies multiplied by the *EB* dummy tracking eligible bonds. The estimated difference, while being statistically significant and oscillating around -50 basis points, does not show any trend up to 2019Q4. This in turn suggests that it is legitimate to assume a common trend between eligible and non-eligible bonds up to PEPP announcement.

Figure 1 - Trend assumption (eligible vs non-eligible)

Estimated difference of the ASW spread at issuance between eligible and non-eligible bonds at the quarterly frequency (continuous line); 95% confidence interval (dotted lines); basis points. Source: Bloomberg; DCM Analytics; ECB.

Table 2 - PEPP effect on eligible bonds

Coefficient	Basic	DID	DID+
Eligible	-21.6159 **	-26.0854 **	-25.8346 **
	(8.3968)	(10.3235)	(10.4257)
Post		67.5987 **	70.292 **
		(28.1024)	(27.4553)
Eligible*Post		7.4050	6.1138
		(13.6899)	(13.7153)
Green			-23.0305 ***
			(5.8691)
Bond controls	YES	YES	YES
Issuer controls	YES	YES	YES
Short-term Market controls	YES	YES	YES
Country*Quarter FE	YES	YES	YES
Observations	5,610	5,610	5,610
R-square	0.7401	0.7405	0.7410

Results from regressions from model (1) and (2) over the period July 2019-September 2020. Eligible is a dummy taking 1 for eligible bonds and 0 otherwise; Post is dummy taking 1 after 18 March, 2020 and 0 before; Green is dummy taking 1 for green bonds and 0 otherwise. Source: Bloomberg, Dealogic DCM Analytics; ECB.

Table 2 reports the coefficient estimations from model (1), when just the EB dummy is added to the controls, and from two regressions from model (2). The windows around the PEPP announcement are set at 9 months. Over the whole period, eligible bonds benefitted from a significant negative premium of 22 basis points (column 1). This result is in line with the literature on the ECB corporate asset purchases (Todorov 2020, Li et al. 2021, Rischen and Theissen 2021). Given that eligible bonds are all rated IG, can be always used as collateral for the ECB main refinancing operations and rely on a stronger demand, they usually face a lower placement cost than similar non-eligible bonds.

However, when caught in the pandemic period post PEPP, eligible bonds did not perform better than the rest of the sample, maintaining the same difference as before the crisis. The estimated β_3 coefficient in column 2 is not statistically significant. As suggested by Zaghini (2023), this evidence can be explained by two circumstances: the change in the market composition and investors' portfolio rebalancing. As common during crisis periods, a flight-to-safety phenomenon moved financial agents away from the risky HY bonds and towards the safer IG segment, thus making the bond market more concentrated on bonds of similar characteristics (and prices) in the *Post* period. Regarding the second issue, after the starting of the purchases under the PEPP, a sizable share of the market became unavailable because of the large ECB demand, thus investors had to rebalance their portfolio with other assets. The choice was to buy bonds of similar creditworthiness: IG bonds which were non-eligible for the ECB asset purchases. This rebalancing in turn generated an endogenous surge in the demand for non-eligible IG bonds that was able to offset the price difference with respect to eligible bonds in the *Post* period. The result is confirmed in column 3, when the set of green bonds is introduced as an additional control variable.

While segment of eligible bonds as a whole did not (selectively) benefit from the introduction of the PEPP, the exceptional nature of the programme might have worked differently for bonds showing other characteristics, even within the set of eligible bonds. Since we argued that green bonds might have been the implicit target of the PEPP increased purchase flexibility, we now focus on the development of the ASW spread on green bonds in the two periods before and after the PEPP.

For the sake of clarity, we first run a set of regressions as if green bonds were the programme treated assets. This descriptive exercise is proposed as a benchmark analysis for the segment of

green bonds as a whole. In addition, it represents an intermediate step towards the DDD estimator by Olden and Møen (2022), that will be employed as the final step. Indeed, the DDD estimator is able to take into account an additional source of discrepancy between treated and non-treated items and provides the correct instrument for the identification of the PEPP effects.[13] Analytically:

$$\begin{aligned} ASW_i &= \beta_0 + \beta_1 GB_i + \beta_2 Post_i + \beta_3 Post_i * GB_i + \\ &\sum_{k \cup l} \delta_j W_{i,j} + \sum_m \delta_m V_{i,m}^{market} + FE_i + \varepsilon_i \end{aligned} \tag{3}$$

where GB is a dummy taking 1 for green bonds and 0 otherwise. Again, the coefficient of interest is β_3 that singles out the different price behavior of green bonds over the 9-month period after the PEPP announcement.

Figure 2 - Trend assumption (green vs non-green)

Estimated difference of the ASW spread at issuance between green and non-green bonds at the quarterly frequency (continuous line); 95% confidence interval (dotted lines); basis points. Source: Bloomberg; DCM Analytics; ECB.

As done for the set of eligible bonds, we first run a regression of the ASW development over time to control for the parallel trend assumption. Figure 2 confirms the statistical goodness of the non-green bonds sample as control group under model (3).

[13] The two sources of discrepancy are the eligibility to the programme and the green label of the bonds. As already explained in the Introduction, the DDD estimator can be thought of as the difference between a DID concerning the evolution of green and non-green bonds within the set of eligible bonds only and a DID concerning the evolution of green bonds and non-green bonds within the set of non-eligible bonds only.

From the basic estimation of model (1) reported in Column 1 of Table 3, we have evidence of a statistically significant negative premium (greenium) of 22 basis points over the 18 months around the PEPP. However, this evidence is better detailed when looking at the DID framework of model (3). The greenium was entirely absent before the PEPP (the coefficient β_1 is not significant in column 2 and 3) and then materialized in the 9-month period of ECB asset purchases. The β_3 estimate suggests a greenium of around 29 basis points.

Table 3 - PEPP effect on green bonds

Coefficient	Basic	DID	DID+
Green	-22.3326 ***	-5.1189	-5.1405
	(5.7009)	(6.1425)	(6.2560)
Post		73.1357 ***	74.8486 ***
		(25.3770)	(25.8860)
Green*Post		-28.7859 ***	-29.3756 ***
		(9.9902)	(9.8072)
Eligible			-22.7112 ***
			(8.3661)
Bond controls	YES	YES	YES
Issuer controls	YES	YES	YES
Short-term Market controls	YES	YES	YES
Country*Quarter FE	YES	YES	YES
Observations	5,610	5,610	5,610
R-square	0.7402	0.7408	0.7413

Results from regressions from model (1) and (3) over the period July 2019-September 2020. Green is a dummy taking 1 for green bonds and 0 otherwise; Post is dummy taking 1 after 18 March, 2020 and 0 before; Eligible is dummy taking 1 for eligible bonds and 0 otherwise. Source: Bloomberg, Dealogic DCM Analytics; ECB.

Given that the effects of the ECB increased demand take time to appear on the primary bond market, the reported evidence squares well with the results by Zaghini (2023) and Bremus et al. (2021). The greenium was not present before the PEPP or in a very early phase of bond purchases (Zaghini 2023), whereas the ECB purchases under the pandemic programme eased the green bond financing over a longer time span (Bremus et al. 2021).

While it seems that the PEPP was able to selectively involve a set of bonds different from eligible bonds, green bonds were not the direct target of the ECB programme, or at least not all of them. Indeed, only some of the green bonds issued in the period under analysis were also eligible for

the ECB purchases. In other words, both model (2) and model (3) fail to accommodate to the two layers of diversification among bonds: the green label and the eligibility to the ECB programme.

In order to disentangle the effects the PEPP, a different identification strategy must be employed. In particular, while remaining in the econometric framework of Imbens and Wooldridge (2007), we distinguish from the existing literature by taking a step further in the analysis. We move from the traditional DID estimator, that as just mentioned above can take into account one control group only, to the triple difference estimator (DDD) as recently revised by Olden and Møen (2022), that instead can take into account two control groups. The DDD estimator is perfectly suited to the task of assessing whether the bonds that at the same time are green and eligible were differently affected by the PEPP with respect to the other (non-eligible) green bonds. Analytically:

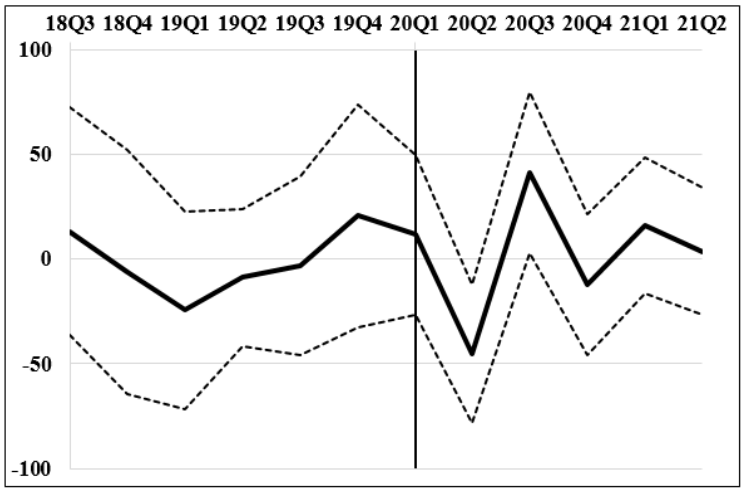
$$\begin{aligned} ASW_i &= \beta_0 + \beta_1 GB_i + \beta_2 EB_i + \beta_3 EB_i * GB_i + \beta_4 Post_i + \\ &\quad \beta_5 Post_i * GB_i + \beta_6 Post_i * EB_i + \beta_7 Post_i * EB_i * GB_i + \\ &\quad + \sum_{k \cup l} \delta_j W_{i,j} + \sum_m \delta_m V_{i,m}^{market} + FE_i + \varepsilon_i \end{aligned} \tag{4}$$

where the coefficient of interest is β_7. As explained in the Introduction, β_7 is the difference between two DID estimators. The first estimating the difference between eligible green bonds and eligible non-green bonds after the PEPP announcement, the second estimating the difference between non-eligible green bonds and non-eligible non-green bonds over the same time span. In other words, the triple difference estimator β_7 of the change in the ASW spread on eligible green bonds after the PEPP announcement comes net of the change happened to the rest of green bonds, namely those in the set of non-eligible bonds.

Two issues are worth noting. The first issue concerns the parallel trend assumption. Indeed, the statistical validity of the control group in model (4) involves two sets of bonds, one for each of the two DID estimators in which the DDD estimator can be decomposed.[14] Figures 3 and 4 show that no trends are at work in our control groups: eligible non-green bonds for the first DID, and non-eligible non-green bonds for the second DID included in model (4).

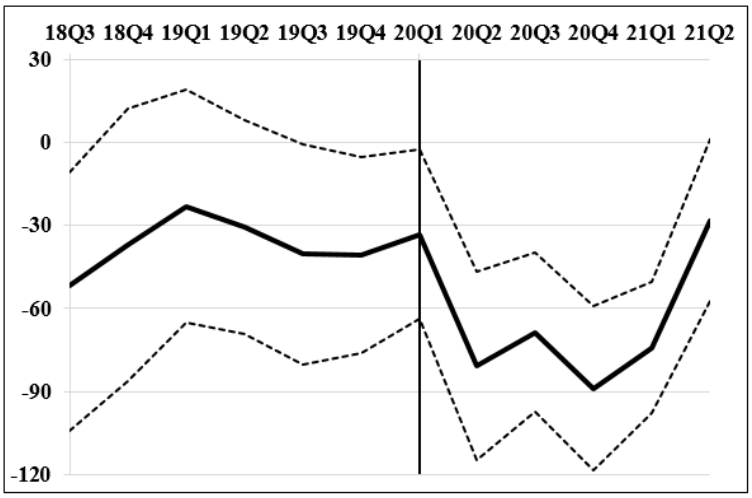
[14] Actually, even if trends were present (before the PEPP) it would be sufficient that the trends were common in both control groups in order to cancel out. According to Olden and Møen (2022), this hypothesis can possibly be tested by checking the parallel trend assumption for the ratio of the dependent variables in each control group.

Figure 3 - Trend assumption for the DDD estimator (control 1)



Estimated difference of the ASW spread at issuance between eligible green and eligible non-green bonds at the quarterly frequency (continuous line); 95% confidence interval (dotted lines); basis points. Source: Bloomberg; DCM Analytics; ECB.

Figure 4 - Trend assumption for the DDD estimator (control 2)



Estimated difference of the ASW spread at issuance between non-eligible green and non-eligible non-green bonds at the quarterly frequency (continuous line); 95% confidence interval (dotted lines); basis points. Source: Bloomberg; DCM Analytics; ECB.

The second issue concerns the estimate of the total effect on the selected group of eligible green bonds in the *Post* period. We have explained above that the coefficient β_7 provides the additional net effect that allows us to correctly identify the consequences of the ECB asset purchases. Thus

this effect does include the changes in the green segment as a whole and in the eligible segment as a whole. Following Olden and Møen (2022), in order to compute the total effect, we have to add three coefficients: β_5, β_6, and β_7. Since eligible green bonds are by definition green bonds, we need to look at the change in the *Post* period of that group (β_5). Analogously, they are by construction eligible, thus we have to add the change in the *Post* period of the set of eligible bonds (β_6). Finally, since neither β_5 nor β_6 include the differential effect of being both eligible and green, we have to add β_7. Thus, in Table 4 we report, in addition to the results of each regression, also the estimate of the total effect given by the sum of the three coefficients and the statistical significance of the T-test.

Model (4) estimation shows that indeed the effect of the PEPP was different within the set of eligible bonds. The estimated β_7 coefficient is statistically significant and negative at 39 basis points (Table 4, column 1), suggesting that eligible green bonds performed much better than eligible non-green bonds. While the whole set of green bonds benefitted from a negative premium of 22 basis points in the *Post* period (the β_5 coefficient), those that were also eligible for purchase by the ECB faced a final discount of 51 basis points (namely, $\beta_5 + \beta_6 + \beta_7$), fully reaping the benefits of the increased and diversified demand under the PEPP.

The size of the premium is significant also from an economic point of view. Given that the unconditional mean of the yield at issuance was 2.72% in the 9-month period up to the PEPP, the benefit gained by corporations issuing eligible green bonds after the PEPP stands at 19% of the cost of funding. From a climate change perspective, this evidence suggests that asset purchase programmes can be an effective way of backing segments of the bond market financing green investment and firms' sustainability projects. The cheaper financing conditions of corporations placing green bonds – especially when eligible to the central bank purchases – allow them to undertake climate-friendly investments at a lower cost.

Table 4 - PEPP effect on eligible green bonds

Coefficient	9-month	12-month	6-month	No banks	Bond IG	CSPP
Green	-12.2576	-16.1763	-6.5862	-12.285	-16.422 *	-43.044
	(7.0789)	(11.3214)	(8.8507)	(12.5136)	(9.6087)	(28.4413)
Eligible	-30.2915 ***	-40.6776 ***	-26.4816 **	-25.0800 **	-23.2082 ***	-45.2175 **
	(10.0412)	(6.2839)	(13.3376)	(10.7334)	(7.6914)	(9.0574)
Green & Eligible	41.0864 ***	40.2109 ***	38.8927 *	31.7503 **	38.7854 ***	63.1963 **
	(11.5938)	(14.4887)	(20.0103)	(12.0787)	(10.5422)	(28.2944)
Post	73.4279 **	81.0118 **	85.1484 *	116.571 ***	52.1135 **	-2.457
	(28.2548)	(31.6551)	(45.3230)	(36.5370)	(20.3901)	(12.5957)
Green*Post	-22.5071 **	-21.3326 *	-30.1940 **	-15.0948	-7.1927	10.6616
	(9.4865)	(12.5923)	(12.2692)	(13.4390)	(10.4939)	(33.2754)
Eligible*Post	10.3452	16.9340	9.3698	-18.1714	23.5131 **	20.5863
	(14.9722)	(11.5443)	(18.5587)	(13.7892)	(9.9404)	(10.4297)
Green*Eligible*Post	-39.0431 **	-28.4032 *	-26.0486	-28.9606 **	-61.5184 ***	-6.5196
	(19.1706)	(16.7374)	(30.3547)	(14.5436)	(18.6803)	(36.7577)
Total effect on E&G bonds	-51.2051 ***	-32.8019 **	-46.8729 *	-62.2269 ***	-45.1980 ***	24.7283
	(15.1737)	(12.6473)	(26.9860)	(13.8875)	(16.8076)	(29.1388)
Bond controls	YES	YES	YES	YES	YES	YES
Issuer controls	YES	YES	YES	YES	YES	YES
Country*Quarter FE	YES	YES	YES	YES	YES	YES
Short-term Market controls	YES	YES	YES	YES	YES	YES
No. observations	5,610	7,469	3,795	3,584	4,503	3,676
R^2	0.741	0.743	0.746	0.729	0.632	0.748

This Table reports the estimates of a DDD estimator around the PEPP (Pandemic Emergency Purchase Programme) announcement (18 March, 2020). The dependent variable is the bond ASW spread. Green is a dummy taking 1 for green bonds and 0 otherwise. Eligible is a dummy taking 1 for bonds eligible to the PEPP programme and 0 otherwise. In the first five columns Post is a dummy taking 1 after 18 March, 2020 and 0 before; in the sixth column taking 1 after 12 September, 2019 and 0 before. In the first, fourth and fifth columns the two time windows around the PEPP are set at 9 months; in the second column at 12 months and in the third column at 6 months. In the fourth column the sample is restricted to the bonds placed by non-bank companies only; in the fifth column by investment grade (IG) companies only. The last column reports the estimates of a DDD estimator around the CSPP (Corporate Sector Purchase Programme) announcement (12 September, 2019). The two time windows around the CSPP are set at 5.5 months. Source: Bloomberg; DCM Analytics; ECB.

5 Robustness

In order to confirm the role of the PEPP in driving the pricing of green bonds, we run several robustness checks concerning the length of the windows around the PEPP announcement and the composition of the control sample. We also run a placebo test to verify that the effect identified for the PEPP is exclusive of this new programme and is not common with the previous CSPP. In addition, we assess the post-PEPP performance of issuers of green and eligible bonds in terms of

ESG scores.

The better performance of green bonds within the segment of eligible bonds is confirmed when increasing the length of the windows around the PEPP announcement to 12 months (Table 4, column 2). The entire structure of coefficients' sign, magnitude and statistical significance follows closely that of the 9-month regression. The β_7 coefficient is estimated at the lower level of 28 basis points, making the whole gain in the *Post* period adding up to 33 basis points. When the length of the windows is reduced to 6 months, the structure is again maintained as concerns the sign and the magnitude of the estimated coefficients, but the statistically significance of the β_7 coefficient is lost (column 3). However, the total effect, estimated at 47 basis points, turns out to be significant and lies in between the estimates for the 9-month and 12-month windows.

Given that the purchases under the PEPP are limited to non-banks corporations only, we restrict the control sample of non-eligible bonds to those issued by NFCs, insurances and other non-bank financial institutions. Column 4 shows again that even in this more homogeneous sample the effect of the ECB purchases is different within the group of eligible bonds. Eligible green bond performed better in the *Post* period than eligible non-green by 29 basis points. Over the same period, the overall additional change stands at -62 basis points.

Another possible adjustment of the control sample is suggested by the fact that all eligible bonds have an investment grade rating as concerns the credit risk. Column 5 reports the regression estimates when the restricted sample of IG bonds is employed. The total effect in the *Post* period for the set of eligible green bonds is aligned with the previous results (45 basis points). We also have an additional insight on green bonds. There is evidence of a greenium of 16 basis points in the sample even before the launch of the PEPP: the β_1 coefficient is statistically significant. This in turn suggests that pro-environmental preferences were already at work before the PEPP and that investors were prone to accept a slightly minor return on green bonds provided that they were of good credit quality

To check whether the selective effect on eligible green bonds is associated to the PEPP only, and it is not common also to the standard corporate purchases programme by the ECB, we run a placebo test around the date of the announcement of the second wave of the CSPP (12 September, 2019). To not overlap with the PEPP, we tailor the two windows to the maximum length of 5.5 months. The lack of statistical significance from the last column of Table 4 shows that the segment

of green bonds was not involved in any yield change, both as a whole (coefficient β_5) and as a sub-set of eligible bonds (coefficient β_7). This in turn confirms that the PEPP effects were different with respect to more conventional ECB policy interventions.

A different check concerns whether the companies benefitting from the lower financing costs induced by the PEPP were also able to improve their environmental performance measured via the ESG score and the Environmental (E) score (sourced from LSEG Eikon). Following the notation adopted for the bonds, we label green companies (eligible companies) those that have issued at least one green (eligible) bond, and eligible green companies those that have issued at least one bond that, at the same time, is eligible and green.

Table 5 - PEPP effect on eligible green companies

Coefficient	ESG 2020	ESG 2021	ESG 2022	E 2020	E 2021	E 2022
Green	8.4443 ***	8.5875 ***	8.4853 ***	12.2565 ***	12.2160 ***	12.0188 ***
	(0.4500)	(0.4782)	(0.4621)	(0.3158)	(0.3176)	(0.3330)
Eligible	15.9891 ***	15.9879 ***	15.7365 ***	17.8183 **	18.4055 ***	18.0438 **
	(3.7145)	(3.9871)	(3.5979)	(4.5434)	(4.4581)	(4.5460)
Eligible & Green	-8.8195 *	-8.9616 *	-8.8975 *	-10.7811 **	-10.8616 **	-10.7796 *
	(3.5912)	(3.6474)	(3.7767)	(4.0541)	(4.0564)	(4.2615)
Post	2.9738 ***	6.0649 ***	6.4961 ***	3.0102 ***	6.0465 ***	6.6583 ***
	(0.2931)	(0.0855)	(0.0663)	(0.1434)	(0.1373)	(0.1129)
Green*Post	0.1534	0.3842	0.6883 *	0.8796 *	1.6287 ***	2.0372 ***
	(0.2127)	(0.2127)	(0.2127)	(0.4490)	(0.3158)	(0.1892)
Eligible*Post	-0.1579	-0.9883	1.4275	-0.5592 **	-2.0758 **	-2.4463 **
	(0.3849)	(0.6851)	(07772)	(0.1818)	(0.5086)	(0.6735)
Eligible*Green*Post	1.1196 **	0.9646 ***	1.2039 ***	1.8362 ***	1.8812 ***	2.2633 ***
	(0.3136)	(0.2356)	(0.3152)	(0.3919)	(0.3569)	(0.5161)
Total effect on E&G companies	1.1151 ***	0.2786	0.4647 *	2.1566 ***	1.4342 **	1.8542 ***
	(0.3841)	(0.2917)	(0.2503)	(0.0525)	(0.3808)	(0.2336)
Nationality FE	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES
Type FE	YES	YES	YES	YES	YES	YES
No. observations	3,296	3,220	3,207	3,296	3,213	3,197
R^2	0.218	0.235	0.239	0.258	0.268	0.273

This Table reports the estimates of a DDD estimator around the PEPP (Pandemic Emergency Purchase Programme). The dependent variable is the ESG score of the companies in the first three columns and the E (Environmental) score of the companies in last three columns. Green is a dummy taking 1 for the issuers of green bonds and 0 otherwise. Eligible is a dummy taking 1 for the issuers of bonds eligible to the PEPP programme and 0 otherwise The window before the PEPP is set at the average value of the 2018-2019 period. In the first and the fourth column the window after the PEPP is 2020; in the second and the fifth column is 2021; in the third and the sixth column is 2022. Source: Bloomberg; DCM Analytics; ECB; LSEG Eikon.

Table 5 shows the estimates of the DDD regressions for the change in both scores one, two and

three years after the PEPP announcement. In particular, the value of both the ESG score and the E score in the period before the PEPP is taken as the 2018-2019 average, whereas the score value in the *Post* period is taken in three different years (2020, 2021 and 2022).

The first column reports the estimates concerning the development of the ESG score from the period 2018-2019 to 2020. The *Post* coefficient suggests an improvement of around 3 points in the ESG score for the whole sample of 3,296 companies (including both issuers and parents), corresponding to a 5.6% increase. At the same time, the two coefficients estimating the differential effect in the *Post* period for the eligible and the green companies are not statistically significant, indicating that neither group behaved differently from the other companies. The interaction coefficient β_7 instead suggests that the green companies within the set of eligible issuers increased their ESG score by a larger amount than non-green companies (1.1 points). This last evidence is still valid when increasing the distance from the PEPP announcement (columns 2 and 3).

Focusing on the development of the E score (columns 4-6), we notice that the group of green companies as a whole improved their score already from 2020 (the coefficient *Green*Post* is always statistically significant), while it happened only in 2022 for the ESG score. In addition, the estimate of the β_7 coefficient points to a larger differential effect within the set of eligible issuers: green companies recorded an improvement in the E score that is around 2 points larger than that of non-green firms. Also the overall effect on the E score for the set of eligible green companies (again computed as $(\beta_5 + \beta_6 + \beta_7)$ and reported in the lower panel of Table 5) is large and statistically significant. It ranges from 1.4 to 2.2 points and corresponds to a 3% to 4.5% additional increase.

All in all, we have evidence that the issuers of eligible green bonds that benefitted from a reduction in the financing costs via the PEPP were also able to improve their environmental performance (especially when measured via the E score) by a larger extent than other issuers. This in turn strengthen the potential role of the ECB as a player in sustaining the green transition.

6 Conclusions

In this paper, we provide evidence that the PEPP, the extraordinary asset purchase programme launched by the ECB to help mitigate the impact of the Corona virus on the euro area, had a significant effect on green bonds. In particular, the segment of bonds that were at the same time

eligible to the programme and green enjoyed a discount of 51 basis points.

In order to achieve this result, we implemented a two-step analysis. We first rely on two separate difference-in-differences (DID) regressions and then we move to a triple differences estimator (DDD) as recently refined by Olden and Møen (2022). Taking two windows of 9 months around the PEPP announcement, we show that the set of eligible bonds as a whole did not perform better that the control sample of non-eligible bonds. This results is consistent with the findings in Zaghini (2023) and attributable mainly to a shift of investors (other than the ECB) towards non-eligible IG bonds. A second DID regression shows instead that the segment of green bonds as a whole benefitted from a discount of around 20 basis points with respect to non-green bonds, in line with the estimates by Bremus et al. (2021).

However, the DID approach implemented in the first step (as also the above-quoted papers) does not take into account that the group of green bonds and that of eligible bonds overlap. Thus, we have to deal with four different sets of bonds: eligible green; eligible non-green; non-eligible green and non-eligible non-green bonds. In order to estimate the possibly different impact of the PEPP on the green bonds that were also eligible to the programme, we implement a DDD estimation. This econometric approach is able to take into account two control groups. It provides an estimate of the selective behavior of eligible green bonds with respect to eligible non-green bonds that takes into account also the development over the same time span of the set of non-eligible green bonds with respect to non-eligible non-green bonds. In this way we distinguish from the existing literature by providing a correct identification strategy to assess the ECB contribution to the bond market development.

We find that eligible green bonds showed in the period after the PEPP announcement a better market pricing than eligible non-green bonds. The estimated discount standing at 39 basis points. This premium must be considered additional to the one that the set of green non-eligible bonds witnessed over the same period (22.5 basis points). Also considering the development in the set of eligible bonds, we estimate a total effect of 51 basis points.

Taking into account that green bonds are among the less substitutable assets in the market, the reported findings are fully consistent with the prediction of the portfolio rebalancing theory by Vayanos and Vila (2021), already employed to describe the effects of treasury securities purchases by the FED (Krishnamurthy and Vissing-Jorgensen 2011, D'Amico and King 2013) and the ECB

(Krishnamurthy et al. 2018, Albertazzi et al. 2021). The idea is that large purchases by the central bank are able to move investors away from the targeted bonds and towards similar non-targeted bonds, thus involving different market segments. However, imperfect substitutability of assets, due to market segmentation and preferred-habitat maturities, implies that changes in the supplies of various assets available to private investors may affect differently the prices and yields of those assets (Bernanke 2012). In other words, the effect of the central bank purchases may be different across market segments. In particular, the less perfect is the substitutability, the stronger is the price effect on the targeted bonds.

As an additional result, we find that the issuers that benefitted most from the PEPP were also able to improve their environmental performance to a larger extent than other issuers. While the period 2020-2022 is characterized by a generalized improvement in Environmental (E) score, the issuers of eligible green bonds improved their performance by an additional 3% to 4.5%.

All in all, we provide support to the ECB role in helping channeling resources towards climate-friendly projects. Even without a declared preference towards green bonds (or low-carbon emitters), the PEPP purchases were able to directly influence the placement cost of eligible green bonds, and indirectly that of the whole green bond segment.

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