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Quantitative easing and corporate innovation

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Abstract

To what extent can Quantitative Easing impact productivity growth? We document a strong and heterogeneous response of corporate R&D investment to changes in debt financing conditions induced by corporate debt purchases under the ECB's Corporate Sector Purchase Program. Companies eligible for the program increase significantly their investment in R&D, relative to similar ineligible companies operating in the same country and sector. The evidence further suggests that by subsidizing the cost of debt, corporate bond purchases by the central bank stimulate innovation through a wealth transfer to innovative companies with low debt levels, rather than by supporting credit constrained firms.

Keywords: Unconventional monetary policy, quantitative easing, corporate innovation, productivity growth
JEL Classification: E5, G10, O3

Non-technical summary

Economic growth depends crucially on productivity-enhancing intangible investments such as research and development (R&D). In turn, R&D investment is costly, and therefore firms' ability to engage in technological innovation can be impaired during the down phase of the business cycle when funding costs are generally higher. From the point of view of monetary policymakers, an important challenge is how to stimulate R&D investment when financial markets are impaired and monetary policy is at or below the Zero Lower Bound. This question is especially important given that in the wake of the Global Financial Crisis, a number of Central Banks have resorted to sizeable asset purchase programs—such as the Fed's Large Scale Asset Purchases (LSAP) and the Corporate Sector Purchase Program (CSPP) of the European Central Bank (ECB)—in order to stimulate the economy.

In this paper, we analyze the impact of the CSPP on corporate R&D investment. Announced in March 2016 as an attempt to enhance the monetary transmission mechanism at record low policy rates, the CSPP committed the ECB to purchasing eligible corporate bonds under strict conditionality, and marked the first time that non-financial corporate bonds became part of the ECB's QE policies. We expect that the CSPP reduced funding costs for eligible firms and boosted their growth prospects, rendering R&D investments more profitable. The differential effect on eligible and non-eligible firms makes it possible to compare R&D investment patterns by otherwise similar firms on both sides of, but close to, the eligibility threshold.

Our main finding is that CSPP-eligible non-financial companies increased significantly and substantially their investment in R&D, compared to companies right below the CSPP rating threshold. The increase in corporate R&D investment is between 9% and 20%, depending on the empirical specification. We also find important dynamic effects. In particular, the instantaneous effect of the CSPP on R&D is zero; it becomes significant in the first year after the Program; and then it increases by about 50% in each subsequent year. The evidence is consistent with the notion that in the presence of high adjustment costs, and when faced with improving funding conditions, firms increase their R&D

investment slowly and gradually.

Second, we document substantial firm-level heterogeneity in the effect of the CSPP on R&D investment. In particular, we find that R&D investment does not increase more for companies with relatively low cash flow, interest coverage, or dividend payout ratio. We also find that the effect of the CSPP on corporate R&D investment is independent of the company's return on assets and equity, as well as of the volatility of the company's return on assets and equity. At the same time, the increase in corporate R&D in response to more favorable external funding conditions is stronger for firms that prior to the introduction of the CSPP had relatively higher levels of R&D investment, intangible investment, and number of patents, as well as for low-leverage companies. Our findings thus suggest that QE stimulates innovation through a wealth transfer to high-quality innovative companies, and not by supporting credit constrained ones.

Our results are important in two different ways. First, the evidence we document is consistent with the idea that access to finance matters at all stages of the life cycle of innovation. While much of the literature has focused on the role that financing constraints play in the innovation decisions of young firms, we show that they also matter in a material way for a certain class of mature firms, too. Second, our evidence suggests that increased funding to the real economy via QE programs is associated with an increase in R&D investment which is notoriously difficult to collateralize. This is especially important in light of recent evidence that intangible investment—such as intellectual property, organizational structure, business strategy, and brand equity—now dominates tangible investment in advanced economies, reducing Central Bank's ability to stimulate economic growth via its preferred channel, the "bank lending" one. Our results suggest that by expanding their toolbox of operational policies, Central Banks can continue supporting today's knowledge-based economies. However, they also caution against blanket support of firms, and speak to the notion that policies need to be designed such that they support firms with high elasticity of investment to the cost of external finance.

1 Introduction

Economic growth depends crucially on productivity-enhancing intangible investments such as research and development (R&D). In turn, R&D investment is costly, and therefore firms' ability to engage in technological innovation can be impaired during the down phase of the business cycle when funding costs are generally higher (Aghion, Angeletos, Banerjee, and Manova, 2010).[1] From the point of view of monetary policymakers, an important challenge is how to stimulate R&D investment when financial markets are impaired and monetary policy is at or below the Zero Lower Bound. While a number of recent studies have analysed the impact of conventional monetary policy on Total Factor Productivity (TFP) growth (Moran and Queralto, 2018; Anzoategui, Comin, Gertler, and Martinez, 2019; Bianchi, Kung, and Morales, 2019), the link between the evolution of productivity-enhancing investment and Quantitative Easing (QE) has largely been overlooked. This omission is all the more surprising given that in the wake of the Global Financial Crisis, a number of Central Banks have resorted to sizeable asset purchase programs—such as the Fed's Large Scale Asset Purchases (LSAP) and the Corporate Sector Purchase Program (CSPP) of the European Central Bank (ECB)—in order to stimulate the economy.

We go to the heart of this question by analyzing the impact of the CSPP on corporate R&D investment. Announced in March 2016 as an attempt to enhance the monetary transmission mechanism at record low policy rates,[2] the CSPP committed the ECB to purchasing eligible corporate bonds under strict conditionality.[3] This marked the first time that non-financial corporate bonds became part of the ECB's QE policies. The theoretical justification behind such central bank purchases of risky private debt is that they can reduce the cost of credit and boost real economic activity when financial intermediaries face balance sheet constraints (Curdia and Woodford, 2011; Gertler and Karadi,

[1] Financial frictions are often considered one of the primary reason for the observed procyclicality of R&D investment (Geroski and Walters, 1995; Fatas, 2000; Comin and Gertler, 2006; Barlevy, 2007; Aghion, Askenazy, Berman, Cette, and Eymard, 2012), which arises despite well understood theoretical arguments that firms will concentrate investment in innovation in recessionary periods when productivity-enhancing activities have a lower opportunity cost (Schumpeter, 1939).

[2] The ECB's deposit facility rate has been negative since June 2014.

[3] Broadly speaking, the ECB would purchase euro-denominated bonds with a rating of BBB- or higher and remaining maturity of at least 6 months, issued by companies domiciled in the euro area.

2011) or in the presence of market segmentation (Vayanos and Vila 2021). These channels should be reinforced during periods of financial stress.

We therefore expect that the CSPP reduced funding costs for eligible firms and boosted their growth prospects, rendering R&D investments more profitable. The CSPP provides us with a clear source of exogenous variation to firms' financing. In particular, yields on eligible bonds declined, relative to yields on non-eligible bonds, resulting in a reduction in funding costs for firms issuing eligible bonds (Todorov, 2020). This makes it possible to compare R&D investment patterns by otherwise similar firms on both sides of, but close to, the eligibility threshold.

Our first result is that non-financial companies affected by the CSPP increased significantly and substantially their investment in R&D. This effect is observed relative to a group of comparable firms that did not benefit from the CSPP, because they were right below the CSPP rating threshold, and thus not eligible in the first place. The increase in corporate R&D investment is between 9% and 20%, depending on the empirical specification. We also find important dynamic effects. In particular, the instantaneous effect of the CSPP on R&D is zero; it becomes significant in the first year after the Program; and then it increases by about 50% in each subsequent year. The initial analysis thus confirms that the response of R&D investment to an exogenous increase in the supply of external funds is significant and increasing over time. This evidence is consistent with the notion that in the presence of high adjustment costs, and when faced with improving funding conditions, firms increase their R&D investment slowly and gradually (Brown, Fazzari, and Petersen, 2009).

We subject this first result to a battery of robustness tests, to make sure that we are really identifying a causal chain of events that goes from targeted corporate bond purchases by the central bank to corporate innovation. To begin with, to address the issue of heterogeneity in bond characteristics, we perform all of our analyses on a matched sample, whereby we restrict the treatment group to firms for which there is a suitable control firm with similar pre-treatment characteristics. We thereby make sure from the start of the analysis that the results are not driven by systematic differences between treatment and control firms. At the same time, our main results are confirmed in different samples based on more and less strict selection criteria.

Crucially, the basic result of the paper obtains in regressions with firm fixed effects, which net out the variation induced by unobservable firm-specific heterogeneity that is fixed over time, such as managerial talent or initial growth opportunities. We also recognize that new technological opportunities during this period also could have led to a demand shift for R&D. To identify the supply effect, our approach accounts for demand in a variety of ways. First, the results do not change in any significant way when we include industry-level time dummies that control for all time-varying demand shocks at the industry level. Second, although demand shocks presumably affected all firms in these industries, we find significant financial effects for CSPP-eligible companies only, which is inconsistent with the view that the financial effects proxy for an unobserved demand shift. Finally, in the main empirical tests, we also include country-level time dummies. These net out the variation induced by unobservable time-varying factors that are common to all firms in a country at the same point in time, such as taxes, regulation, or global risk aversion.

We perform a number of placebo tests to make sure that the effect we document is not part of a more general trend, precluding a causal interpretation. First, the main result of the paper no longer obtains when we replicate our empirical strategy on a group of comparable eligible and non-eligible firms (according to the CSPP criteria) whose bonds cannot be purchased by the ECB because they are not domiciled in the euro area. Second, the main result disappears when we compare the same two groups of eligible and ineligible firms during a period of comparable length before the CSPP came into force. This suggests that we are indeed picking up a causal effect of the ECB's CSPP, rather than a euro-area trend which pre-dates the program, or a global trend whereby R&D investment increased across the globe after 2016 for a particular type of firms.

In the second part of the paper, we analyse the firm-level heterogeneity in the response of R&D investment to changes in debt financing conditions. This analysis yields four main findings. First, we find that R&D investment does not increase more for companies with relatively low cash flow, interest coverage, or dividend payout ratio. To the extent that these firm-level factors are well-accepted empirical proxies for credit constraints (e.g., Fazzarri, Hubbard, and Petersen, 1988; Almeida, Campello, and Weisbach, 2004), our results suggest that credit constraints are not relevant for the mechanisms activated by the CSPP.

Second, we find that the increase in corporate R&D in response to more favorable external funding conditions is strongest for firms in the manufacturing than for firms in transportation, communication, or utilities. The same is true for firms that prior to the introduction of the CSPP had relatively higher levels of R&D investment, intangible investment, and number of patents. The evidence therefore suggests that an increase in the supply of external debt finance increase R&D investment mostly for firms that are already engaging in innovative activities. Put differently, the overall increase in R&D that we document is driven by an uptick in innovative activities on the intensive, rather than on the extensive margin.

Third, we find that the response of corporate R&D to the CSPP is significantly large for low-leverage companies. This strongly suggests that corporate structure matters for the effect of changes in funding costs on innovation. A number of models have asserted that there is an ”optimal” level of debt (e.g., Jensen and Meckling, 1976; Myers, 1977). Our evidence is consistent with the notion that in the case of companies that are over-leveraged, further reductions in the cost of debt are irrelevant for real activities. Conversely, companies with relatively low levels of debt benefit from QE because they can bring their leverage closer to the ”optimal” level, with positive implications for investment in innovation.

Finally, we find that the effect of the CSPP on corporate R&D investment is independent of the company's return on assets and equity, as well as of the volatility of the company's return on assets and equity. We conclude that the company's risk-return profile is not relevant for the effect of QE on innovative activities.

Our findings thus suggest that QE stimulates innovation through a wealth transfer to high-quality innovative companies, and not by supporting credit constrained ones. The evidence is therefore consistent with models of long-term investment by innovative firms in the presence of liquidity shocks, where the expectation of future liquidity constraints depresses productivity-enhancing investment today (Aghion, Angeletos, Banerjee, and Manova, 2010). More broadly speaking, the empirical regularities we document support the idea that financial development promotes growth by improving the allocation of investment to growth opportunities (e.g., Fisman and Love, 2007; Wurgler, 2000). They are, however, less consistent with the idea that finance promotes growth by relaxing credit constraints (e.g., Rajan and Zingales, 1998). Identifying the link between financing conditions and innovation has proven elusive in empirical work. This is mainly because the general absence of clear sources of exogenous variation in the supply of external finance makes it difficult to study in a causal way how the availability of external financing affects firm decisions. The early literature relied on the hypothesis that if firms face binding financing constraints because of capital-market imperfections, proxies for internal funds or liquidity will affect firms' investment, holding investment opportunities constant. Therefore, if one finds in the data that the firm's investment responds to shocks to the firm's cash flow, this will imply that such firms are credit constrained (see Fazzari, Hubbard, and Petersen, 1988). At the same time, shocks to cash flows may not be orthogonal to (unobservable) investment opportunities. In this case, a positive correlation between cash flow and investment becomes uninformative about how relaxing financing constraints affects firm investment (see, e.g., Kaplan and Zingales, 1997; Cleary, 1999; Alti, 2003; and Moyen, 2004). To address this point, more recent work has focused on isolating an exogenous component of the firm's financing conditions that is uncorrelated with its investment opportunities. Examples include oil price shocks (Lamont, 1997), shocks to firms' defined pension contributions schemes (Rauh, 2006), or the American Jobs Creation Act which significantly lowered US firms' tax bill when accessing their unrepatriated foreign earnings (Faulkender and Petersen, 2012). We contribute to this research effort by exploiting the exogenous variation in the supply of external debt finance induced by the ECB's QE.

Our paper is related to the literature on the impact of conventional (e.g., Gertler and Gilchrist, 1994; Jimenez, Ongena, Peydro, and Saurina, 2012) and especially unconventional monetary policy (e.g., Acharya, Eisert, Eufinger, and Hirsch, 2018; Eser and Schwaab, 2016; Giannone, Lenza, Pill, and Reichlin, 2012; Gilchrist and Zakrajsek, 2013; Gilchrist, Lopez-Salido, and Zakrajsek, 2015; Heider, Saidi, and Schepens, 2018; Ferrando, Popov, and Udell, 2019) on both nominal and real economic variables. A sub-strand of this literature has looked specifically at the economic impact of central bank asset purchases, with a clear focus on the effects of the Fed's asset purchases programs. Krishnamurthy and Vissing-Jorgensen (2011) study the impact of the Federal Reserve's large-scale asset program on interest rates and outline several important channels through which asset purchases affects bond yields. Foley-Fisher, Ramcharan, and Yu (2016) investigate the impact of the Fed's Maturity Extension Program and find that firms more dependent on longer-term debt experienced an increase in stock prices and expanded employment and investment. Song and Zhu (2018) study which bonds are more likely to be purchased by the Fed. There is also more recent research on the impact of the ECB's CSPP on bank lending. The evidence suggests that by reducing the cost of funding for eligible firms, the CSPP has pushed banks to increase lending to smaller firms (Betz and De Santis, 2019; Ertan, Kleymenova, and Tuijn, 2019; Grosse-Rueschkamp, Steffen, and Streitz, 2019; Bats, 2020; Arce, Gimeno, and Mayordomo, 2021). Closest to our paper is Todorov (2020) who finds that during the three months after the announcement of the CSPP, asset purchases were successful in boosting corporate debt issuance, but that they had no impact on firms' real decisions. We contribute to this line of research by identifying a real impact of the ECB's corporate bond purchase program, namely, an increase in innovation by non-financial corporations benefiting from the program in the medium-run (four years). Thus, we improve on the analysis in Todorov (2020) who only looks at one quarter before and one quarter after the CSPP announcement, a frequency at which long-term investment such as R&D is not expected to move much.

Several recent theory papers have argued for a link between monetary policy and innovation. These include Bianchi, Kung, Morales (2018), Moran and Queralto (2018), and Anzoategui, Comin, Gertler, and Martinez (2019). These papers develop and estimate quantitative macroeconomic frameworks with conventional monetary policy, nominal rigidities, and endogenous TFP dynamics. In the latter two models, the Zero Lower Bound limits the ability of monetary authorities to stimulate the economy, with negative consequences for TFP growth. In the former, monetary policy affects TFP growth through its effect on aggregate demand and interest rates, which in turn affect equity investment. In contrast, we focus on unconventional monetary policy, and we show how it can increase innovation by reducing the cost of external debt for companies already engaging in innovative activities. Moreover, the heterogeneous response we observe across firms suggests that QE policies—which by definition target large firms—are transmitted into real economic activity not so much by relaxing overall credit constraints, but through a wealth transfer to a particular class of firms, as well as by reducing future liquidity risk.

Our paper also contributes to the literature that has sought to establish in a robust causal way whether variations in the supply of external finance are associated with variations in corporate innovation. We make three contributions to this literature. Firstly, while a number of papers have established that financing conditions are very relevant for innovation by small and young firms (e.g., Ayyagari, Demirguc-Kunt, and Maksimovic, 2011), we show that they matter for large mature firms, too. Secondly, we confirm that easier financing conditions are beneficial for corporate innovation not only at early stages of the innovation process, as much of the literature has argued, but also at later ones. This evidence is consistent with models of staged long-term investment where further innovation takes place after the quality of the technology is revealed (Aghion, Angeletos, Banerjee, and Manova, 2010). Lastly, our results suggest that unconventional monetary policy can have an impact on investment that is not easy to collateralize (such as R&D). We thereby document that monetary policy can complement the bank lending channel, which is the channel whereby central bank policies typically transmit to the real economy.

Our work is further related to the literature on the link between financial development and innovation. A number of papers based on country-level and sector-level analysis have demonstrated that higher levels of financial development are associated with higher innovation rates and TFP growth (e.g., Beck, Levine, and Loayza, 2000a,b; Rioja and Valev, 2004; Bonfiglioli, 2008; Aghion, Angeletos, Banerjee, and Manova, 2010; Madsen and Ang, 2016). At the same time, largely due to data limitations, few studies have evaluated how financing frictions affect R&D investment, and the results in these studies are decidedly mixed. For example, Hall (1992) and Himmelberg and Petersen (1994) report a strong positive relation between R&D and cash flow in U.S. manufacturing firms. Brown, Fazzari, and Petersen (2009) and Brown and Petersen (2009) find a strong link between R&D and equity finance for young publicly traded U.S. firms. At the same time, Bond, Harhoff, and van Reenen (2005) find that neither German firms nor U.K. firms display a correlation between their level of R&D and cash flow. Hall, Mairesse, Branstetter, and Crepon (1999) find that R&D is much more sensitive to cash flow in U.S. firms than in French and Japanese firms. Bhagat and Welch (1995) report no evidence of a positive R&D-cash flow link across firms in the U.S., Canada, U.K., Continental Europe and Japan. Hall and Lerner (2010) provide a comprehensive summary of the literature and conclude that it remains an open question whether financing constraints matter for R&D.

We contribute to this literature in a number of distinct ways. First, we show that financing conditions may have a material effect on the innovative activities of mature firms, and not only of young firms. Second, we show that R&D investment benefits from an increase in the supply of external funds at later stages of the innovative process. Third, we show strong evidence that financing conditions are relevant for R&D investment by European firms, too, and not only by US corporations. Our evidence thus expands on Brown, Martinsson, and Petersen (2012). Finally, we link firm innovation to funding via bond market financing. This mechanism is largely overlooked in empirical work which has documented a positive effect of stock market development, and no effect of credit market development on R&D investment and innovation (e.g., Brown, Martinsson, and Petersen, 2013; 2017).

2 Institutional background

On March 10, 2016, the ECB announced the novel Corporate Sector Purchase Programme (CSPP), with the intention to "further strengthen the pass-through of Eurosystem's asset purchases to the financing conditions of the real economy".[4] This was the first time that non-financial corporate bonds became part of the ECB's QE program.

In April 2016, the ECB released the criteria for bonds to be eligible for CSPP purchases. According to these, corporate bonds are eligible for the CSPP if they satisfy the following criteria: 1) they are denominated in euros; 2) they have a minimum credit rating of BBB-/Baa3/BBBL from at least one of the four credit rating agencies (Standard & Poor's, Moody's, Fitch Ratings and DBRS); 3) they have remaining maturity longer than six months, but shorter than 30 years at the time of purchase; 4) they satisfy eligible collateral requirements under the Eurosystem collateral framework for credit operations; 5) they are issued by a company incorporated in the euro area, but may have a parent company outside of the Eurozone; 6) they are issued by a non-bank corporation, whereby both the issuer and its parents are not subject to banking supervision; and 7) the security's yield has to be larger than the ECB's deposit facility rate.

The program was implemented in June 2016, and securities were purchased on both the primary and secondary market. Figure 1 depicts the evolution of the ECB's holdings of corporate bonds under the CSPP, from 2016-Q2 to 2020-Q3. While the ECB supervises the bond purchase program, the actual purchases are carried out by the Central Banks of Belgium, Finland, France, Germany, Italy, and Spain. These six national central banks are responsible for purchases based on the geographic location of the borrower. The amount of purchases from the overall allocated volume is based on these banks' contribution to the Eurosystem. Central banks are instructed not to differentiate among securities whose parent operates in the Eurozone, nor favor local securities over foreign securities that are under the responsibility of a particular central bank.

[4]For more detail refer to the official press release from 16-March-2016.

The stated purpose of the CSPP is to facilitate financial intermediation for a group of borrowers by stimulating financial disintermediation for another group of borrowers. The ECB argued that the CSPP would increase the supply and liquidity of credit in the economy, reducing the cost of debt for eligible firms and allowing them to rely (more) on bond financing. As a result, banks with affected corporate borrowers would experience a reduction in demand for their loans from the corporate sector and smaller yields. The reduced demand by corporate customers could increase banks' willingness to lend to SMEs. As SMEs are typically a part of banks' commercial lending portfolio, they provide a natural substitute to large corporate loans. While banks could in theory respond differently—by distributing dividends, investing in non-loan assets, or steering toward other types of loans, such as mortgages (Chakraborty, Goldstein, and MacKinlay, 2020)—recent evidence suggests that the CSPP has pushed banks to increase lending to smaller firms (Betz and De Santis, 2019; Ertan, Kleymenova, and Tuijn, 2019).

In terms of the financial effect on large bond issuers themselves, two effects have already been documented in the literature. First, bond issuance by eligible firms increased substantially, by around 1.94 billion EUR each week, corresponding to a 49% rise in newly issued QE-eligible debt (Todorov, 2020). Second, bond yields dropped an average 30 basis points after the announcement (ibid). The combination of these two facts suggest that each year after the start of the CSPP, Euro area corporations issued extra bonds worth around 100 bln. euro, and paid 300 mln. euro less than it would have cost them in the absence of the CSPP. This fact points to a substantial reduction in the cost of funding, and to a substantial increase in the size of external funding available to eligible firms. It naturally gives rise to the question we study in this paper, namely, what is the impact of improved access to finance on corporate innovation.

3 Data

Our analysis uses firm-level accounting data from Compustat Global on internationally listed firms, merged with bond-level data from Bloomberg and from the ECB's Security Holdings Statistics by the Eurosystem (SHSE), as well as credit rating data from Standard & Poor's, Moody's, Fitch Ratings and DBRS.

3.1 Bond-level data

The bond data come from Bloomberg and from the Security Holdings Statistic (SHS) by the Eurosystem. Bloomberg provides information on bond ratings and issuer, which enables us to determine which companies were eligible to be purchased by the ECB under the CSPP. The SHS database provides information on holdings at the security level as identified by the International Securities Identification Number (ISIN). For the purpose of our analysis, we focus on the issuers of the bonds that were purchased under the CSPP. The SHSE first records bond holdings under the CSPP in 2016-Q2.

As we are primarily interested in the impact on the companies' R&D expenditures, it is important to consolidate the issuers to their parent companies because financial securities are typically issued by the financial subsidiaries that have limited balance sheet information. This is evident in Figure 1, where the largest share of the purchase volume appears to have been issued by the financial sector. In fact, the vast majority of those bonds were issued by financial subsidiaries affiliated with large non-financial corporations.

Thus, we hand-collect information on each issuer's parent company. When the parent is either unidentifiable, sovereign or family-owned, we retain the subsidiary. In the few cases, where bonds were purchased from both, the parent and the subsidiary, we only retain the parent company. The information we collect makes it possible to compare companies with both eligible and purchased bonds to ineligible ones. We also note that of the 98 eligible companies with full balance sheet information in our dataset, only 10 did not have their bonds purchased by the ECB through the CSPP.

3.2 Firm-level data

We merge the set of the companies that were eligible and/or had their bonds purchased by the ECB, with balance sheet information from Compustat Global. Our sample holds quarterly data from 2012-Q1 to 2019-Q4, which gives us four years before and after the CSPP announcement. All companies are consolidated. We further define a company as eligible for the CSPP if it had active corporate bonds in December 2015 with minimum credit assessment of BBB-/Baa3/BBBL (S&P, Fitch, Moody's, DBRS).[5]

For our main analysis, we focus on companies headquartered in the Euro area and exclude companies in Agriculture (SIC 0100-0999), Finance (SIC 6000-6799) and non-classifiable companies (SIC 9900-9999). This leaves us with 145 eligible and 2,432 ineligible companies. Next we exclude all companies without information on R&D expenditure, which is available annually, and only retain those companies for which there is at least one observation on R&D expenditure recorded before and after 2016-Q1 (i.e., the CSPP announcement). This is an essential restriction to evaluate the impact on corporate innovation following the CSPP announcement. Lastly, we omit all companies without information on total assets and sales.

This reduces the initial sample to 98 eligible and 814 ineligible companies. 85 of the eligible companies are in Manufacturing (SIC 2000-3999) and in Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999). The remaining 13 eligible companies operate across five other different sectors. To allow for fixed effect estimations at the sector level, we must restrict the sample to economic sectors with a sufficiently large number of companies, and thus focus on 1) Manufacturing, and 2) Transportation, Communications, Electric, Gas and Sanitary service.

[5] For our placebo analysis on foreign-domiciled companies, we apply the same eligibility criteria to companies headquartered outside the Euro area but here we set the eligibility dummy equal to zero if the company had issued eligible bonds on Euro area capital markets. This is because for a security to be eligible under the CSPP, it must be issued by a euro area institution but the parent may be located outside the Euro area.

The prioritization of those two sectors is supported by the evidence in Table 1, where we compare corporate innovation across all firms in core economic sectors in the Euro area and the United States before the CSPP announcement. Innovation is measured as the ratio of R&D expenditure to sales because both are flow variables from the cash flow statement. Moreover, in most countries, including Europe, R&D expense is not capitalized but expensed. In Europe, Manufacturing (SIC 2000-3999) and in Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999) account for 73% of all firms engaged in innovation activities. The Manufacturing sector alone accounts for more than 60% of all firms in United States and in Europe. Overall, the United States is more innovative, relative to Europe, across all sectors except for Retail and Wholesale Trade. For both, innovation is strongest in Manufacturing and Services, whereas it is weakest in Construction and Retail / Wholesale Trade.

3.3 Matched sample

Our primary identification strategy is based on comparing the investment behavior of eligible and ineligible firms with similar innovation strength and firm size in the same sector and country before and after CSPP treatment, while isolating sector-wide and country-side shocks that are common to both types of firms.

To minimize the statistical difference between eligible and ineligible firms (Imbens and Wooldridge, 2009), we conduct a one-to-one matching procedure to choose a first-best sub-sample of comparable control firm. Control companies are selected from the set of firms that are ineligible for the corporate bond purchases.

We match our 85 eligible firms based on their observable traits to the first-best control firm before the CSPP announcement in 2015-Q4. We match conditional on the following firm-level variables: (1) geography (headquarter location), (2) economic sector (SIC code 1-digit), (3) ex-ante innovation strength (R&D expenditure / sales) and (4) ex-ante firm size (total assets). To define ex-ante innovation strength and firm-size, we use each firm's last available observation in 2015, to avoid overlap with the CSPP announcement. Recall that firms report in different quarters and innovation expense is available only annually. The matching is executed with replacement so that for each eligible firm we identify one control firm that is ineligible for corporate bond purchases. If a control firm is matched to several eligible companies, we adjust the sample accordingly such that the number of eligible is equal to the number of ineligible companies.

We successfully match all but four eligible companies due to the lack of a control firm in the same country and sector. Thus, the final matched sample contains 81 eligible (treated) and 81 non-eligible (control) companies from Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, and Spain. Approximately two-thirds of all companies are in manufacturing. Of these 81 eligible companies, 74 had their bonds purchased by the ECB after the announcement of the CSPP.[6]

3.4 Descriptive Statistics

In Table 2, we present summary statistics on matched sample from 2012-Q1 to 2019-Q4. Recall that control companies are matched according to their headquarter location, economic sector, innovation strength and firm size. Due to frequency of reporting of R&D expenses, the summary statistics are taken on an annual level. The average R&D expense-to-sales ratio for the matched sample is 2.93%, and the median ratio is 1.81%. Overall, our sample is characterized by relatively few firms with a high R&D-to-sales ratio and relatively more firms with a low R&D-to-sales ratio, which is a natural consequence of R&D being a relatively "lumpy" investment (Bond, Harhoff, and van Reenen, 2005).

To assess the validity of our matching method Table 3 shows the sample means before the CSPP announcement, differentiating between companies in the eligible and ineligible firms. The eligible firms are—on average and significantly in a statistical sense—larger in terms of assets compared to the ineligible firms. There are no statistically significant differences in terms of their R&D expense-to-

[6]To assess the robustness of our matching and control group selection, we also show that our results hold in samples based on alternative matching techniques and control groups.

sales, capital expenditure-to-assets ratio and acquisition-to-assets. The ineligible companies are more cash-intensive, and this difference is also significant in the statistical sense.

4 Empirical strategy and identification

4.1 Empirical model

Our main econometric model focuses on the relationship between firm-level R&D expenses and participation in and/or eligibility the CSPP and the firm-quarter level. Our main specification takes the following form:

$$\frac{R\&D_{f,t}}{Sales_{f,t}} = \beta Eligible_f \times Post_t + \gamma_f + \mu_{c,t} + \phi_{s,t} + \varepsilon_{f,t}, \tag{1}$$

where $R\&D_{f,t}$ is R&D investment by firm f in quarter t, and $Sales_{ft}$ is that same firm's total sales during the same quarter. Turning to the explanatory variables, $Eligible_f$ is a dummy variable equal to one if the firm's bonds were eligible for purchase by the ECB as part of its CSPP, and to zero otherwise. $Post_t$ is a dummy variable equal to one following the CSPP announcement in 2016-Q1. The sample period runs from 2012-Q1 to 2019-Q4, therefore, we are looking at the impact of the CSPP on corporate innovation over a period of four years prior to the CSPP announcement in 2016-Q1, and fours years after the announcement. This is a substantial lengthening of the period of the analysis relative to Todorov (2020), who looks at the period January-June 2016, i.e., one quarter before and one quarter after the CSPP announcement.

We include firm-fixed effects γ_f to control for unobservable firm-specific time-invariant factors explaining variation in investment behavior. The term $\mu_{c,t}$ is an interaction of country and quarter dummies, which absorbs any time-varying varying variation in business conditions that is common to all firms in a country. The term $\phi_{s,t}$ is an interaction of 1-digit SIC sector and quarter dummies, which absorbs any time-varying shocks to demand or technology that are common to all firms in a sector. With the inclusion of these dummy interactions, we aim to net out the independent effect of any structural developments and demand shocks, both at the level of the sector and at the level of the domestic market. Finally, $\varepsilon_{f,t}$ is the idiosyncratic error term. In all regressions, we cluster the standard errors at the country-year level.

We do not include the variable $Eligible_f$ separately in the model specification above because its direct effect on investment is absorbed by the firm fixed effects. Analogously, we do not include the variable $Post_t$ on its own because its direct effect on investment is absorbed by the country-quarter and sector-quarter fixed effects. At the same time, we also estimate specifications that are less saturated with fixed effects, and which therefore allow us to gauge the independent effect of being treated and of the cycle.

The coefficient of interest is β. A positive coefficient β would imply that all else equal, R&D investment increases for firms whose bonds were purchased by the ECB relative to firms with similar ex-ante innovation strength and firm size in the same country and economic sector. The point estimate of β thus measures the numerical change in R&D investment, divided by sales, from switching the firm from the control group to the treatment group. All models are estimated using ordinary least squares. We cluster the standard errors at the country-year level, to account for potential correlation among firms within the unit where the shock takes place.

5 CSPP and innovation: Empirical results

5.1 Main test

We begin by estimating more parsimonious versions of Equation (1), gradually building towards the most saturated specification. In Table 4, column (1), we estimate a specification without any fixed effects. This allows us to include the variables $Eligible_f$ and $Post_t$ on their own. We then advance the model to include company fixed effects in column (2). The most saturated model in column (3) incorporates interactions of Quarter X Country and Quarter X Sector dummies. We need to emphasize that we do have annual, and not quarterly, data for each firm. At the same time, different firms report in different quarters of the year. The quarter fixed effects thus pick the within-year cycle of economic activity.

The estimates reported in column (1) confirm the validity of our matching procedure: there are no statistical differences on average between eligible and ineligible firms. The coefficient on the variable $Eligible_f$ is close to zero and not significant in the statistical sense.

In column (2), we include company fixed effects, therefore we can no longer include the variable $Eligible_f$ on its own. In this specification, statistical differences emerge in a differences-in-differences sense between treated and control companies. Given a mean value of R&D investment of 2.93% for eligible firms prior to the CSPP announcement, the coefficient of 0.245 implies that after treatment, investment increases by about 8% relative to the pre-announcement average. The coefficient on the variable $Post_t$ is close to zero and insignificant, suggesting that R&D investment does not increase over time for the group of control (ineligible) companies. Finally, we include interactions of Country X Quarter and Sector X Quarter fixed effects. We thereby control for trends that are common to all firms in a country (e.g., monetary policy, changes in the propensity to save or invest) and in a sector (e.g, global shifts in technology, demand for a particular product). The preferred specification in column (3) reveals that companies that had their bond purchased under the ECB's CSPP increased their R&D expenses as a share of sales post-CSPP purchases by an almost identical amount to the one reported in column (2), as a share of sales, and relative to the control group. The coefficient of 0.273 thus implies that after treatment, investment increases by about 9% relative to the pre-announcement average. This effect is statistically significant at the 1% statistical level, and it is large compared to the average R&D expense-to-sales ratio for the treatment companies of 2.93%. Our evidence is thus consistent with the idea that as a result of the shock to the supply of external finance generated by the unconventional monetary policy in question, eligible companies increased investment in R&D, compared with otherwise similar but ineligible companies.

What is the implied aggregate effect? CSPP-eligible firms account for around 55% of total sales by all bond-issuing companies in the countries under consideration, and have similar R&D-to-sales levels. Therefore, our results suggest that a 9% increase in R&D investment by CSPP-eligible firms translates into a 5% aggregate increase in R&D investment by bond-issuing in euro area countries during the post-CSPP period.

The Appendix presents three modifications of our principle empirical model: one related to sample robustness, one related to model robustness, and one related to variable robustness. In Table A1, we re-run Equation (1) on a sample that includes the Services sector, covering 87 eligible companies. The main result remains stable, both in a qualitative and in a quantitative sense.

In Table A2, we test for the dynamic effect of the CSPP on corporate innovation by replacing the Post-CSPP dummy with Post-CSPP Year dummies. The results reveal that R&D investment gradually increases for the treatment group over time. Specifically, there is no significant increase in R&D investment in the first year of the program (2016). After which R&D is progressively higher for the eligible, relative to the ineligible companies: by 8.1% in 2017, by 10.8% in 2018, and by 16% in 2019. The evidence is thus consistent with the idea that R&D investment has a large fixed component, in terms of human capital involved (see, for example, Brown, Fazzarri, and Petersen, 2009), and so adjustment are by default gradual.

Finally, in Table A3 we re-run the main specification where the dependent variable is calculated as the ratio of R&D investment to total assets, rather than to sales. The main result of the paper continues to obtain in this specification, suggesting that it is not an artefact of using a particular empirical proxy for innovation.

5.2 Parallel trend assumption

One of the underlying assumptions of our difference-in-differences empirical approach is that the two groups of firms that we compare were not already on different trends before the CSPP came into force. To address this issue formally, we now run the following version of Equation (1):

$$\frac{R\&D_{f,t}}{Sales_{f,t}} = \sum_{n=2012}^{2019} \beta_n Eligible_f \times D_{year=n} + \gamma_f + \mu_{c,t} + \phi_{s,t} + \varepsilon_{f,t}, \quad (2)$$

The sample period is 2012–2019, and the reference year is 2016 (i.e., the announcement year of the CSPP). The estimates from this test are presented in Figure 2, which plots yearly point estimates and confidence intervals. The figure makes it clear that there were no statistical differences in any year before 2015 between eligible and ineligible firms, relative to 2016. This strongly suggests that the parallel-trend assumption is not violated. At the same time, the difference in R&D investment across the two group becomes significant from 2017 onward, with the effect only growing stronger over time.

5.3 Falsification tests

One potential concern with our results so far is that they are simply indicative of a general trend that took place around 2016 of highly rated publicly traded companies increasing their innovative activities around the globe, relative to marginally lower-rated ones. Possible explanations for this phenomenon could include a booming stock market or declining global uncertainty which larger better rated companies benefit relatively more from. Under this alternative hypothesis, there is nothing special about the trend we document in the euro area, and the ECB's CSPP is not the primary driver of the development we observe.

To neutralize this criticism, we now perform two alternative tests. We first test for whether the trend documented in Table 4 is a global phenomenon in 2016. We then test for whether the trend documented in Table 4 was already present in the Euro area prior to the CSPP.

5.3.1 Placebo 1: Foreign-domiciled companies

In Table 5, we report estimates from Equation (1) where the sample is constructed using comparable non-euro area companies. The CSPP only affected the funding costs of companies domiciled in the euro area. Therefore, if we observe a similar divergence in R&D investment between eligible and ineligible companies outside of the euro area, the rationale that the trend we observe in Table 4 must be due to the ECB's QE would be compromised.

For this test, we use Compustat data on publicly traded companies in five large non-Euro-area bond markets: US, Japan, the United Kingdom, Switzerland and Sweden. For comparability, we focus on companies in Manufacturing (SIC 2000-3999) and in Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999). In each of these markets, we classify a company as pseudo-eligible for the CSPP if the company had active corporate bonds in December 2015 with minimum credit assessment of BBB-/Baa3/BBBL (S&P, Fitch, Moody's, DBRS). We exclude foreign-domiciled companies that issue investment-grade corporate bonds in the Euro area capital markets because those bonds are eligible for CSPP purchases. These companies constitute the pseudo-treatment group. All publicly traded companies in the same country (countries) whose rating falls below the CSPP threshold are placed in the pseudo-control group.

We implement the identical matching strategy as for the Euro area main sample by selecting first-best control firms on their observable traits to the before the CSPP announcement in 2015-Q4. This includes: (1) geography (headquarter location), (2) economic sector (SIC code 1-digit), (3) ex-ante innovation strength (R&D expenditure / sales), and (4) ex-ante firm size (total assets). Subsequently we replicate our empirical strategy with firm fixed effects and Quarter X Sector fixed effects. We further include Quarter X Country fixed effects for the joint estimation of Great Britain, Sweden and Switzerland in column (1). The variable $Post_t$ is a dummy equal to one 2016-Q1 for all pseudo-eligible and pseudo-ineligible companies, and to zero otherwise.

The point estimates reported in Table 5 are uniformly insignificant at any acceptable statistical level. The evidence thus strongly rejects the hypothesis that highly rated and less highly rated companies diverged in their propensity to invest in R&D across the globe around the time when the CSPP was introduced, for reasons unrelated to the CSPP.

5.3.2 Placebo 2: False announcement

We next test for the possibility that the trend documented in Table 4 was in place already before the CSPP came into force. If so, then the CSPP simply coincided with a secular increase in R&D investment by one type of highly rated bond-issuing companies, and did not precipitate it. To that end, we re-estimate Model (1) for the same two groups of eligible and ineligible companies included in the tests reported in Table 4, but we do so for the pre-CSPP period. We choose the period between 2010-Q1 and 2015-Q4, as it allows us to avoid an overlap with the CSPP announcement. We introduce the pseudo treatment in the middle of the period, i.e., as of 2013-Q1, whereby we compare three years before and after the announcement. Part of the new sample period coincides with the euro area sovereign debt crisis, meaning that firms may have been affected by the crisis in terms of growth prospects or access to finance. At the same time, our approach allows us to test for whether any such trends were different across the two types of firms that later benefited to a different extent from the CSPP announcement.

The estimates form this test are reported in Table 6. Column (1) suggests that the two types of companies were indistinguishable in the statistical sense in their average propensity to invest in R&D over the pre-CSPP period. Column (2) in turn suggests that when controlling for firm fixed effects, there was a clear trend towards increasing R&D investment over time, although it is a statistically insignificant one. Finally, our preferred specification in column (3) reveals that R&D investment by eligible companies did not increase already before the CSPP, relative to control ones. The falsification test yields a positive insignificant effect from the hypothetical treatment. We conclude that the increase in R&D investment by companies which benefited from the CSPP is indeed an artefact of the program itself, and not part of a trend which preceded it.

5.4 Robustness tests

To assess the validity of our main result, we must subject our matching method and matched sample to a battery of robustness tests. In the next sections we first use an alternative matching method and estimate Equation (1) relative to a new control group. Second, we investigate the impact on corporate innovation by splitting our sample according to economic sector.

5.4.1 Robust matching and sample

In Table 7, we begin by applying a different matching technique in column (1). Whilst the matching attributes remain unchanged (i.e., headquarter location, economic sector, ex-ante innovation strength, and ex-ante firm size), we enforce a one-to-one matching without replacement such that for each eligible company there is exactly one unique control company that is not eligible for CSPP purchases. This implies that there are no duplicate control companies. Thereby we control for potential sampling bias arising from multiple selection of a control company in the original methodology. However, this is at the expense of a declining sample size because the set of suitable control companies available for matching naturally decreases as the number of successfully matched pairs increases. This is observed in column (1), where the count of eligible companies reduces to 77 due to a lack of a suitable control in the same country and economic sector. Overall we find a similar positive effect on R&D investment, statistically significant at the 10% level, when comparing eligible companies to ineligible.

In column (2), we re-estimate our main result Table 4 comparing our 81 eligible companies to all ineligible companies that reside in the same country and sector as a control group. Thereby we allow one eligible companies to be compared to several control companies. We further require that the R&D-to-sales distribution of the control group conforms that of the eligible group but we do not impose a selection on firm size or direct matching on ex-ante innovation strength. This implies that our 81 eligible companies will be matched with at least one or more suitable control companies. The point estimate on the main variable of interest larger to than the one in Table 4, column (3), suggestive of a 10.7% investment increase in innovation. Furthermore, this effect is significant at the 5-percent statistical level.

Next, in column (3) we compare all companies that had their bonds purchased under the CSPP with all ineligible companies in the same country and sector. Again, we do not enforce a one-to-one matching such that a treated company is mapped with several ineligible controls. The results reveal that companies that had their bond purchased under the ECB's CSPP increased their R&D expenses as a share of sales post-CSPP purchases by 10.5% relative to the ineligible companies in the control group. The coefficient is statistically significant at the 5% level, and the economic significance is in line with previous estimates.

The tests reported in Table 7 thus uniformly support the idea that companies which benefited from the CSPP in terms of higher supply of external funding—either because their bonds were purchased by the ECB, or were eligible to be purchased—increased significantly their R&D investment in the wake of the program. The magnitude of this effect is sensitive to the sample construction, nevertheless, it continues being economically meaningful and statistically significant in a number of specifications where treatment and control firms are chosen based on different econometric criterion.

6 CSPP and innovation: Mechanisms

In this section, we evaluate a number of hypotheses related to the mechanisms whereby an increase in the supply of external finance stimulated innovation. These tests are informed by different conjectures as to how exactly firms benefited from the CSPP. There are two broad possibilities. The first one is that at the time of the announcement of the Program, some companies faced unfavorable external financing conditions. The CSPP helps these companies overcome binding credit constraints, and consequently, they increased their R&D investment. The second possibilities is that credit constraints were not binding for the companies targeted by the CSPP. Instead, the reduction in funding costs that the CSPP generated is a wealth transfer to firms that were eligible for the program, and they used these extra "savings" to increase their productivity-enhancing investment. Alternatively, by generating a long-term reduction in funding costs, the CSPP reduces future liquidity risk. This leads firms to increase their level of innovation to the "optimal" one. This mechanism is likely stronger for companies with a particular corporate structure, innovation expertise, and risk-return profile.

To evaluate these hypotheses, we estimate the following specification:

$$\begin{aligned} \frac{R\&D_{f,t}}{Sales_{f,t}} &= \beta_1 Eligible_f \times Post_t + \beta_2 X_f \times Post_t + \beta_3 Eligible_f \times X_f \times Post_t \\ &+ \gamma_f + \mu_{c,t} + \phi_{s,t} + \varepsilon_{f,t}, \end{aligned} \tag{3}$$

where X_f is a firm-specific proxy for credit constraints, corporate structure, innovation profile, or riskiness.

6.1 The role of credit constraints

The first hypothesis we test is related to the role of credit constraints. A large literature has argued that financial development is mostly relevant for companies that are credit constrained, as easier access to finance allows them to overcome these constraints and increase investment on the margin (e.g., Fazzari, Hubbard, and Petersen, 1988; Rajan and Zingales, 1998).

To evaluate this hypothesis, we turn to well-established empirical proxies for credit constraints at the firm level (e.g., Almeida, Campello, and Weisbach, 2004; Kaplan and Zingales, 1997; 2000). The first proxy is cash flow divided by total assets. This proxy measures how easy it is for a company to tap into cash if it needs to fund extra investment or operating costs. We denote as credit constrained companies with below-median cash-to-total assets ratio during the last year before the CSPP announcement. The second proxy is the interest coverage ratio (ICR). The ICR is defined as earnings before interest, taxes, depreciation, and amortization (EBITDA) divided by interest expenses. The ICR thus measures how easy it is for a company to pay expenses on its outstanding debt. We denote as credit constrained companies with below-median ICR during the last year before the CSPP announcement. The third proxy is the dividend payout ratio, calculated as the sum of dividends and stock repurchases, divided by operating income. The idea is that firms which face binding credit constraints cannot afford to pay dividends and to repurchase common stock to the same extent as unconstrained firms. We denote as credit constrained firms in the bottom half of the distribution of this ratio, which is consistent with prior work (e.g., Almeida, Campello, and Weisbach, 2004).

The estimates form these tests are reported in Table 8. We fail to reject the hypothesis that credit constraints do not matter. Instead, the data strongly suggest that credit constrained firms eligible for the CSPP are no more likely to increase innovation after the Program announcement than eligible unconstrained firms. This is true for all three proxies for credit constraints that we employ. This result extends the findings in numerous papers that financing constraints are very relevant for small and young firms (e.g., Beck, Demirguc-Kunt, Laeven, and Levine, 2008; Ayyagari, Demirguc-Kunt, and Maksimovic, 2011). Our evidence suggests that among *listed* companies, the ones that benefit the most from QE, in terms of innovation, are not necessarily those that are more credit constrained.

6.2 The role of prior innovation

6.2.1 The role of sector-level innovation intensity

We now ask whether prior innovation played a role in the transmission of more favorable financing conditions to R&D investment. We begin by introducing a triple interaction with a dummy variable equal to one if the company is defined as belonging to the manufacturing sector. The dummy is equal to zero if the company belongs to the sector "Transportation, Communications, Electric, Gas and Sanitary Services." We hypothesize that eligible firms in more innovative sectors will respond more to the CSPP, in terms of higher R&D investment, than eligible firms in sectors for which R&D is not a primary investment activity.

The results in Table 9 strongly support this notion. The point estimate on the variable of interest in our preferred specification suggests that eligible companies in Manufacturing are significantly more likely than control firms to invest in R&D after the activation of the CSPP than non-manufacturing companies. The coefficient 0.860 is significant at the 5-percent statistical level. Recall that according to Table 1, the Transportation, Communications, Electric, Gas and Sanitary Services is not among the most innovation-intensive sectors in Europe, while manufacturing is. We conclude that the CSPP stimulates R&D investment considerably more in sectors with technologically higher innovation intensity.

6.2.2 The role of firm-level innovation intensity

Does the innovation expertise of the firm matter for the effect of Quantitative easing on R&D investment? In the previous table, we already documented that firms in more innovative sectors are more likely to innovate further in the wake of a positive supply shock to the cost of external debt. In Table 10, we attempt to answer the same question using firm-level heterogeneity in the propensity to innovate.

Consistent with the idea that R&D investment is a continuous long-term process that depends on the realization of the technology embedded in the initial innovation, one hypothesis states that *ceteris paribus*, the increase in R&D expenses for the treatment group following the announcement of the CSPP will be correlated with the company's extent of innovation activities prior to the CSPP purchases. This implies that companies with high levels of innovation before the announcement of the CSPP will increase R&D expenses by more compared to companies with low levels of innovation during the pre-CSPP period. We formally test this hypothesis in Table 10, where we differentiate between QE-eligible companies based on their innovation strength. In column (1), we report a test where we split companies into those with above- and those with below-median levels of patents normalized by sales prior to the CSPP.[7] In column (2), we split companies into those with above- and those with below-median levels of R&D investment normalized by sales prior to the CSPP. Finally, in column (3), we split companies into those with above- and those with below-median intangible assets normalized by total assets prior to the CSPP.

The evidence strongly suggests that whether companies benefiting from the CSPP increase R&D investment or not depends crucially on whether these companies were already innovating prior to the CSPP. In column (1), we find that eligible companies with above-median patents increased significantly more their R&D expenses, as a share of sales, than eligible companies with relatively low patenting activity before the CSPP. The coefficient of 0.586 is significant at the 1% statistical level, and together with the coefficients on the double interaction, it implies that R&D investment by eligible companies increased by around 6% relative to the pre-announcement average if they had above-median patents. Similarly, R&D investment by CSPP-eligible companies increases by 4.4% for eligible companies with above-median pre-CSPP levels of R&D investment, relative to those with below-median R&D investment (column (2)). At the same time, there is no difference in the elasticity of R&D investment to external debt finance for eligible firms with high, versus eligible firms with below-median intangible assets (column (3)).

The evidence thus strongly suggests that in our sample, changes in access to debt finance are more relevant for continuing as opposed to initial innovation. Our findings are thus consistent with models of smooth R&D investment in the presence of staged innovation, such as Green and Scotchmer (1995) and Aghion, Angeletos, Banerjee, and Manova (2010).

[7] Data on company-level patents come from PATSTAT.

6.3 The role of corporate structure

We next confront the natural question whether our results are at least to some extent explained by differences in corporate structure at the company level. The literature has long established that credit constraints high levels of debt can impede investment, especially long-term one, because the returns to new investment mostly accrue to the existing debt holders (e.g., Jensen and Meckling, 1976; Myers, 1977). This suggests that the response of R&D investment to a CSPP-induced decline in the cost of debt can depend on the extent to which eligible companies are already debt-financed.

To test for this possibility, we introduce a triple interaction with a dummy variable *Lowleverage* which is equal to one if the company is below the sample median in terms of its leverage during the pre-CSPP period (i.e., 2011-Q1 - 2015-Q4). We define leverage as the sum of long term debt and debt in current liabilities, divided by total assets and by total equity. Table 11 reports the point estimates from this version of Equation (3) where *Lowleverage* is defined as below-median leverage-to-assets (column (1)), and as below-median leverage-to-equity (columns (2)).

In both cases, the point estimate on the triple interaction is positive and significant at the 5% statistical level. Focusing on the former normalization, the point estimate of β_3 is 0.430. Together with the coefficient on the double interactions, it implies a more than doubling of R&D expenses for eligible companies with below-median leverage levels. A similar pattern emerges using the latter normalization, by equity (column (2)). Uniformly, the evidence suggests that after the CSPP treatment, companies with relatively lower leverage increased significantly their investment in R&D, while companies with relatively high leverage did not.

The empirical regularities documented in Table 11 strongly point in the direction that the corporate structure of the company matters. When debt is already high enough, subsidizing it further makes no difference to the company. Conversely, companies with low enough debt benefit from debt being cheaper, and so they bring their debt level closer to the optimum, with an increase in R&D investment as one of the consequences. This is consistent with the idea that debt overhang may depress productive long-term investment (Myers, 1977).

6.4 The role of firm growth and riskiness

Finally, in Table 12, we test for whether ex-ante differences in terms of firm-level risk and return helps predict the elasticity of the company's R&D investment to the supply of external funds. These tests serve two separate purposes. First, they aim to shed light on the type of firms through which the transmission of more beneficial funding conditions to R&D investment took place, in terms of risk-return profile. Second, we aim to address the question, who benefits from monetary policy. This question has been subject to renewed attention recently, with some authors claiming that (unconventional) monetary policy favors unproductive (zombie) firms, rather than efficient companies, thereby interfering with the process of creative destruction (e.g., Acharya, Eisert, Eufinger, and Hirsch, 2019).

We calculate two empirical proxies, one for return and for for risk. We calculate return both as return on assets and as return on equity. Next, we calculate risk in terms of the volatility of the return to assets or the return to equity. Then, similar to our strategy so far, we create a triple interaction with eligibility and post-CSPP dummies which allows us to compare eligible companies after the introduction of the CSPP in terms of their risk-return profile.

The evidence suggests that neither firms with higher pre-CSPP returns, nor firms with lower pre-CSPP return volatility, are more likely to respond to the CSPP-induced reduction in the cost of external debt from the CSPP, in terms of R&D investment. This is true both when we calculate return and risk in terms of assets (column (1)) and in terms of equity (column (2)).

We conclude that the main result in the paper does not depend on whether the eligible companies were credit constrained or had better return-risk profiles. At the same time, the main result is largely driven by companies that had low leverage levels, and were more innovative to begin with. Table A4, we run a horse race between different combinations of low leverage and prior innovation, and we confirm that the two channels are operations simultaneously, rather than one of them dominating the other. We conclude that the CSPP increased R&D investment not by relaxing credit constraints or by increasing the return to innovation on higher-growth or higher-risk firms. Rather, it was a wealth transfer to firms whose corporate structure allowed them to benefit from lower costs of debt, and whose existing asset structure increased the return to innovative activities.

7 Conclusion

Determining whether access to external finance matters for innovation, and who benefits from it, is important for identifying the causal link between financial development and economic growth, as well as for understanding how financing frictions influence real economic activity. Equally important is understanding whether the numerous examples of Quantitative Easing by Central Banks throughout the world since the Global Financial Crisis have supported the real economy, in particular in the form of productivity-enhancing activities by firms.

In this paper, we address both questions by studying the impact of the ECB's corporate QE on R&D expenses by large listed European companies. We find strong evidence that cheaper finance matters for R&D investment in the short-to-medium run. Focusing on the sample of firms that were eligible under the QE, we find that those companies whose bonds were purchased by the ECB increased R&D spending by 9% on average in the next four years. This response grows in time, with R&D investment 16% higher for eligible than for ineligible firms in the fourth year after the announcement of the program. Controlling in a number of different ways for demand shocks, for composition effects, and for global trends, we confirm that we document a genuine response of productivity-enhancing investment to the exogenous increase in the supply of external funding.

Next, we dig into the heterogeneity of the response across firms and sectors. We find that the main result in the paper is largely driven by companies that had low leverage levels, and that were more innovative to begin with. At the same time, the response of R&D investment to a reduction in the cost of external debt does not depend on whether the firm is credit constraint and on its risk-return profile. This evidence helps us distinguish between the various mechanisms proposed in the literature whereby finance supports innovation. We conclude that rather than relaxing credit constraints, the CSPP provided a wealth transfer to firms whose corporate structure allowed them to benefit from the debt subsidy, and whose existing innovation increased the return to future one. The evidence also supports theories where innovation is depressed by future liquidity risk, which the CSPP helped reduce (e.g., Aghion, Angeletos, Banrjee, and Manova, 2010).

Our results are important in two different ways. First, the evidence we document is consistent with the idea that access to finance matters at all stages of the life cycle of innovation. While much of the literature has focused on the role that financing constraints play in the innovation decisions of young firms, we show that they also matter in a material way for a certain class of mature firms, too. Second, our evidence suggests that increased funding to the real economy via QE programs is associated with an increase in R&D investment which is notoriously difficult to collateralize. This is especially important in light of recent evidence that intangible investment—such as intellectual property, organizational structure, business strategy, and brand equity—now dominates tangible investment in advanced economies, reducing Central Bank's ability to stimulate economic growth via its preferred channel, the "bank lending" one (e.g., Corrado and Hulten, 2010; Döttling and Ratnovski, 2020). Our results suggest that by expanding their toolbox of operational policies, Central Banks can continue supporting today's knowledge-based economies. However, they also caution against blanket support of firms, and speak to the notion that policies need to be designed such that they support firms with high elasticity of investment to the cost of external finance.

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Figure 1: The ECB's Corporate Sector Purchase Programme

This figure displays the cumulative holdings of the Eurosystem's Corporate Sector Purchase Program (CSPP) by economic sector. Economic sectors are classified according to NACE codes. The purchases were first implemented in 2016-Q2. Financial subsidiaries of non-financial corporations are unconsolidated, and thus are classified as the 'Finance and real estate' sector (i.e., Bayer Capital Corp. B.V.).

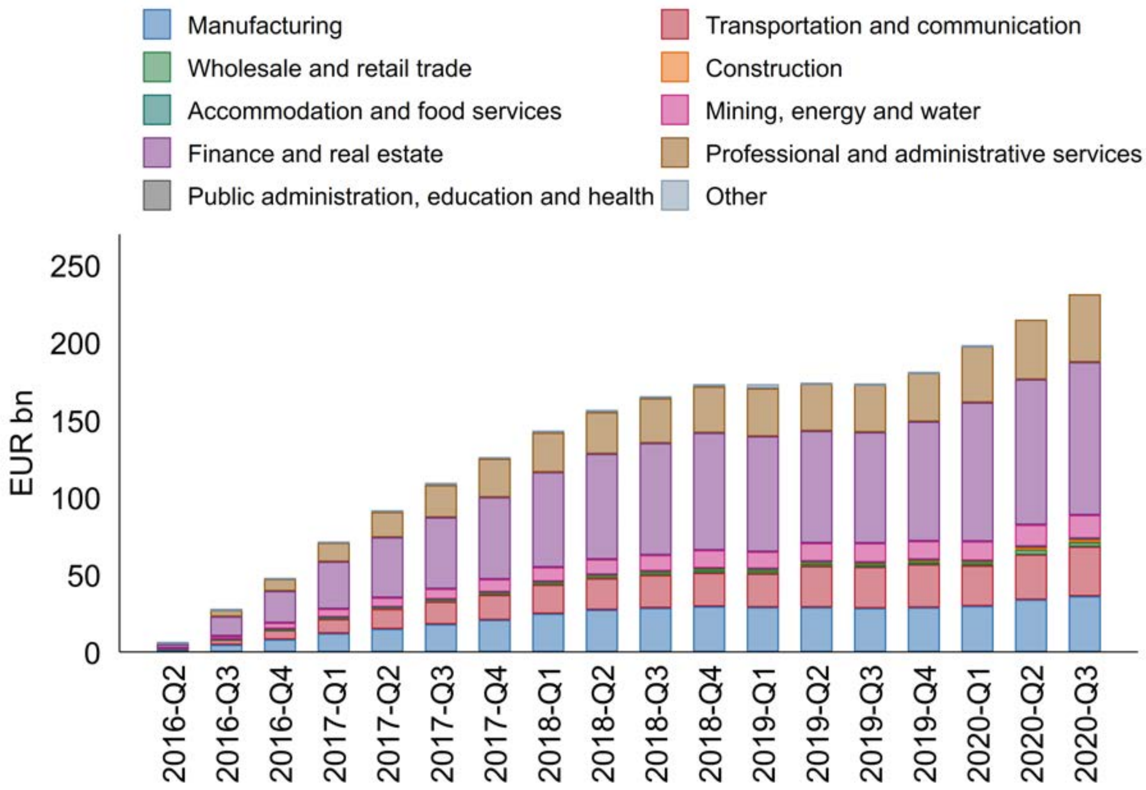

Figure 2: Corporate innovation trends, 2012 - 2019

This figure depicts the difference in corporate innovation between the eligible and the ineligible firms. The sample period is 2012 to 2019, and the reference year is 2016 (i.e., the first year of the CSPP). Using a difference-in-difference set up, we estimate the following specification:

$$\frac{R\&D_{f,t}}{Sales_{f,t}} = \sum_{n=2012}^{2019} \beta_n Eligible_f \times D_{year=n} + \gamma_f + \mu_{c,t} + \phi_{s,t} + \varepsilon_{f,t},$$

where $\frac{R\&D_{f,t}}{Sales_{f,t}}$ is the ratio of R&D expenditure to sales of firm f in quarter-year t. The dummy variable $Eligible_f$ takes on the value of 1 if the company had issued bonds eligible for CSPP purchases. The variable $D_{year=n}$ corresponds to year n, where $n \in \{2012, ..., 2019\}$.$\gamma_f$ are firm fixed effects, $\mu_{c,t}$ are country-time fixed effects, $\phi_{s,t}$ are sector-time fixed effects and $\varepsilon_{f,t}$ is the error term. Standard errors are clustered at the country-year level.

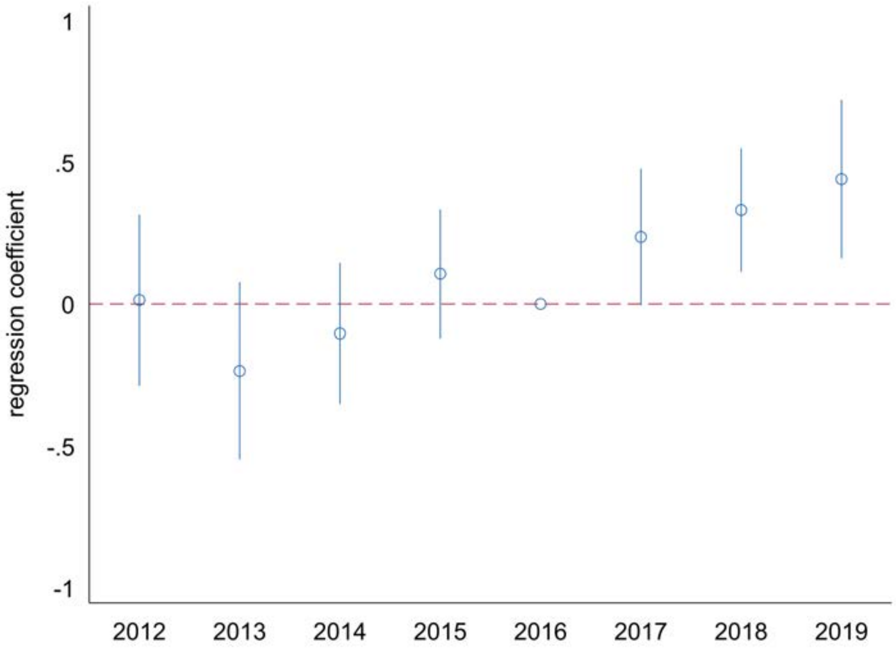

Table 1: Corporate Innovation in the United States and Europe

This table presents summary statistics on corporate innovation for companies headquartered in the United States and Europe (EA19). The statistics are calculated for core economic sectors at 1-digit SIC level in 2015 (i.e., the year before the CSPP was announcement). We exclude agriculture (SIC 0100-0999), financial services (SIC 6000 - 6799), and non-classifiable companies (SIC 9900-9999). Corporate innovation defined as the ratio of R&D expenditure to sales. The extreme values in the R&D-to-sales distribution are replaced by the 90th percentile.

Europe	mean	sd	p50	N
Construction	0.41	0.63	0.26	23
Manufacturing	4.11	5.13	2.04	601
Mining	1.57	3.41	0.12	7
Retail Trade	1.55	4.66	0.34	15
Services	7.27	7.63	4.50	180
Transportation	1.38	2.80	0.33	61
Wholsesale Trade	1.19	2.19	0.25	14
Total	4.35	5.77	1.91	901

United States	mean	sd	p50	N
Construction	2.19	3.18	0.21	5
Manufacturing	19.26	35.65	5.73	1251
Mining	7.55	20.21	0.96	21
Retail Trade	0.06	0.82	0.00	207
Services	16.26	20.60	12.07	459
Transportation	11.38	13.47	5.42	35
Wholsesale Trade	0.11	0.32	0.00	61
Total	15.77	30.39	4.47	2039

Table 2: Summary statistics

This table reports summary statistics for the matched sample used in the subsequent analyses, which contains 81 eligible and 81 ineligible companies from 2012-Q1 to 2019-Q4. Companies are matched according to their headquarter location, economic sector, ex-ante innovation strength and ex-ante firm size. All companies are headquartered in the Euro area, and are either in Manufacturing (SIC 2000-3999) or in Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999). Firm size is calculated as the log of total assets. Research and development expenses are scaled by sales. Cash holdings, capital expenditure and acquisition expenditure are all scaled by total assets. Data unavailability explains the lower observation count for acquisition expenditure.

	(1) N	(2) mean	(3) sd	(4) p50	(5) min	(6) max
Firm Size [log(Assets)]	1,176	8.99	1.89	9.03	1.54	13.10
Research Expense / Sales (%)	1,176	2.93	3.51	1.81	0.00	21.15
Cash / Assets (%)	1,176	10.29	7.77	8.38	0.06	54.27
CapEx / Assets (%)	1,168	4.28	2.84	3.76	0.12	23.89
Acquisitions / Assets (%)	774	2.23	4.69	0.48	-5.90	35.88
#Eligible	81	81	81	81	81	81
#Ineligible	81	81	81	81	81	81

Table 3: Distributional differences in the matched sample

This table tests for differences in the distribution between the matched eligible and ineligible firms. Column (1) and (2) refer to the eligible companies and column (3) and (4) to the ineligible companies. The statistics are calculated for each firms' last available observation before the CSPP announcement, which was announced in 2016-Q1. Column (5) presents the results from the Mann-Whitney two-sample statistic, which tests that the eligible and ineligible groups are from populations with the same distribution. Firm size is calculated as the log of total assets. Research and development expenses are scaled by sales. Cash holdings, capital expenditure and acquisition expenditure are all scaled by total assets. Data unavailability explains the lower observation count for acquisition expenditure. *** p<0.01, ** p<0.05, * p<0.1

	eligible		ineligible		
	(1) N	(2) mean	(3) N	(4) mean	(5) difference
Firm Size [log(Assets)]	81	10.03	81	7.51	***
Research Expense / Sales (%)	81	2.84	81	2.54	
Cash / Assets (%)	81	8.47	81	12.73	***
CapEx / Assets (%)	81	4.27	79	4.62	
Acquisitions / Assets (%)	54	3.04	39	3.50	
# Companies	81	81	81	81	

Table 4: The effect of the CSPP on corporate innovation

This table presents estimates of the effect of the CSPP on corporate innovation. The sample period is between 2012-Q1 and 2019-Q4. Companies are matched according to their headquarter location, economic sector, ex-ante innovation strength and ex-ante firm size. All companies are headquartered in the Euro area, and are either in Manufacturing (SIC 2000-3999) or in Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999). In column (3), using a difference-in-difference set-up, we estimate the following specification:

$$\frac{R\&D_{f,t}}{Sales_{f,t}} = \beta Eligible_f \times Post_t + \gamma_f + \mu_{c,t} + \phi_{s,t} + \varepsilon_{f,t},$$

where $\frac{R\&D_{f,t}}{Sales_{f,t}}$ is the ratio of R&D expenditure to sales of firm f in quarter-year t. The dummy variable $Eligible_f$ takes on the value of 1 if the company is eligible for ECB bond purchases. The variable $Post_t$ is equal to 1 following the CSPP announcement in 2016-Q1. γ_f are firm fixed effects, $\mu_{c,t}$ are country-time fixed effects, $\phi_{s,t}$ are sector-time fixed effects and $\varepsilon_{f,t}$ is the error term. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) R&D/ Sales	(2) R&D / Sales	(3) R&D / Sales
Eligible X Post	0.102	0.245**	0.273***
	(0.179)	(0.094)	(0.103)
Post	0.056	0.004	
	(0.318)	(0.079)	
Eligible	0.096		
	(0.152)		
#Eligible	81	81	81
#Ineligible	81	81	81
Observations	1,176	1,176	1,176
R-squared	0.001	0.014	0.132
Company	No	Yes	Yes
Quarter X 1-Dig. Sector	No	No	Yes
Quarter X Country	No	No	Yes

Table 5: Placebo test: Foreign-domiciled companies

This table presents the placebo effect of the CSPP on foreign-domiciled companies for the United States, Japan, Great Britain, Switzerland and Sweden. We classify a foreign-domiciled company as eligible for the hypothetical CSPP if the company had active corporate bonds in December 2015 with minimum credit assessment of BBB-/Baa3/BBBL (SP, Fitch, Moody's, DBRS). We exclude foreign-domiciled companies that issue investment grade corporate bonds in the Euro area capital markets because those bonds are eligible for CSPP purchases (of which some are part of the ECB's CSPP portfolio). The sample period is between 2012-Q1 and 2019-Q4. For comparability, we restrict our sample to companies in Manufacturing (SIC 2000-3999) or Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999). The hypothetical treatment date coincides to the CSPP announcement in 2016-Q1. The dependent variable is the ratio of R&D expenses divided by sales. Column (1) pools Great Britain, Switzerland and Sweden. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) non-EA	(2) JP	(3) USA
Pseudo-Eligible X Post	-0.107	-0.009	0.540
	(0.266)	(0.046)	(0.406)
#Pseudo-Eligible	28	29	113
#Pseudo-Ineligible	28	29	113
Observations	409	466	1,749
R-squared	0.142	0.132	0.030
Company	Yes	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes	Yes
Quarter X Country	Yes	No	No

Table 6: Placebo test: False announcement

This table presents the falsification effect of the CSPP. The sample period is between 2010-Q1 and 2015-Q4, the hypothetical treatment date is introduced in 2013-Q1 to maintain a balanced sample to maintain a balanced sample before and after the treatment. The reduction the treatment and control companies is explained by data unavailability before 2012-Q1. The dependent variable is the ratio of R&D expenditure divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) R&D / Sales	(2) R&D / Sales	(3) R&D / Sales
Eligible X Post	-0.100	-0.008	0.024
	(0.404)	(0.127)	(0.149)
Post	0.173	0.121	
	(0.349)	(0.127)	
Eligible	0.266		
	(0.264)		
#Eligible	68	68	68
#Ineligible	66	66	66
Observations	764	764	764
R-squared	0.001	0.009	0.183
Company	No	Yes	Yes
Quarter X 1-Dig. Sector	No	No	Yes
Quarter X Country	No	No	Yes

Table 7: Robust samples

This table presents the effect of the CSPP on corporate innovation for different samples. For all estimations the sample period is between 2012-Q1 and 2019-Q4. All companies are headquartered in the Euro area, and are either in Manufacturing (SIC 2000-3999) or in Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999). Column (1) applies matching without replacement. Column (2) compares eligible companies from the main samples against all ineligible companies, which reside in the same sectors and countries. Column (3) repeats the exercise but only for companies which had their bonds purchased under the CSPP. The dependent variable is the ratio of R&D expenditure divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

	(1) Match w/o Replacement	(2) Eligible Ineligible	(3) Purchased Ineligible
Eligible X Post	0.256*	0.316**	0.311**
	(0.136)	(0.124)	(0.132)
Eligible	77	81	74
of which purchased	70	74	74
Ineligible	77	509	509
Observations	1,131	4,247	4,199
R-squared	0.123	0.023	0.024
Company	Yes	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes	Yes
Quarter X Country	Yes	Yes	Yes

Table 8: Role of firm financial constraints

This table presents the estimates of the effect of the companies' financial constraints prior to the CSPP announcement on corporate innovation. The sample period is between 2012-Q1 and 2019-Q4. We consider three measures of ex-ante financial constraints: cash-to-assets (C/A), the interest rate coverage ratio (ICR), and the payout ratio ($Payout$). C/A is computed as the ratio of cash and short-term investments to total assets, ICR as the ratio of earnings before interest and taxes to interest expenses, and $Payout$ as total dividends divided by net income. We compute each measure for the last year before the CSPP announcement and subsequently define $FinanciallyConstrained$ according to the eligible and ineligible group median. The dummy takes on the value of one if the company's financial constraints exceed the respective group median. The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) C/A	(2) ICR	(3) $Payout$
Post X Eligible	0.215	0.341*	0.129
	(0.157)	(0.186)	(0.095)
Post X Financially Constrained	-0.047	-0.009	-0.469***
	(0.102)	(0.178)	(0.167)
Post X Eligible X Financially Constrained	0.241	-0.062	0.094
	(0.207)	(0.234)	(0.138)
#Eligible	81	81	81
#Ineligible	81	81	81
Observations	1,152	1,144	634
R-squared	0.139	0.137	0.234
Company	Yes	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes	Yes
Quarter X Country	Yes	Yes	Yes

Table 9: Role of sector-level innovation intensity

This table presents the effect of the CSPP on corporate innovation for two major economic sectors. For all estimations the sample period is between 2012-Q1 and 2019-Q4. Sector is a dummy equal to one if the company belongs to the Manufacturing sector (SIC 2000-3999). The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) *Manufacutring*
Post X Eligible	-0.296
	(0.236)
Post X Sector	-2.981***
	(0.412)
Post X Eligible X Sector	0.860**
	(0.339)
#Eligible	81
#Ineligible	81
Observations	1,176
R-squared	0.234
Company	Yes
Quarter X 2-Dig. Sector	Yes
Quarter X Country	Yes

Table 10: Role of firm-level innovation intensity

This table presents the estimates of the effect of the companies' innovation strength prior to the CSPP announcement on corporate innovation. The sample period is between 2012-Q1 and 2019-Q4. We consider three measures of ex-ante innovation strength: patent-to-sales (*Patents*), R&D-expenditure-to-sales (*R&D*), and intangibles-to-assets (*Intangibles*). For each measure, we compute the average in the pre-period, 2012 - 2015, and subsequently define the high innovation group according to the eligible and ineligible group median. Patent data comes from the EPO's PATSTAT. The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) *Patents*	(2) *R&D*	(3) *Intangibles*
Post X Eligible	-0.093	-0.102	0.255*
	(0.092)	(0.081)	(0.143)
Post X High Innovation	-0.417***	-0.469***	0.124
	(0.156)	(0.176)	(0.128)
Post X Eligible X High Innovation	0.586***	0.602***	0.038
	(0.201)	(0.226)	(0.212)
#Eligible	81	81	81
#Ineligible	81	81	81
Observations	1,174	1,176	1,176
R-squared	0.140	0.140	0.134
Company	Yes	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes	Yes
Quarter X Country	Yes	Yes	Yes

Table 11: Role of corporate structure

This table presents estimates of the effect of the companies' leverage ratio on corporate innovation following the CSPP purchases. The sample period is between 2012-Q1 and 2019-Q4. We consider two measures of financial leverage: debt-to-assets (D/A), and debt-to-equity (D/E). The former is defined as long-term debt and debt in current liabilities divided by total assets, and the latter is defined as long-term debt and debt in current liabilities divided by shareholder's equity. The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) D/A	(2) D/E
Post X Eligible	0.033	-0.008
	(0.086)	(0.126)
Post X Low Leverage	-0.068	-0.156
	(0.140)	(0.142)
Post X Eligible X Low Leverage	0.430**	0.489**
	(0.198)	(0.221)
#Eligible	81	81
#Ineligible	81	81
Observations	1,176	1,176
R-squared	0.138	0.138
Company	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes
Quarter X Country	Yes	Yes

Table 12: Role of firm growth and riskiness

This table presents estimates of the effect the companies' ex-ante riskiness on corporate innovation. The sample period is between 2012-Q1 and 2019-Q4. We define the return on assets, (*RoA*), as net income divided by total assets, and return on equity, (*RoE*), as net income divided invested capital. We then compute firm return and riskiness as the firm-level mean and standard deviation of each measure respectively during the pre-period. Subsequently, we define the firm growth and risk dummies according to the eligible and ineligible group median. The dummies are equal to 1 if the value exceeds the respective group median. The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) $\mu(ROA)$	(2) $\mu(ROE)$
Post X Eligible	0.097	0.192
	(0.142)	(0.138)
Post X High Firm Growth	0.058	0.097
	(0.129)	(0.135)
Post X Eligible X High Firm Growth	0.342	0.171
	(0.211)	(0.191)
#Eligible	81	81
#Ineligible	81	81
Observations	1,176	1,176
R-squared	0.139	0.136
Company	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes
Quarter X Country	Yes	Yes

	(1) $\sigma(ROA)$	(2) $\sigma(ROE)$
Post X Eligible	0.219	0.188
	(0.165)	(0.136)
Post X Low Firm Risk	0.167	-0.092
	(0.164)	(0.124)
Post X Eligible X Low Firm Risk	0.106	0.192
	(0.232)	(0.213)
#Eligible	81	81
#Ineligible	81	81
Observations	1,176	1,176
R-squared	0.137	0.133
Company	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes
Quarter X Country	Yes	Yes

Appendix

Table A1: Robustness: Manufacturing, Transportation and Services

This table presents the results on impact of the CSPP on corporate over time. The sample period is between 2012-Q1 and 2019-Q4. Companies are matched according to their headquarter location, economic sector, innovation strength and firm size. All companies are headquartered in the Euro area, and are either in Manufacturing (SIC 2000-3999), Transportation, Communications, Electric, Gas and Sanitary service (SIC 4000-4999) or Services (SIC 7000-8999). The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) R&D / Sales	(2) R&D / Sales	(3) R&D / Sales
Eligible X Post	0.213	0.269**	0.303**
	(1.022)	(2.423)	(2.333)
Post	0.009	-0.018	
	(0.029)	(-0.179)	
Eligible	0.030		
	(0.174)		
#Eligible	87	87	87
#Ineligible	87	87	87
Observations	1,282	1,282	1,282
R-squared	0.001	0.008	0.147
Company	No	Yes	Yes
Quarter X 1-Dig. Sector	No	No	Yes
Quarter X Country	No	No	Yes

Table A2: The dynamic effect of the CSPP on corporate innovation

This table presents the results on the gradual effect of the CSPP on corporate innovation over time. Using a difference-in-difference set up, we estimate the following specification:

$$\frac{R\&D_{f,t}}{Sales_{f,t}} = \sum_{n=2016}^{2019} \beta_n Eligible_f \times D_{year=n} + \gamma_f + \mu_{c,t} + \phi_{s,t} + \varepsilon_{f,t},$$

where $\frac{R\&D_{f,t}}{Sales_{f,t}}$ is the ratio of R&D expenditure to sales of firm f in quarter-year t. The dummy variable $Eligible_f$ takes on the value of 1 if the company had their bonds purchased by the ECB. The variable $D_{year=n}$ corresponds to year n, where $n \in \{2016, ..., 2019\}$.$\gamma_f$ are firm fixed effects, $\mu_{c,t}$ are country-time fixed effects, $\phi_{s,t}$ are sector-time fixed effects and $\varepsilon_{f,t}$ is the error term. Standard errors are clustered at the country level. *** p<0.01, ** p<0.05, * p<0.1

	(1) R&D / Sales
Eligible X 2016	0.085
	(0.134)
Eligible X 2017	0.238**
	(0.115)
Eligible X 2018	0.317***
	(0.119)
Eligible X 2019	0.469***
	(0.152)
#Eligible	81
#Ineligible	81
Observations	1,176
R-squared	0.136
Company	Yes
Quarter X 1-Dig. Sector	Yes
Quarter X Country	Yes

Table A3: Alternative specification for corporate innovation

This table presents estimates of the effect of the CSPP on an alternate measure of corporate innovation. We define corporate innovation as the ratio of R&D expenses divided by total assets. The sample period is between 2013-Q1 and 2019-Q4. All estimations are based on the matched sample from Table 3. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1) Baseline
Eligible X Post	0.222*
	(0.120)
#Eligible	81
#Ineligible	81
Observations	1,176
R-squared	0.136
Company	Yes
Quarter X 1-Dig. Sector	Yes
Quarter X Country	Yes

Table A4: Robustness: The impact of ex-ante leverage and innovation strength

This table presents the results on impact of the CSPP on corporate over time. The sample period is between 2012-Q1 and 2019-Q4. The dependent variable is the ratio of R&D expenses divided by sales. All regressions include fixed effects as specified. Standard errors clustered at the country-year level appear in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)	(4)
Leverage measure:	*Debt/Assets*	*Debt/Assets*	*Debt/Equity*	*Debt/Equity*
Innovation measure:	*Patents*	*R&D*	*Patents*	*R&D*
Post X Eligible	-0.211	-0.204	-0.276*	-0.294**
	(0.134)	(0.125)	(0.154)	(0.131)
Post X Low Leverage	-0.032	-0.055	-0.152	-0.135
	(0.141)	(0.148)	(0.150)	(0.141)
Post X High Innovation	-0.351***	-0.420**	-0.380**	-0.426**
	(0.130)	(0.174)	(0.175)	(0.170)
Post X Eligible X Low Leverage	0.319*	0.326*	0.409*	0.410*
	(0.190)	(0.182)	(0.216)	(0.225)
Post X Eligible X High Innovation	0.479**	0.469**	0.490**	0.532**
	(0.193)	(0.196)	(0.204)	(0.229)
#Eligible	81	81	81	81
#Ineligible	81	81	81	81
Observations	1,176	1,176	1,176	1,176
R-squared	0.143	0.144	0.143	0.144
Company	Yes	Yes	Yes	Yes
Quarter X 1-Dig. Sector	Yes	Yes	Yes	Yes
Quarter X Country	Yes	Yes	Yes	Yes

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