The Bond-Lending Channel of Quantitative Easing

Hee Su Roh

JOB MARKET PAPER


February 10, 2022

[Click here for the most recent version]

Abstract: With quantitative easing (QE), central banks buy long-term government bonds to lower long-term interest rates. QE removes from the market both the investment risk associated with ownership of the bonds and also the transaction services conveyed by these bonds, which include facilitating the matching of buyers and sellers in the bond market. To the extent that it lends its stock of bonds back to market participants, a central bank replaces these transaction services. In contrast, by not lending its bonds, the central bank further lowers long-term rates by increasing the scarcity of these transaction services. This amplification of the impact of QE on long-term rates through reduced bond lending allows the European Central Bank to achieve its QE rate objective more easily because the alternative of even greater purchases of bonds could be politically contentious.

1First Draft: May 7, 2019. The most recent version is available at http://www.heesuroh.com. I circulated an earlier version of this paper with the title “Repo Specialness in the Transmission of Quantitative Easing.” I want to thank my advisor Darrell Duffie for invaluable advice and suggestions. I also benefited tremendously from my committee members Arvind Krishnamurthy and Hanno Lustig. In addition, I thank Yu An, Samuel Antill, William Arrata, Alexander Bechtel, Juliane Begennau, Laura Blattner, Claus Brand, Johannes Breckenfelder, Greg Buchak, Narayan Bulusu, Daniel Chen, Stefano Corradin, Stefania D'Amico, Sebastian Di Tella, Lorenzo Ferrante, Benjamin Hebert, Stephan Jank, Peter Koudijs, Francois Koulischer, Wenhao Li, Yiming Ma, Angela Maddaloni, Loriano Mancini, Timothy James McQuade, Emanuel Mönch, Benoît Nguyen, Monika Piazzesi, Loriana Pelizzon, Joshua Rauh, Ricardo Reis, Glenn Schepens, Martin Schneider, Kenneth Singleton, Martin Souchier, Christopher Tonetti, Miklos Vari, Chaojun Wang, Pierre-Olivier Weill (discussant) for helpful discussions. I thank participants of the finance department internal student presentation, the Poster Session of the ECB Forum on Central Banking, and the FRBSF-BoC Conference on Advances in Fixed Income Macro-Finance Research. I thank Christian Hirschfeld from the Finance Agency of Germany for helping me with the data. The financial support from the Europe Center at Stanford University and the George P. Shultz Dissertation Fund from the Stanford Institute for Economic Policy Research (SIEPR) is gratefully acknowledged. Any errors are my own.

2Stanford Graduate School of Business. 655 Knight Way, Stanford, CA 94305. Email: heesuroh@stanford.edu.
1 Introduction

Investors hold long-term government bonds for two reasons. First, investors get the associated coupon and principal payments. Holding the bonds for this purpose involves bearing investment risk. Second, investors can use government bonds for various transaction services. For example, access to the bonds allows short-selling by investors who may wish to hedge interest rate risk or speculate on rate movements. In 2018 alone, Eurozone banks borrowed more than 28 trillion euros of long-term government bonds. Investors can also use the bonds to collateralize trades in the derivatives market. Further, access to a significant stock of bonds facilitates the matching of buyers and sellers by reducing search frictions. The prices of long-term government bonds reflect both the promised payments of coupon and principal, which carry investment risk, and also the various transaction services conveyed by access to the bonds (Krishnamurthy and Vissing-Jorgensen, 2012a).

Central banks, unable to lower their short-term rates much below zero, resorted to quantitative easing (QE), buying significant quantities of long-term government bonds. By removing both investment risk (Altavilla, Carboni, and Motto, 2015; Krishnamurthy and Vissing-Jorgensen, 2012) and transaction services from the market (Krishnamurthy and Vissing-Jorgensen, 2012), QE lowers long-term rates. In order to supply transaction services back to market participants, central banks can lend some of their purchased stock of government bonds to the market. Investors borrowing these bonds do not hold the associated investment risk because they have no claims to the coupons and principal. However, investors borrowing the bonds do receive the associated transaction services.

A central bank conducting QE decides both how much bonds to purchase and also how much of its purchased bonds to lend back to the market. Most central banks are unconstrained in this choice and lend their bonds freely to the market. For example, the Federal Reserve makes all of its Treasury securities available for lending. The ECB, however, faces a constraint on its bond purchases because of the political structure of the European Union.

---

3 Author calculation from the BrokerTec data.
4 https://www.newyorkfed.org/markets/rrp_faq
The ECB has chosen a much different mix of QE purchases and bond lending. Since the beginning of its QE in March 2015, the ECB has applied a cap on the net amount of bonds that it lends to the market. Although the ECB gradually raised this cap, it is still only €75 billion as of August 2021, a mere 2.47% of the ECB’s bond holdings.\(^5\)

This paper is the first to consider the trade-off a central bank faces when choosing how much of its QE purchases to lend back to the market. On the one hand, by lending more long-term government bonds, a central bank provides more transaction benefits to investors. On the other hand, when lending a relatively small quantity of bonds, transaction services become relatively scarce, causing investors to assign higher values to these transaction services. As a result, long-term government bond yields drop even more (Duffie, Garleanu, and Pedersen, 2002; Krishnamurthy and Vissing-Jörgensen, 2012; Vayanos and Weill, 2008). Moreover, through the portfolio substitution effect, other long-term rates, including corporate bond yields, are pushed down further. I call this sequence of QE-amplifying effects the “bond-lending channel of QE.”

The bond-lending channel works as follows. If a central bank does not lend its government bonds, finding sufficient amounts of bonds from other government bond lenders is more difficult, thereby increasing government bond lending fees (Duffie, Garleanu, and Pedersen, 2002). The expectation of earning higher future lending fees drives up the prices of government bonds (Bartolini, Hilton, Sundaresan, and Tonetti, 2011; Buraschi and Menini, 2002; D’Amico, Fan, and Kitsul, 2018; D’Amico and Kaminska, 2019; Duffie, 1996; Duffie, Garleanu, and Pedersen, 2002; Jordan and Jordan, 1997; Krishnamurthy, 2002; Vayanos and Weill, 2008). However, some large buy-side investors, such as insurance companies and pension funds, are relatively inefficient at lending their bonds and forgo some or all of the potential compensation for lending bonds (Eisenschmidt, Ma, and Zhang, 2021a; Madaloni and Roh, 2021).\(^6\) When government bonds become more expensive because of their heightened lending fees, those buy-side investors who are relatively inefficient at lending their government bonds substitute their government bond investments with investments

\(^5\)See Section 9.3 of the Appendix for more information on the restrictive features of the securities lending facilities that the ECB and the national central banks in the eurozone operated. See Table 1 for more details.

\(^6\)See Section 9.1 of the Appendix.
in riskier assets such as corporate bonds. This extra demand amplifies the effect of QE on lowering the borrowing costs of households and firms.

Instead of removing transaction services from the market, a central bank can alternatively purchase a larger quantity of government bonds so as to achieve a given reduction in long-term rates. However, doing so incurs potential fiscal and political costs. A central bank may be “perceived to be monetizing the debt and serving as a buyer of last resort in the name of lowering risk-free rates” (The Federal Open Market Committee 2009). This perception can undermine the independence and credibility of the central bank in the long run, as also noted by the Federal Open Market Committee (FOMC).

Unlike other central banks, the European Central Bank (ECB) must also consider the political tension among Eurozone countries (Brunnermeier, James, and Landau 2016). The Maastricht Treaty of 1992, which laid the foundation of the European Union, prohibits the ECB from financing the fiscal deficits of member countries (Mersch 2016). To avoid breaching this treaty, the ECB established a strict policy for its flagship QE program – the Public Sector Purchase Program (PSPP) – of not buying more than 33% of the outstanding government bonds of any member country. Although the ECB has imposed this limit since the beginning of the PSPP, the program nevertheless created serious political tensions. For example, a group of 1,750 German citizens led by economists and attorneys challenged the legality of the PSPP in the German constitutional court. The complainants argued that the ECB violated the Maastricht Treaty by buying risky government bonds from peripheral Eurozone countries (BVerfG 2020). The 33% purchase limit was a crucial part of the ECB’s defense of its QE program in court (BVerfG 2020). Although the ECB somewhat relaxed its cap in light of the pandemic-induced economic crisis in 2020, the ECB clarified that it would revert to the 33% rule as soon as the pandemic is over (Mersch 2016).

The bond-lending channel for amplifying the impact of QE on long-term rates becomes more useful when a central bank, such as the ECB, is constrained by the amount of bonds

---

7 See Section 9.4 of the Appendix. By government bonds, I mean bonds issued by sovereign governments, local and municipal governments, and recognized public agencies.
8 See the Financial Times article “German court calls on ECB to justify bond-buying programme” on May 6, 2020.
that it may buy. The ECB held almost 30% of Finnish and German bonds by the end of 2018. The ECB has been lending much fewer bonds than other central banks have. On average, the net lending of government bonds by the ECB to the market was 0.28% of its holdings, in terms of the nominal amount, over the period covering the ECB’s purchases of government bonds from March 2015 to December 2018, and from November 2019 to August 2021. Meanwhile, the net lending of Treasury securities by the Federal Reserve was 1.86% of its holdings, which is over six times the rate at which the ECB was lending its bonds. Table 1 summarizes the lending of bonds by four major central banks.

As a counterfactual policy experiment designed to show the impact of the bond lending channel, I suppose that in October 2018, the ECB announced a plan to purchase €20 billion of government bonds each month for the following ten years. The total purchase quantity would be €2.4 trillion, which is roughly what the ECB is actually holding as of September 2021. If the ECB did not lend its bonds, the estimates of Andrade, Breckenfelder, De Fiore, Karadi, and Tristani (2016) and Koijen, Kouilischer, Nguyen, and Yogo (2020) suggest that 10-year BBB corporate bond yield would go down by 70 basis points. However, suppose that the ECB freely lent its bonds to accommodate borrowing needs of investors. I estimate that 10-year BBB corporate bond yield would go down by only 44 basis points. To offset this rise in bond yields, the ECB would have to increase its purchases to €3.9 trillion. Assuming that the total outstanding amounts of eurozone government bonds were to remain the same until 2028, this additional purchase would force the ECB to hold 48% of eurozone government bonds.

---

9The author’s computation based on the data from the ECB website.
10The ECB and the national central banks (NCBs) comprising the Eurosystem lends their bonds in a decentralized manner. Each NCB has its own securities lending facility. For more details, see Section 9.3 of the Appendix.
11I consider only Treasury securities.
12The Eurosystem made the net purchase of government bonds between March 2015 and December 2018 and between November 2019 and September 2021.
14The Bank of Japan had a legacy Japanese Government Bonds (JGBs) purchase program since the 1990s. However, the Bank of Japan started expanding the purchase of JGBs on December 19, 2008. I use data from December 2008 to September 2021.
15The Bank of Canada started its quantitative easing on April 1, 2020.
Table 1 Lending of Government Bonds Against Cash Collateral by Four Central Banks

Panel A: Borrowing Limits as of September 2021

<table>
<thead>
<tr>
<th>Central Bank</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The Eurosystem</strong></td>
<td>The loan balance summed across the ECB and national central banks should not exceed € 75 billion (2.45% of holdings).</td>
</tr>
<tr>
<td>The ECB</td>
<td>Per counterparty: € 200 million or 2.5% of the outstanding amount for each bond, whichever is lower.</td>
</tr>
<tr>
<td>The Bank of France</td>
<td>Per counterparty: € 200 million for each bond</td>
</tr>
<tr>
<td>The Bank of Spain</td>
<td>Per counterparty: € 200 million or 2.5% of the outstanding amount for each bond, whichever is lower.</td>
</tr>
<tr>
<td>The National Bank of Belgium</td>
<td>There is a borrowing limit per counterparty. But the exact number is not disclosed to the public.</td>
</tr>
<tr>
<td>The Bank of Italy</td>
<td>Unclear whether borrowing limit exists.</td>
</tr>
<tr>
<td>The Dutch Central Bank</td>
<td></td>
</tr>
<tr>
<td>The Bank of Slovenia</td>
<td></td>
</tr>
<tr>
<td>The Deutsche Bundesbank</td>
<td></td>
</tr>
<tr>
<td>The Bank of Finland</td>
<td></td>
</tr>
<tr>
<td>Other national central banks</td>
<td>No lending at all.</td>
</tr>
<tr>
<td><strong>The Federal Reserve</strong></td>
<td></td>
</tr>
<tr>
<td>Total: unlimited</td>
<td></td>
</tr>
<tr>
<td>Per counterparty: $160 billion</td>
<td></td>
</tr>
<tr>
<td><strong>The Bank of Japan</strong></td>
<td></td>
</tr>
<tr>
<td>Unlimited</td>
<td></td>
</tr>
<tr>
<td><strong>The Bank of Canada</strong></td>
<td></td>
</tr>
<tr>
<td>Total: 50% of holdings</td>
<td></td>
</tr>
<tr>
<td>Per counterparty: CAD 4 billion</td>
<td></td>
</tr>
</tbody>
</table>

Panel B: Daily Loan Balance (% of Holdings) During Government Bond QE

<table>
<thead>
<tr>
<th>Central Bank</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The Eurosystem</strong></td>
<td>1.19</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>The Federal Reserve</strong></td>
<td>21.29</td>
<td>1.86</td>
</tr>
<tr>
<td><strong>The Bank of Japan</strong></td>
<td>33.64</td>
<td>7.60</td>
</tr>
<tr>
<td><strong>The Bank of Canada</strong></td>
<td>7.48</td>
<td>2.52</td>
</tr>
</tbody>
</table>

Notes: Data come from the websites of central banks.
bonds by October 2028, well above the ECB’s policy caps.

Because of the additional transaction services provided to the market, the counterfactual additional bond lending by the ECB would have increased annual gains from trade in the bond market by an estimated € 3.74 billion, or about 10.59%. For example, investors in the counterfactual scenario could have borrowed bonds more quickly from the ECB rather than searching for lenders in the bilateral European bond repo market, incurring longer delays. By selling the additional bonds they had borrowed from the ECB, investors who wished to short-sell could have better hedged the interest rate risk of their portfolios or better achieved their other investment objectives related to holding government bond collateral. By assisting more investors in borrowing and selling bonds, the ECB would have also benefited investors who wished to buy bonds. It takes less time to buy bonds if there are more potential sellers in the market.

The rest of the paper is structured as follows. Section 2 explains the contribution of this study to the literature. Section 3 presents a brief overview of the repo market, in which bonds may be borrowed, and the Public Sector Purchase Program (PSPP) of the ECB. Section 4 presents a theoretical model of portfolio rebalancing by investors between government bonds and corporate bonds. In Section 5, I estimate the magnitude of the price impacts associated with the QE bond-lending channel. In Section 6, I quantify the impact of the ECB’s restrictive bond-lending policy on the gains from trade in the government bond market. Section 7 discusses other implications of the ECB’s decision to lend relatively fewer bonds. My concluding remarks are given in Section 8. Proofs for all propositions can be found in the Appendix.

2 Literature Review and Contribution

This study contributes to a growing strand of the literature on the effect of central banks’ QE programs on asset prices. I demonstrate a new channel of QE involving the lending and borrowing of bonds. To the best of my knowledge, the role of this bond-lending channel in
increase the effects of government bond purchases by the central bank on asset prices has not been identified in previous studies. This paper is the first to show that central banks can remove or supply transaction services of long-term bonds independently of the investment risk they hold.

One of the most widely cited transmission channels of QE is the duration risk channel (Krishnamurthy and Vissing-Jorgensen, 2012; Vayanos and Vila, 2021). By purchasing long-term bonds, QE programs reduce the total duration risk private investors bear and lower the price of duration risk. As a result, QE programs reduce all long-term bond yields. However, bond lending does not affect investors’ total holding of duration risk. The bond borrower does not hold any investment risk. Hence, if the duration risk channel were the only channel for QE, a central bank would not affect bond yields through lending its bonds.

The channel that I analyze is related to the convenience yield channel (Krishnamurthy and Vissing-Jorgensen, 2012; Diamond, 2020; Diamond, Jiang, and Ma, 2021; Van Binsbergen, Diamond, and Grotteria, 2022), which is based on the concept that investors have a preference for safe and liquid assets such as sovereign bonds or central bank reserves (Krishnamurthy and Vissing-Jorgensen, 2012). QE affects sovereign bond yields by reducing the total availability of safe and liquid long-term assets (Krishnamurthy and Vissing-Jorgensen, 2012) and increasing the total availability of safe and liquid short-term assets in the economy (Diamond, 2020; Diamond, Jiang, and Ma, 2021; Van Binsbergen, Diamond, and Grotteria, 2022). Liquid assets give more transaction services to their owners because it is easier to buy and sell those assets. Likewise, Ferdinandusse, Freier, and Ristimäki (2020) explore the impact of QE on the transaction services conveyed by bonds in the cash market. With fewer bonds circulating in the market, investors cannot buy or sell bonds easily.

These earlier works show that when purchasing bonds, central banks remove both investment risk and transaction services from the market. My work is different from these earlier works by showing that central bank has a policy instrument (i.e., bond lending facility) to remove only transaction services from the market but not investment risk. In addition, I separately identify the bond-lending channel and show its quantitative importance.
This study is related to the empirical literature on the determination of European repo rates.\footnote{See Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020); Ballensiefen and Ranaldo (2019); Barbiero, Schepens, and Sigaux (2020); Bechtel, Ranaldo, and Wrampelmeyer (2020); Boissel, Derrien, Ors, and Thesmar (2017); Brand, Ferrante, and Hubert (2019); Corradin and Maddaloni (2020); Dufour, Marra, Sangiorgi, and Skinner (2020); Dunne, Fleming, and Zholos (2011); Ebner, Fecht, and Schulz (2016); Eisenschmidt, Ma, and Zhang (2021); Ferrari, Guagliano, and Mazzacurati (2017); Mancini, Ranaldo, and Wrampelmeyer (2016); Miglietta, Picillo, and Pietrunti (2019); Nyborg (2019); Nyborg and Rösler (2019); Piquard and Salakhova (2018); Ranaldo, Ballensiefen, and Winterberg (2020); Ranaldo, Schaffner, and Vasiös (2019); Sangiorgi (2017); Schaffner and Ranaldo (2019).} Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) show that the ECB’s QE contributed to lowering European repo rates by removing government bonds from the market. My theoretical model is related to that of Huh and Infante (2021), who consider dealers’ use of repo for intermediation in the bond market. In contrast, I evaluate the intervention of the central bank in the bond market through repos.


If one were to think in the spirit of the Friedman rule (Friedman, 1969), central banks should lend all bonds in their portfolio. Bond lending is not costly for central banks and benefits private investors. I argue that central banks may not want to follow the Friedman rule because they may want to lower long-term rates even further.
Figure 1 Illustrative Example of a Repo Transaction.

Notes: This diagram illustrates a repo transaction in which firm B executes a reverse repo on a bond from firm A. Firm A then executes a repo on the bond to firm B. The risk-free rate is 2% and the repo rate is 1.5%. The downward deviation in the repo rate from the risk-free rate—which is 0.5% in this example—is the specialness premium.

3 Repo Market and the Public Sector Purchase Program

3.1 Repo Market

This study focuses on the repo market, which is the primary market for investors to borrow and lend sovereign bonds. In addition, the repo market is the largest money market in Europe, with a turnover of 16 trillion euros in 2019 (ICMA 2020). One can replace the repo market in my model or empirical analysis with the securities lending market without affecting the main results. A securities lending transaction with cash collateral is very similar to a repo transaction.

Figure 1 provides an illustrative example of a repo transaction. A sovereign bond repo is a contract covering the sale of a sovereign bond by one firm A to another firm B with the promise by firm A to repurchase the bond at a future date. In effect, firm B makes a cash loan to firm A, which is collateralized with a sovereign bond. The repo rate is the return on firm B’s cash investment as indicated by the initial sale price and future repurchase price of the bond.

If the bond is scarce in the repo market, it is costly for firm B to find an alternative coun-
terparty that owns the bond. As a result, firm B might be willing to lend cash at a repo rate lower than the risk-free rate. The downward deviation in the repo rate (1.5%) from the risk-free rate (2%) is the repo specialness premium (0.5%). Borrowing cash at a low repo rate and subsequently investing it at a higher risk-free rate earns firm A extra revenue. In repo market terminology, firms A and B conduct a repo and a reverse repo, respectively. The repo specialness premium tends to be higher when the bonds are more difficult to locate in the market (Corradin and Maddaloni 2020; Duffie 1996; Jank, Moench, and Schneider 2020; Jank and Mönch 2018; Vayanos and Weill 2008). The repo specialness premium is economically similar to securities lending fees.

3.2 The Public Sector Purchase Program

In March 2015, the ECB began purchasing debt instruments of eurozone governments and recognized agencies under the PSPP. As shown in Figure 2, the quarterly net supply of sovereign bonds of core eurozone countries to private investors dropped by up to 500 billion euros. These sovereign bonds became increasingly scarce in the market. As a result, the repo specialness of these sovereign bonds increased by up to 40 basis points.

The PSPP was controversial since its inception because the Maastricht Treaty does not allow the ECB to finance the fiscal deficits of eurozone countries. To mitigate legal controversy, the ECB chose not to buy more than 33% of the outstanding sovereign bonds of any country under the PSPP.17

In light of the pandemic-induced economic crisis of 2020, the ECB introduced the Pandemic Emergency Purchase Program (PEPP), which sets no limits on ECB purchases of sovereign bonds. In particular, the combined aggregate holdings of sovereign bonds under the PEPP and the PSPP can exceed 33%. To avoid legal controversy, the ECB has announced it will terminate the program as soon as the pandemic is over (Mersch 2020). Despite this clarification, German politicians have filed a lawsuit challenging the legality of the PEPP.

17 See section 9.4 of the Appendix for more information on why the ECB’s capacity to purchase sovereign bonds is limited.
Figure 2 Net Supply of Core Sovereign Bonds and the Repo Specialness.

Notes: The data come from the ECB website and BrokerTec. The figure plots the transaction volume-weighted average repo specialness of sovereign bonds issued by the core eurozone countries. Core eurozone countries refer to Austria, Belgium, Finland, France, Germany, and the Netherlands; their sovereign bonds have the highest specialness premia in the repo market. I compute the repo specialness as the difference between the GC pooling ECB extended basket rate and the repo rate. If the repo rate is higher than the GC pooling ECB extended basket rate, the specialness is zero. I compute the net supply as the net issuance of core sovereign bonds minus the ECB's net purchase of core sovereign bonds for the PSPP. I average both the net supply and the repo specialness in quarterly frequency. The vertical dashed line shows the beginning and end of the PSPP. However, the ECB restarted the PSPP in November 2019.


4 A Model of Portfolio Substitution

This section presents a theoretical framework for the bond-lending channel of quantitative easing. Central bank’s bond lending causes banks and nonbanks, such as insurance companies and pension funds, to rebalance their portfolios between government bonds and corporate bonds. Section 9.6 of the Appendix provides notation explanation.

The model features two assets: government bonds and corporate bonds. The main argument holds with any financial asset that nonbanks consider substitutable with a government
Figure 3 Fraction of the Debt Instruments of Governments and Recognized Agencies Purchased by the ECB for the PSPP.

Notes: The data of the purchase history of the PSPP come from the ECB website. The data of the outstanding amounts of the debt instruments of governments come from the Securities Issues Statistics of the ECB. The data of the outstanding amounts of the debt instruments of recognized agencies come from Thomson Reuters Eikon. Governments include central government, regional governments, and local governments.
bond. Consumption goods represent the numeraire. The model considers three markets: frictionless government bond cash market, over-the-counter government bond repo market, and frictionless corporate bond cash market. In a cash (repo) market, investors buy or sell (borrow or lend) assets. Both defaultable corporate bonds and risk-free government bonds are perpetual. Each bond pays $D$ as coupons per unit of time.

The default time of corporate bonds is stopping time $\tau_\eta$ with exogenous intensity $\eta$. $\Lambda$ is the loss given default for a corporate bond and $N_t$ is a Poisson process modeling the default time of the corporate bonds. This default shock is a systematic shock affecting all firms simultaneously. As in Feldhütter (2012), the subsequent restructuring of firms immediately replaces old corporate bonds with new ones. However, the restructuring costs bondholders a fraction $\Lambda$ of the market value of the corporate bonds.

For simplicity, similar to Vayanos and Weill (2008), I assume that the borrower of a government bond pays the lender $M$ per unit of time, which is conceptually equivalent to repo specialness. In my model, no repo matures. The model of this section does not consider the search and bargaining process between lenders and borrowers. Instead, the quantity of bonds lent by bond owners is an exogenous increasing function of specialness. Higher specialness induces bond owners to overcome transaction costs and lend more bonds as discussed in Duffie (1996). Section 6 presents a model with a fully endogenous search and bargaining process.

Every investor in the economy can borrow or lend at the exogenous short-term rate $r$, which represents the policy rate of the central bank. The policy rate is fixed because the model considers the central bank at the effective zero lower bound. Five groups of agents are considered in the model: a continuum of risk-neutral banks, a continuum of risk-averse nonbanks, agent lenders, the central bank, and short-sellers.
4.1 Risk-Averse Nonbanks and Agent Lenders

Risk-averse nonbank financial institutions such as insurance companies or pension funds can invest in either long-term government bonds or long-term corporate bonds. The model does not allow them to hold other assets to reflect their strong preference for long-term bonds.

The continuum of risk-averse nonbanks is indexed by $i$. There is a constant flow of new nonbanks entering the market. The mass of new entrants is $n$ per unit of time. New nonbanks are endowed with wealth $W_0$. After entry, each nonbank receives another Poisson shock with rate $\chi$, after which it exists the market. This Poisson shock is independent across nonbanks. Upon exiting, each nonbank consumes all of its financial wealth. Let $W_{it}$ denote the financial wealth of nonbank $i$ at time $t$ and $\bar{W}_t = \int_i W_{it}di$ denote the aggregate financial wealth of all nonbanks in the economy. By the law of large numbers, $\bar{W}_t$ evolves as equation (1). Therefore, in a stationary equilibrium, aggregate financial wealth, $\bar{W}_t$, is constant at $nW_0/\chi$

$$\frac{d}{dt} \bar{W}_t = nW_0 - \chi \bar{W}_t \tag{1}$$

Equation (2) captures the consumption and investment problem of nonbank $i$. Let $\beta$ denote nonbank’s subjective discount factor. Nonbank $i$ holds $\theta_{ict}$ corporate bonds and $\theta_{igt}$ government bonds at time $t$; $P_c$ and $P_g$ are the prices of a corporate and a government bond, respectively. $P_c$ and $P_g$ do not have time subscripts as the model is stationary. Let $\tau_\chi$ denote stopping time, reflecting nonbank’s market exit.

Total financial wealth $W_{it}$ of nonbank $i$ changes in three aspects. First, it consumes $C_{it}$ per unit of time. Second, it receives coupons $D(\theta_{ict} + \theta_{igt})$ per unit of time for holding bonds. Lastly, the nonbank earns revenue $\theta_{igt}zM$ per unit of time by lending its government bonds in the repo market.

The continuum of agent lenders includes one lender for each nonbank. An agent lender
is a financial intermediary who can lend bonds in the repo market on behalf of nonbanks. Although the term “agent lender” is often used in the securities lending market, I borrow the term here. First, each nonbank gives all of its bonds to its agent lender; then, the agent lender finds a counterparty in the over-the-counter repo market. Because of the search friction in the repo market, the agent lender can lend only a fraction $f(M) \in [0, 1]$ of the bonds, where $f(M)$ is the utilization ratio that increases in specialness $M$ (Duffie, 1996). I assume $f(0) = 0$ and $\lim_{M \to \infty} f(M) = 1$. Higher specialness incentivizes the agent lender to find counterparties more aggressively. As a result, more bonds make their way into the repo market and the agent lender earns a higher profit.

Agent lender’s trading behavior is not endogenous. Agent lenders mechanically lend bonds on behalf of nonbanks. Whereas banks can earn $M$ per unit of time from lending a government bond, nonbanks earn only $zM$ per unit of time (Eisenschmidt, Ma, and Zhang, 2021; Maddaloni and Roh, 2021). Nonbanks make less revenue because they pay fees to agent lenders.¹⁸

The second constraint in equation (2) is the budget constraint. The third constraint implies that the nonbank cannot short-sell government bonds or corporate bonds.

\[
\sup_{\theta_{ict}, \theta_{igt}, C_{it}} \mathbb{E}_t \left[ \int_{t+\tau}^{t+\tau} e^{-\beta(u-t)} \ln C_{iu} du + e^{-\beta\tau} \ln \left( W_{t+\tau} \right) \right]
\]

such that

\[
\begin{align*}
    dW_{it} &= -C_{it} dt + (\theta_{ict} + \theta_{igt}) D dt - \theta_{ict} P_c dN_t + \theta_{igt} zM dt \\
    W_{it} &= \theta_{ict} P_c + \theta_{igt} P_g \\
    \theta_{ict}, \theta_{igt} &\geq 0
\end{align*}
\]

¹⁸See Appendix 9.1 for more reasons why non-banks may be less efficient in using the repo market than banks.
4.2 Risk-Neutral Banks

The continuum of risk-neutral banks has a total mass \( m_b \). Each risk-neutral bank is indexed by \( j \). The consumption and portfolio investment problem of risk-neutral banks is identical to that of nonbanks except for four points. First, their utility function is linear in consumption. Second, risk-neutral banks do not exit the market and no new banks enter the market. Third, when risk-neutral banks lend bonds in the repo market, they earn specialness \( M > z M \). Fourth, risk-neutral banks can freely short-sell government bonds.

\[
\sup_{\theta_{jct}, \theta_{jgt}, C_{jt}} \mathbb{E}_t \left[ \int_{u=t}^{\infty} e^{-\beta (u-t)} C_u du \right]
\]

such that

\[
dW_{jt} = -C_{jt} dt + (\theta_{jct} + \theta_{jgt}) D dt - \theta_{jct} P_c \Lambda dN_t + \theta_{jgt} M dt
\]

\[
W_{jt} = \theta_{jct} P_c + \theta_{jgt} P_g
\]

\[
\theta_{jct} \geq 0
\]

Because risk-neutral banks can take any long or short position in government bonds, their first-order condition pins down the price \( P_g \) of a government bond as in equation (4). Banks in this model cannot short-sell corporate bonds because the European repo market for corporate bonds is small and underdeveloped (Hill, 2017a). If I allow banks to short-sell corporate bonds with regulatory costs, the implications remain the same.

\[
P_g = \frac{M + D}{r}
\]

4.3 Short-Sellers

The continuum of short-sellers in the economy has a total mass \( Q_{\text{short}} \). Similar to Duffie, Garleanu, and Pedersen (2005), each short-seller can only short one unit of a government bond.
bond. A short-seller obtains a bond from the repo market and sells it in the cash market. The short position earns the short-seller a flow of benefits $b$ per unit of time. For example, short-selling the bond allows the investor to hedge the interest rate risk of its endowments (Duffie, Garleanu, and Pedersen, 2005).

4.4 Equilibrium

Investors other than central banks hold $F$ government bonds. Let $S_c$ denote the supply of corporate bonds. The central bank supplies $Q_{g, ECB}$ government bonds to the repo market.

**Definition 1 No-Shorting Equilibrium.** I define the no-shorting equilibrium as the bond prices $(P_c, P_g)$, specialness $M$, bond holdings of risk-neutral banks $(\theta_{jct}, \theta_{jgt})$, and bond holdings of risk-averse nonbanks $(\theta_{ict}, \theta_{igt})$ such that

(i) the corporate bond market clears as in equation (5);  
(ii) the government bond market clears as in equation (6);  
(iii) the repo market clears as in equation (7);  
(iv) each risk-averse nonbank optimally chooses its bond holdings as in equation (2);  
(v) each risk-neutral bank optimally chooses its bond holdings as in equation (3);  
(vi) a short-seller’s flow of benefit $b$ exceeds repo specialness $M$; and  
(vii) no-shorting constraints of nonbanks do not bind.

I focus on the no-shorting equilibrium because the ECB data reveal that insurance companies and pension funds hold substantial amounts of government and corporate bonds.\(^{19}\) Thus, their short-selling constraints are unlikely to be binding.

\(^{19}\) Data source is ECB Statistical Data Warehouse.
\[
\int \theta_{ict} di + \int \theta_{jct} dj = S_c
\]  \hspace{1cm} (5)

\[
F = -Q_{\text{short}} + \int \theta_{jgt} dj + \int \theta_{igt} di
\]  \hspace{1cm} (6)

\[
Q_{g, ECB} + \int \theta_{jgt} dj + f(M) \int \theta_{ict} di = Q_{\text{short}}
\]  \hspace{1cm} (7)

**Proposition 1** Suppose \(Q_{g, ECB} + F < [1 - f(M^*)] \cdot \frac{r}{D + M} \cdot \left[ \frac{nW_0}{\chi} - S_c \frac{D}{r + \eta \Lambda} \right] \), where \(M^* = \left\{ -\frac{\eta \Lambda}{r + \eta \Lambda} \left( \frac{r + \eta \Lambda}{D} - \frac{S_c}{W^*} \right) + \eta \right\} \left\{ \frac{1 - z}{r + \eta \Lambda} \left( \frac{r + \eta \Lambda}{D} - \frac{S_c}{W^*} \right) - \frac{\eta}{W^*} \right\}^{-1} \). Then, a unique no-shorting equilibrium exists. The corporate bond price \(P_c\) is given as

\[
P_c = \frac{r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D - \sqrt{\left( \frac{r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \right)^2 - \frac{4S_c \Lambda^r \frac{D + zM}{D + M} D}{2S_c W^* \Lambda}}} \]

The repo specialness \(M\) of a government bond is a solution to

\[
Q_{g, ECB} + F = [1 + f(M)] \cdot \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c P_c \right]
\]  \hspace{1cm} (9)

Corporate bond price \(P_c > \frac{D}{r + \eta \Lambda}\) increases in repo specialness \(M\) of a government bond.

The first condition of Proposition 1 states that the total quantity of government bonds available for lending in the repo market is sufficiently small. This condition is more likely to hold if the central bank buys government bonds for QE but does not lend them.

A smaller supply of government bonds for lending leads to a higher specialness in the repo market. Banks trade in the government bond market so that the price of a government bond increases to reflect an opportunity to earn more revenue in the repo market. However, nonbanks can earn only a fraction \(z\) of specialness \(M\), which is reflected in the government bond prices. Nonbanks substitute overpriced government bonds with relatively cheaper corporate bonds. This additional demand pushes up corporate bond prices as well.
The lower the supply of government bonds in the repo market, the more corporate bonds nonbanks buy. If the supply of government bonds to the repo market is sufficiently small, banks may not want to hold corporate bonds because corporate bonds are too expensive. Banks cannot short-sell corporate bonds and neutralize the impact of nonbanks on corporate bond prices. Therefore, the equilibrium corporate bond price is higher than the simple expected value of its cash flow $\frac{D}{r+\eta\lambda}$. Risk-averse nonbanks—not banks—are the marginal investors in the corporate bond market.

**Proposition 2** In a no-shorting equilibrium, the repo specialness $M$ of a government bond decreases with the central bank’s supply of bonds $Q_{g, ECB}$ to the repo market. The price $P_C$ of a corporate bond also decreases with $Q_{g, ECB}$.

Proposition 2 is the main policy experiment. As the central bank scales back its bond lending, government bonds become more special. Higher specialness raises government bond prices and—through portfolio substitution—corporate bond prices. I refer to this sequence of effects as the bond-lending channel of quantitative easing.

**Proposition 3** Suppose that nonbanks are as efficient as banks in monetizing repo specialness so that $z = 1$. Then, the corporate bond price $P_C$ is completely independent of repo specialness $M$.

**Proof.** Substitute $z = 1$ into equation (8).

### 5 Event Study Analysis

#### 5.1 Evidence of the Bond Lending Channel

In this section, I describe an event on November 23, 2016 supporting the existence of the bond-lending channel. Since the beginning of the PSPP, the ECB has lent some bonds to private investors through the securities lending facility against adequate collateral. In the
beginning, the facility was restrictive because the collateral was required to be a different bond that was also eligible for the PSPP. If an investor wanted to borrow a scarce bond, the investor had to give the ECB another similarly scarce bond. Therefore, the lending facility did not alleviate the overall bond scarcity in the repo market.

On December 8, 2016, the ECB announced that cash would be an acceptable form of collateral.\textsuperscript{20} Cash (or central bank reserve) is less scarce than bonds in the eurozone, which makes it easier for investors to borrow bonds from the securities lending facility. An anonymous ECB official leaked the collateral policy change to the press prior to the official announcement. Reuters broke the story on November 23, 2016, at 11:37 CET.\textsuperscript{21}

Figure 4 shows that core sovereign bond yields and corporate bond yields immediately spiked up in response to the news. Core eurozone countries are Austria, Belgium, Finland, France, Germany, and the Netherlands. I focus on core eurozone countries because their government bonds are most heavily borrowed in the repo market. Therefore, the ECB’s lending decision affects bonds from these countries the most.

The Reuters article did not mention the quantity of bonds (i.e., 50 billion euros) that would be lent by the ECB against cash collateral; thus, investors had to conjecture. On December 8, 2016, the ECB announced that it would not lend more than 50 billion euros of bonds against cash collateral. The cap was highly restrictive because the ECB was holding more than 1.2 trillion euros of government bonds at the time.\textsuperscript{22} Therefore, the absolute magnitude of yield changes should not be used to assess the importance of the bond-lending channel. Nevertheless, this event clearly shows that the bond-lending channel exists. In Section 9.11 of the Appendix, I discuss why other confounding factors are unlikely to be important drivers of bond yield movements on that day.

I focus on corporate bond yields because the availability of high-frequency data allows me to precisely identify the bond-lending channel. However, the bond lending channel can

\textsuperscript{20}See the ECB press release “Eurosystem Introduces Cash Collateral for PSPP Securities Lending Facilities” on December 8, 2016.
\textsuperscript{21}The title of the article was “Exclusive: ECB seeks to lend out more bonds to avert market freeze – sources.”
\textsuperscript{22}Data source: the ECB website.
Figure 4 The Movement of Bond Yields in Response to the Reuters Article

Notes: Data source: Bloomberg CBBT. The graph plots the yields of bonds with durations between 5 years and 10 years as of November 23, 2016. Core sovereign bonds are bonds issued by the central governments of Austria, Belgium, Finland, France, Germany, and the Netherlands. I normalize the yields at 11:37 CET to zero. The red vertical line indicates 11:37 CET, the time the Reuters article was released.
affect other asset prices as well.

5.2 Overview of the Empirical Analysis

In this section, I quantify the bond-lending channel of quantitative easing. I consider how bond yields would have moved for a number of different counterfactual scenarios. For the baseline scenario, suppose that in October 2018 the ECB announced a plan to purchase a total of 2.4 trillion euros in government bonds for the following 10 years. The ECB would buy 20 billion euros of bonds each month. That is roughly the size of its government bond holdings as of September 2021.\(^{23}\) In addition, suppose that the ECB planned to not freely lend its bonds.

\(^{23}\)Data source: the ECB website.

Koijen, Koulischer, Nguyen, and Yogo (2020) estimate that the ECB purchases of 1% of the outstanding amounts of government bonds lowers government bond yields by 2.5 basis points. As of October 2018, the total outstanding amounts of all eurozone government bonds was 7.95 trillion euros.\(^{24}\) Hence 10-year government bond yields would go down by 76 basis points. Andrade, Breckenfelder, De Fiore, Karadi, and Tristani (2016) show that when the ECB announced the PSPP, BBB corporate bond yields went down by 0.929 basis points for every basis point drop in government bond yields. Thus 10-year BBB corporate bond yields would have gone down by 70 basis points under the baseline scenario.

I consider two alternative counterfactual policies. First, suppose that the ECB announced that it would freely lend its bonds so as to prevent the repo specialness of government bonds from increasing. The bond-lending channel theory predicts that this lending decision would cause 10-year BBB corporate bond yields to go down by less. Second, if the ECB wanted to lower 10-year BBB corporate bond yields by the same 70 basis points while lending bonds freely, how much should it increase its purchase quantity?

Figure 5 illustrates transmission channels of quantitative easing. Suppose that the ECB

\(^{24}\)Data source: the ECB SDW.
The ECB buys government bonds → Higher repo specialness for government bonds

Step 1

Lower corporate bond yields ← Lower government bond yields

Step 2

Step 3

Figure 5 Transmission Channels of Quantitative Easing

Note: this figure shows two different channels of quantitative easing. The blue arrows indicate the lending channel. The black arrows indicate the investment risk channel.

does not lend its bonds after buying those bonds for QE. The black arrows indicate the conventional QE channel (i.e., removing investment risk from the market). The three blue arrows indicate the three steps of the lending channel. The ECB can eliminate any transmission through this channel by freely lending bonds. The three steps in the mechanism of the bond-lending channel when the ECB decides to lend fewer bonds are the following:

1. Expectation of the reduced availability of bonds for borrowing causes investors to expected higher lending fees for government bonds in the future.

2. Expectation of higher lending fees lowers government bond yields.

3. Lower government bond yields leads to lower corporate bond yields.

The goal of my empirical analysis is to compare the magnitude of the lending channel with every other channel. I estimate each step of the bond-lending channel separately. I combine individual estimates later. The event on November 23, 2016 can be thought of as the reverse of this sequence because the ECB decided to lend more bonds. I cannot use the event of November 23, 2016 to quantify Steps 1 and 2 because investors did not know exactly how many additional bonds would be loaned. Therefore, I use different identification strategies.
5.3 Step 1: Impact of the PSPP on Repo Specialness

I first measure the response of repo specialness of core sovereign bonds to bond purchases by the ECB. Equation \((10)\) captures the reduced-form specification. \(S_{ct}\) is the average specialness of sovereign bonds from country \(c\) in month \(t\).\(^{25}\) \(QE_{ct}\) is defined as in Equation \((11)\). \(Purchase_{ct}\) is the cumulative net purchase amount of government bonds from country \(c\) over the 12 months preceding month \(t\). \(Borrowable_{ct}\) is the amount of borrowable government bonds that are outstanding as of month \(t\). By borrowable bonds, I mean bonds that are less than 12 months old. As bonds become older, they no longer circulate in the repo market or the securities lending market. Old bonds are held by buy-and-hold investors (i.e., insurance companies) that do not trade assets frequently.\(^{26}\)

\[
S_{ct} = \beta \cdot QE_{ct} + F E_{c} + F E_{t} + u_{ct} \tag{10}
\]

\[
QE_{ct} = \frac{Purchase_{ct}}{Borrowable_{ct}} \tag{11}
\]

The necessary identification assumption is that bond purchases by the central bank are orthogonal to repo specialness. This assumption may be violated if the ECB is less likely to purchase bonds with high specialness (Benoît Cœuré, 2015). This would lead to biased ordinary least squares (OLS) estimates.

Following Koijen, Koulischer, Nguyen, and Yogo (2020), I instrument the QE purchase variable using the ECB purchase rule. The ECB purchase rule is as follows. The ECB sets a target of euro-zone bond purchases every month (e.g., 50 billion euros). The ECB then purchases bonds from each country roughly in proportion to its capital key. The capital key \(K_{ct}\) of country \(c\) is the simple average of each country’s share of population and GDP in the

\(^{25}\)Regional government bonds are never traded on BrokerTec. So I only use the repo specialness of sovereign bonds.

\(^{26}\)See Figure 16 of the Appendix.
eurozone.\textsuperscript{27}

\[ K_{ct} = \frac{1}{2} \left( \frac{GDP_{ct}}{\sum_{c \in \text{Eurozone}} GDP_{ct}} + \frac{Population_{ct}}{\sum_{c \in \text{Eurozone}} Population_{ct}} \right) \]  \hspace{1cm} (12)

The instrument $Z_{ct}$ is constructed as follows:

\[ Z_{ct} = \frac{K_{c,1970} \cdot PSPP_t}{\text{BondMarketSize}_{c,2000}} \]  \hspace{1cm} (13)

My instrument has three components. First, I construct a capital key measure $K_{c,1970}$ using the population and GDP data recorded in 1970. The ECB recomputes each country’s capital key approximately once every five years using the most recent population and GDP figures. I used population and GDP figures from 1970 to mitigate any potential omitted variable bias.

Next, I multiply the constructed capital key with the monthly target purchase quantity for the entire QE program $PSPP_t$. The numerator is the quantity of bonds that the ECB would have purchased from each country if the ECB used the capital key figures from 1970. Lastly, I divide this number by the outstanding amount of each country’s government bonds in 2000.

The capital key $K_{c,1970}$ and the government bond market size $\text{BondMarketSize}_{c,2000}$ are pre-determined. The ECB determines the size of the PSPP based on the macroeconomic conditions of the entire eurozone, which I account for with time fixed effects. The identification assumption is that the nonlinear interaction between the pre-determined variables and the PSPP size affects the repo specialness only through the PSPP.\textsuperscript{28}

Table\textsuperscript{2} summarizes the data. My repo data are obtained from BrokerTec, a leading elec-

\textsuperscript{27}Deviations of actual bond purchases from the capital key rule may occur if some country’s bond are highly illiquid.

\textsuperscript{28}See Paravisini (2008) for a similar identification strategy
tronic trading platform for the European repo market. The sample covers the period between February 2014 and March 2019. I use the general collateral (GC) pooling ECB extended basket rate as the risk-free rate when computing specialness. The GC pooling ECB extended basket repo is a contract in which a cash borrower can deliver any of 3,000 bonds accepted as collateral by the ECB. Table 3 shows the estimation results. I find that, if the ECB purchases 1% of the total borrowable government bonds, the average specialness of government bonds increases by 1.48 basis points.

Table 2 Repo Specialness Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>St.Dev.</th>
<th>N</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repo Specialness (basis points)</td>
<td>11.66</td>
<td>7.10</td>
<td>571</td>
<td>BrokerTec for specific repo rates, Bloomberg for GC repo rates</td>
</tr>
<tr>
<td>The Fraction of Borrowable Government Bonds Purchased by the ECB (%)</td>
<td>21.03</td>
<td>19.59</td>
<td>571</td>
<td>ECB website, the Securities Issue Statistics (SIS) of the ECB</td>
</tr>
</tbody>
</table>

Notes: BrokerTec is a leading electronic trading platform for the European repo market. The sample covers the period between February 2014 and March 2019. I consider a bond to be borrowable if it is less than 12 months old.

For Step 2, I assume that government bond yields go down by a basis points for every basis point rise in the average repo specialness in the future.

5.4 Step 3: Transmission from Government Bonds to Corporate Bonds

For Step 3, I use movements in bond yields on November 23, 2016. The main identification assumption is that government bond yields move only in response to changes in their repo specialness expected in the future.

I focus only on core sovereign bonds because their yields are the most important in transmission. I exclude peripheral sovereign bonds or regional government bonds from analysis.
Table 3 Impact of the PSPP on Repo Specialness of Core Sovereign Bonds

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$QE_{ct}$ (%)</td>
<td>1.482***</td>
<td>0.267***</td>
<td>0.267***</td>
<td>0.088</td>
<td>0.206***</td>
<td>0.206***</td>
</tr>
<tr>
<td></td>
<td>(0.230)</td>
<td>(0.028)</td>
<td>(0.049)</td>
<td>(0.021)</td>
<td>(0.025)</td>
<td>(0.053)</td>
</tr>
<tr>
<td>Fixed Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month</td>
<td>571</td>
<td>571</td>
<td>571</td>
<td>571</td>
<td>571</td>
<td>571</td>
</tr>
<tr>
<td>Country</td>
<td>2SLS</td>
<td>2SLS</td>
<td>2SLS</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.8186</td>
<td>0.6038</td>
<td>0.6038</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective</td>
<td>89.667</td>
<td>2,570.278</td>
<td>26.857</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-Statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Value</td>
<td>37.418</td>
<td>37.418</td>
<td>37.418</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>for 5% Nagar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias</td>
<td>23.109</td>
<td>23.109</td>
<td>23.109</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: The table shows the estimation of the model (10). $QE_{ct}$ is the fraction of borrowable government bonds from country $c$ purchased by the ECB under the PSPP. I consider government bonds to be borrowable if they are less than 12 months old. Columns (1) to (3) show 2SLS estimations of the model using the instrument $Z_{ct}$ in Equation (13). The effective F-statistics come from the Olea and Pflueger (2013) test of weak instruments. The sample covers the period between February 2014 and March 2019. Repo specialness is in basis points. Cluster-robust standard errors are reported in parentheses *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.
To identify the bond-lending channel, a shock to the sovereign bond market needs to be directly caused by the repo market. To illustrate, if sovereign bond yields move by a basis point because of the repo market, corporate bond yields may move by 0.5 basis points. However, corporate bond yields might move by only 0.2 basis points if sovereign bond yields moved because of tax-related reasons.

I obtain bond yield data from Bloomberg. I use all euro-denominated sovereign bonds and corporate bonds for which executable quote data from dealers are available. I compute yield change using 11:37 CET as benchmark. Table 4 summarizes the data.

### Table 4 Summary Statistics for the Intra-day Bond Data on November 23, 2016, between 10:07 and 13:17 CET

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate bond yield change (bp)</td>
<td>1.21</td>
<td>2.09</td>
<td>28,314</td>
</tr>
<tr>
<td>Sovereign bond yield change (bp)</td>
<td>3.01</td>
<td>2.94</td>
<td>5,121</td>
</tr>
<tr>
<td>Corporate bond duration (years)</td>
<td>5.35</td>
<td>4.75</td>
<td>726</td>
</tr>
<tr>
<td>Sovereign bond duration (years)</td>
<td>6.68</td>
<td>7.12</td>
<td>162</td>
</tr>
</tbody>
</table>

Notes: Data source: Bloomberg.

5.4.1 Model

Equation (14) shows the model, where subscripts $i$ and $k$ represent corporate bonds and sovereign bonds, respectively. Subscript $\tau$ reflects the number of minutes elapsed since the Reuters article was released; $\Delta y_{c_i}^{\tau}$ is the intra-day change in the yield of corporate bond $i$.

$$
\Delta y_{c_i}^{\tau} = \left[ \beta_S \mathbb{1}_{D_i<2} + \beta_M \mathbb{1}_{D_i\in[2,10]} + \beta_L \mathbb{1}_{D_i>10} \right] \frac{\sum_k K(D_i, D_k) \Delta y_{s_k}^{\tau}}{\sum_k K(D_i, D_k)} + u_{i\tau} \tag{14}
$$

The main explanatory variable is the kernel-weighted-average value of changes in sovereign bond yields $\Delta y_{s_k}^{\tau}$. The kernel accounts for the relative substitutability between corporate bond $i$ and sovereign bond $k$. Equation (15) shows the kernel definition, where $\phi$ is a posi-
tive parameter, and \( D_i \) and \( D_k \) are the durations of corporate bond \( i \) and sovereign bond \( k \), respectively. Bonds with similar durations are more easily substitutable.

\[
K(D_i, D_k) = \exp(-\phi|D_i - D_k|)
\]  

(15)

In Equation 14, \( \beta_S 1_{D_i < 2} + \beta_M 1_{D_i \in [2,10]} + \beta_L 1_{D_i > 10} \) is the spillover intensity from the sovereign bond market to the corporate bond market; \( 1_{D_i < 2} \) is an indicator variable equal to 1 if and only if the duration of a corporate bond is shorter than 2 years; \( 1_{D_i \in [2,10]} \) is equal to 1 if and only if the duration is between 2 and 10 years; and \( 1_{D_i > 10} \) is equal to 1 if and only if the duration is longer than 10 years. Spillover intensity depends on the duration of the corporate bond.

The choice of two threshold values - 2 years and 10 years - is based on the following observations. First, the impact of ECB’s action on the short-term bond market is likely limited. When hedging interest rate risk, investors prefer to borrow and sell long-term bonds than short-term bonds. Therefore, demand to borrow short-term bonds is lower than demand to borrow long-term bonds. Figure 6 shows that sovereign bonds with durations shorter than 2 years reacted considerably less to the Reuters article than longer-dated bonds.

Second, bonds with durations longer than ten years are very illiquid in the repo market. Figure 7 shows that the turnover rates in the repo market drop significantly for bonds with durations longer than ten years. The most heavily traded debt instruments in Europe are on-the-run 10-year bonds.

To construct my instrument, I first define \( Z_i \), shown in equation 16, as the kernel-weighted-average value of changes in sovereign bond yields within 5 min after the Reuters article was released. I replace \( \Delta y^k_{s\tau} \) in the main explanatory variable \( \sum_k K(D_i, D_k) \Delta y^k_{s\tau} \) with \( \Delta y^5_{k\tau} \). Considering the sovereign bond yield movement within an ultra-short window ensures that the cross-sectional variation in \( Z_i \) originates only from the repo market.
Figure 6 Movements in Sovereign Bond Yields Within 20 Minutes of the News Release

Notes: Data source: Bloomberg. The sample consists of euro-denominated sovereign bonds issued by Austria, Belgium, Germany, Finland, or the Netherlands. The vertical axis represents the change in bond yields between 11:37 AM and 11:57 AM. The red vertical line represents duration of 2 years.
Figure 7 The Turnover Rate in the Repo Market and Duration of the Bond

Notes: Data source: BrokerTec and Thomson Reuters Eikon. The sample consists of euro-denominated sovereign bonds issued in Germany. The sample covers the period between March 1, 2013, and March 31, 2019. For each bond on a given day, I compute the turnover rate as the ratio of the trade volume on BrokerTec to the initial amount issued. I compute the average value of the turnover rates across all bonds belonging to the same duration bucket.
\[
Z_i = \frac{\sum_k K(D_i, D_k) \Delta y_{k5}^s}{\sum_k K(D_i, D_k)}
\]  
(16)

The instruments for GMM are \(1_{\tau > 0}, Z_i \cdot 1_{D_i < 2}, Z_i \cdot 1_{D_i \in [2, 10]}, \) and \(Z_i \cdot 1_{D_i > 10}.\)

5.4.2 Results

Table 5 shows generalized method of moments (GMM) estimates. To interpret the results, suppose that all sovereign bonds are 10-year bonds. Suppose also that sovereign bond yields decrease by one basis point because investors expect higher specialness in the future. \(\beta_M\) is a slope parameter for an AAA corporate bond with durations between 2 years and 10 years. My GMM estimate of \(\beta_M\) is 0.442, which suggests that each basis point drop in sovereign bond yields decreases corporate bond yields by 0.442 basis points. As expected, \(\beta_S\) is estimated to be smaller than \(\beta_M\) or \(\beta_L\).

The estimated spillover coefficients are the largest for bonds with ratings between BBB- and A+. This result may be because this credit rating bucket has the largest number of bonds. Thus, the attenuation bias is likely to be the smallest.

In particular, the estimated spillover coefficients for bonds with the lowest credit ratings are smaller than for bonds with ratings between BBB- and A+. This may reflect the limited liquidity of the riskiest corporate bonds. The dealers intermediating trades on these bonds are unlikely to immediately update their quotes when new information arrives to the market. Therefore, the prices of the riskiest corporate bonds in intraday data may not capture the full transmission effect. This measurement error may lead to smaller estimates associated with the riskiest corporate bonds.

The standard errors of the kernel parameter estimates (\(\phi\)) are relatively large. In Section ?? of the Appendix, I show that the estimates of the three spillover parameters \((\beta_S, \beta_M, \beta_L)\) are not sensitive to the value of \(\phi\) as long as \(\phi\) is larger than 2. For all three credit rating buckets, the estimates of \(\phi\) are well above 2. Large values for the kernel parameter \(\phi\) imply
Table 5 Impact of Repo-Driven Change in Sovereign Bond Yields on Corporate Bond Yields on November 23, 2016

<table>
<thead>
<tr>
<th></th>
<th>AA- to AAA</th>
<th>BBB- to A+</th>
<th>CCC+ to BB+</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_L$</td>
<td>0.505***</td>
<td>0.855***</td>
<td>0.654***</td>
</tr>
<tr>
<td></td>
<td>(0.073)</td>
<td>(0.063)</td>
<td>(0.086)</td>
</tr>
<tr>
<td>$\beta_M$</td>
<td>0.442***</td>
<td>0.908***</td>
<td>0.680***</td>
</tr>
<tr>
<td></td>
<td>(0.074)</td>
<td>(0.045)</td>
<td>(0.091)</td>
</tr>
<tr>
<td>$\beta_S$</td>
<td>0.234*</td>
<td>0.785***</td>
<td>0.525**</td>
</tr>
<tr>
<td></td>
<td>(0.122)</td>
<td>(0.134)</td>
<td>(0.236)</td>
</tr>
<tr>
<td>$\phi$</td>
<td>3.037</td>
<td>8.184</td>
<td>5.156</td>
</tr>
<tr>
<td></td>
<td>(4.392)</td>
<td>(22.52)</td>
<td>(19.10)</td>
</tr>
<tr>
<td>$N$</td>
<td>36,314</td>
<td>46,163</td>
<td>7,839</td>
</tr>
<tr>
<td>Cluster</td>
<td>Bond</td>
<td>Bond</td>
<td>Bond</td>
</tr>
</tbody>
</table>

Notes: The table shows the GMM estimates of the model (14). Column headings indicate the credit ratings of corporate bonds used for estimation. Estimates are obtained in 5 min frequency. The sample covers the period between 10:07 and 15:37 CET on November 23, 2016. Cluster-robust standard errors are reported in parentheses. *, **, *** indicate statistical significance at 10%, 5%, and 1%, respectively.
that bonds may not be highly substitutable across the yield curve. This result is in line with D’Amico and King (2013) whose result implies a $\phi$ value of 2.02.\footnote{See Section 9.15 for details.}

5.4.3 Robustness

I conduct a series of robustness exercises. First, Section 9.13 of the Appendix shows that the estimates are robust to alternative definitions of maturity buckets. For example, I modify the short-term bonds definitions to include bonds with durations shorter than three years and obtain similar results. Second, I provide estimates using different time windows. While the baseline window is 270 minutes long, I provide estimates using time lengths between 150 minutes and 330 minutes. I find that the estimates of the three spillover parameters are robust to changes in the time window length.

Section 9.14 of the Appendix provides estimates from an alternative specification of the spillover intensity, which is shown in Equation (17). The alternative specification estimates are similar to those obtained from the main specification.

$$\Delta y_{i\tau}^c = \left[ \beta_S \cdot 1_{D_i<2} + \beta_A \cdot 1_{7<D_i<10} + \beta_B \cdot 1_{7<D_i<10, D_i>2} \right] \frac{\sum_k K(D_i, D_k) \Delta y_{k\tau}^g}{\sum_k K(D_i, D_k)} + u_{i\tau} \quad (17)$$

I complement the evidence associated with the one-time event on November 23, 2016, with an additional estimation that uses the full sample of bond yields from March 1, 2013, to March 31, 2019. My identification strategy is based on the Granular Instrumental Variable (GIV) method of Gabaix and Koijen (2020). See Subsection 9.10 for details. I find that a one-basis point rise in sovereign bond yields raises the yields of AAA 10-year corporate bonds by 0.522 basis points. This finding is in line with the results on Table 5.
5.5 Counterfactual Analysis

Using my estimates from earlier sections, I can now compute corporate bond yield movements under different counterfactual scenarios. I assume that quantities such as the outstanding amount of bonds remain the same throughout ten years following October 2018. Table 6 summarizes those parameter values.

**Table 6 Key Parameters for Counter-Factual Policy Experiments**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The outstanding amounts of borrowable core government bonds</td>
<td>€ 1.233 trillion</td>
</tr>
<tr>
<td>The outstanding amounts of core government bonds</td>
<td>€ 6.152 trillion</td>
</tr>
<tr>
<td>The outstanding amounts of eurozone government bonds</td>
<td>€ 7.950 trillion</td>
</tr>
<tr>
<td>The annual gross issuance of eurozone corporate bonds</td>
<td>€ 3.308 trillion</td>
</tr>
<tr>
<td>The maturity of eurozone corporate bonds</td>
<td>7.58 years</td>
</tr>
</tbody>
</table>

Data source: ECB SDW and Thomson Reuters Eikon.

I assume that the ECB strictly follows the capital key rule when purchasing bonds. The combined capital key of six core eurozone countries (i.e., Austria, Belgium, Finland, France, Germany, the Netherlands) is 61%. Thus, under the baseline scenario, the ECB buys 20.05% of borrowable core government bonds each year. According to my estimates of Step 1, the repo specialness of core government bonds rise by 28.8 basis points under the baseline scenario. My estimates of Step 3 imply that this rise in repo specialness lowers 10-year BBB corporate bond yields by 26.19 basis points.

For the second scenario, suppose that the ECB freely lends its government bonds so as to prevent the repo specialness of government bonds from rising. Then 10-year BBB corporate bond yields would rise by only 70.22 - 26.19 = 44.03 basis points.

For the third scenario, suppose that the ECB wants to lower 10-year BBB corporate bond yields by the same 70 basis points while freely lending its bonds. Then the cumulative
purchase amount needs to increase up to \( 2.4 \times \frac{70}{14} = 3.9 \) trillion euros. The ECB would have to purchase 48\% of the outstanding government bonds, which is far above the 33\% purchase limit.

### Table 7 Summary of Counter-Factual Policy Experiments

<table>
<thead>
<tr>
<th>Freely lend bonds?</th>
<th>Purchase quantity</th>
<th>Reduction in 10-year BBB corporate bond yield</th>
<th>Interest expenses saved for eurozone firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>€2.4 trillion</td>
<td>70 basis points</td>
<td>€176 billion</td>
</tr>
<tr>
<td>Yes</td>
<td>€2.4 trillion</td>
<td>44 basis points</td>
<td>€110 billion</td>
</tr>
<tr>
<td>Yes</td>
<td>€3.9 trillion</td>
<td>70 basis points</td>
<td>€176 billion</td>
</tr>
</tbody>
</table>

Notes: The impact of bond purchases on yields is based on Andrade, Breckenfelder, De Fiore, Karadi, and Tristani (2016) and Koijen, Koulisher, Nguyen, and Yogo (2020).

Between October 2018 and September 2019, eurozone firms raised 3,308 billion euros through the bond market.\(^{30}\) The volume-weighted average maturity at issuance between October 2018 and September 2019 is 7.58 years.\(^{31}\) I assume that all corporate bonds are zero-coupon BBB-rated bonds with durations of 7.58 years. Under the base scenario, QE reduces the interest expenses of firms by \( 3,308 \times 7.58 \times 70 \times 10^{-4} = 176 \) billion euros. Under the second scenario, QE reduces the interest expenses by only 110 billion euros.

### 6 Gains from Trade in the Government Bond Market

In this section, I quantify the impact of the ECB’s decision to not lend bonds freely on the total gains from trade in the government bond market. Investors often want to short-sell long-term bonds to speculate on rates or hedge the duration risk of their portfolios. Short-selling a bond typically requires borrowing the bond from the repo market. If bonds

\(^{30}\) Data source: Securities Issues Statistic (SIS) of the ECB. For the sector of issuer, I consider non-financial corporations (S1100), other monetary financial institutions (S1220), other financial intermediaries (S1230), and insurance companies and pension funds (S1250).

\(^{31}\) Data source: Thomson Reuters Eikon.
become scarce in the repo market, shorting cost increases.

6.1 Model

I extend the model of Vayanos and Weill (2008) to quantify the foregone gains in trades in the bond market owing to the ECB’s decision to not lend bonds. The central bank’s bond lending can help investors take either long or short positions more quickly in the over-the-counter cash market. I present a somewhat simplified version of the full model in this section. Section 9.9 of the Appendix describes the full model.

Figure 8 shows the life cycle of a bond investor. There is a continuum of idle investors who are not interested in trading. Long or short positions do not benefit the investor. At the same time, all investors incur a cost $y$ per unit of time when they long or short bonds. This cost could represent, for example, the balance sheet costs of banks. Therefore, it is optimal for idle investors not to trade at all. As in Vayanos and Weill (2008), I assume that every risk-neutral investor can long or short-sell exactly one unit of bonds.

Every idle investor obtains a long preference shock with rate $\rho_L$ and a short preference shock with rate $\rho_S$. After a long preference shock, an investor obtains an extra flow of benefit $x_L$ per unit of time only if the investor purchases a bond. This benefit could represent the demand for long-term bonds by insurance companies and pension funds to manage their durations.

After a long preference shock, an investor that has been idle goes to the over-the-counter cash market to purchase a bond. After the purchase, the investor goes to the over-the-counter repo market to lend the bond to earn extra revenue. After lending the bond, the investor becomes a “long nonsearcher” and no longer finds a counterparty. A long nonsearcher can obtain another preference shock with rate $k_L$. After the shock, the investor no longer obtains the flow of benefit $x_L$ per unit of time for holding the bond but incurs only the cost $y$ per unit of time for holding the bond. The investor recalls and sells the bond to avoid the cost $y$ per unit of time. After unwinding the long position, the investor again
Figure 8 The Life Cycle of a Bond Investor

Notes: The figure shows a life cycle of a bond investor in the model I use to quantify the allocative inefficiency induced by the shortage of bonds in the market.

becomes an idle investor.

After a short preference shock, an investor that has been idle wants to short a bond and earn an extra flow of benefit $x_S$ per unit of time. The investor borrows a bond from either the bilateral repo market or the central bank. The investor subsequently sells a bond to the cash market and becomes a “short nonsearcher.” The investor receives another preference shock at rate $k_S$ and no longer obtains the flow of benefit $x_S$ per unit of time. To avoid the cost $y$ per unit of time, the investor buys back a bond, returns a bond, and becomes an idle investor again.

Investors who received long or short preference shocks can revert to idle investors before successfully taking short or long positions. In such cases, investors miss opportunities to earn benefit $x_S - y$ or $x_L - y$. The longer it takes for investors to borrow, buy, or sell bonds, the more likely investors are to return to the idle state without obtaining benefits. Therefore,
search frictions that delay borrowing, buying, or selling bonds can reduce the gains from trade in the government bond market.

I model the repo market and the cash market as over-the-counter markets. In the cash market, buyers and sellers randomly encounter one another and negotiate the price. In the repo market, lenders and borrowers randomly meet one another and negotiate the repo specialness.

The model parameters are calibrated such that the model-implied moments match the data. I consider the moments of repo specialness, bond yields, trade volume, and other factors. I focus on a stationary equilibrium in which the mass of agents in each state and the market prices do not change over time. The sample covers the period between October 1, 2018, and March 31, 2019.

Following Hugonnier, Lester, and Weill (2020), I define the aggregate gains from trade as the combined flow of benefits and costs of all investors per unit of time. Let $\mu_{LY}$ denote the mass of long investors who obtain net benefit $x_L - y$ per unit of time from holding a bond. Let $\mu_{LN}$ denote the mass of investors who own a bond but no longer receive benefit $x_L$ per unit of time; they try to sell the bonds to avoid the cost $y$ per unit of time. Similarly, let $\mu_{SY}$ and $\mu_{SN}$ denote the masses of short investors who receive and do not receive benefit $x_S$, respectively. I define the gains from trade as shown in equation (18). I assume that $x_L > y$ and $x_S > y$.

$$Gain_t = (x_L - y) \cdot \mu_{LY} + (x_S - y) \cdot \mu_{SY} - y \cdot (\mu_{LN} + \mu_{SN}) \quad (18)$$

The gains of trade measure increases in $\mu_{LY}$ and $\mu_{SY}$ but decreases in $\mu_{LN} + \mu_{SN}$. For maximum allocational efficiency, investors should be able to unwind their long or short positions instantly if they no longer derive benefit from those positions. In such cases, $\mu_{LN} + \mu_{SN}$ would be zero. In addition, after a preference shock, an idle investor should be able to

---

32 The measure in the Appendix accounts for the fee that investors pay to borrow bonds from the central bank. The implications remain the same.
long or short-sell bonds immediately. In such cases, more investors receive benefit $x_L - y$ or $x_S - y$ per unit of time.

Bond lending by the central bank improves the gains from trade by making transactions happen faster. With an additional option to borrow a bond from the central bank, an investor can more quickly borrow a bond after a short preference shock. As a result, $\mu_{SY}$ increases. The increased presence of short-sellers makes the cash market more liquid as in Vayanos and Weill (2008). With more investors trying to sell their borrowed bonds in the cash market, it becomes easier for long investors to purchase bonds; as a result, $\mu_{LY}$ increases.

6.2 Counterfactual Analysis

This section provides an analysis of gains from trade for the counterfactual scenarios that I consider in Section 5.5. First, I consider how the repo specialness of government bond moves for every additional billion euro of gains from trade in the market. To do so, I vary the contact rate between a borrower and the central bank and gauge how the repo specialness and gains from trade change. Figure 9 shows the results. Once I combine the two panels of Figure 9, I derive that the repo specialness of core government bonds rises by 7.7 basis points for every billion euros of foregone gains from trade.

Finally, I combine the estimated relation between gains from trade and repo specialness with the results in Section 5.5. Table 8 shows the results. If the ECB freely lends its bonds, the annual gains from trade increase by €3.74 billion, from €35.32 billion to €39.06 billion.

7 Discussion

My theoretical model illustrates that insurance companies and pension funds substitute assets in their portfolios with corporate bonds. At the same time, anecdotal evidence indicates that ultra-low euro-area government bond yields recently caused European insur-
Figure 9 Counterfactual Exercise

Notes: The left panel shows how the repo specialness premia of core sovereign bond changes as the central bank changes the supply of its bonds to the repo market or the securities lending market. The right panel shows how the aggregate gains from trade change.

ance companies to purchase more sub-sovereign and agency (SSA) bonds as well (Gruber, 2016); some insurance companies and pension funds began to invest in risky properties (O’Donnell and Cohn, 2016). Such portfolio rebalancing is likely to cause the prices of risky assets (e.g., SSA bonds) to appreciate.

The influence of ultra-low government bond yields on the prices of risky assets can also operate through any financial institution that cannot use the repo market efficiently. For example, the new European regulation\(^{33}\) does not allow money market funds to supply more than 10\% of their assets to the repo market. Another example is small banks, which are not

### Table 8 Summary of Counterfactual Policy Experiments

<table>
<thead>
<tr>
<th>Freely lend bonds?</th>
<th>Purchase quantity</th>
<th>Reduction in 10-year BBB corporate bond yield</th>
<th>Foregone annual gains from trade in the bond market</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>€2.4 trillion</td>
<td>70 basis points</td>
<td>€3.74 billion</td>
</tr>
<tr>
<td>Yes</td>
<td>€2.4 trillion</td>
<td>44 basis points</td>
<td>€0</td>
</tr>
<tr>
<td>Yes</td>
<td>€3.9 trillion</td>
<td>70 basis points</td>
<td>€0</td>
</tr>
</tbody>
</table>

Notes: The impact of bond purchases on yields is based on Andrade, Breckenfelder, De Fiore, Karadi, and Tristani (2016) and Koijen, Koulischer, Nguyen, and Yogo (2020). The gains from trade are expressed on an annualized basis.

members of central clearing parties (CCPs) and participate in the repo market indirectly through larger bank dealers. Small banks do not have a large flow of repo transactions to justify the fixed cost of becoming members of CCPs ([ICMA, 2019]). Hence, similar to the nonbanks in my model, small banks incur extra costs such as the fee paid to larger banks. Because the repo specialness premium further lowers government bond yields, small banks are likely to substitute government bonds with riskier assets such as loans to firms. Through the PSPP, the Eurosystem policymakers wanted to encourage the banking sector to substitute government bonds with riskier corporate loans ([Benoît Cœuré, 2015]). Thus, the repo specialness premia on government bonds may have amplified this function.

The actual reduction in the interest expense of firms due to the bond-lending channel is likely to be larger than what I present in Section 5.4 because I do not consider the loan market. The amplification of the bond-lending channel through the loan market may be particularly important in the European context where the loan market is much larger than the bond market. Lower corporate bond yields induce large established firms with access to the capital market to substitute bank loans with corporate bonds. As a result, banks have higher lending capacity, which allows them to extend loans to smaller firms that do not have access to the bond market ([Grosse-Rueschkamp, Steffen, and Streitz, 2018]).
7.1 The Consumption-Savings Decisions of Households

The higher specialness and lower yields of government bonds can further lower savings rates for households. One example is life insurance products. Households in Europe invest approximately 19% of their financial assets in life insurance (Delbecque 2020). Returns on life insurance in Europe move lockstep with sovereign bond yields.

Life insurers in many European countries guarantee the minimum level of returns on their policies and often link the minimum guaranteed returns to the historical moving average of 10-year benchmark sovereign bond yields in their countries (Berdin, Pancaro, and Kok 2017). For example, in Germany, the returns move with the moving average of the 10-year Bund yields of the previous 10 years (Berdin, Pancaro, and Kok 2017). However, when computing the guaranteed returns, insurers do not adjust for the level of repo specialness (Berdin, Pancaro, and Kok 2017). Therefore, the higher specialness of sovereign bonds lowers their yields and the returns on life insurance products. Lower returns on savings affect the consumption-savings decisions of households.

7.2 Fiscal Implications

The higher repo specialness of government bonds makes them less expensive to issue in the primary market. French and German governments might have benefited the most because their government bonds command high specialness in the repo market. Moreover, to issue their bonds, both the French and German governments rely on primary dealers, which are banks that can actively conduct repo transactions on their government bonds once acquired. Therefore, primary dealers can bid higher prices to purchase government bonds in anticipation of creating revenues in the repo market. The aggressive bidding by primary dealers can help lower the financing costs of governments.

34 According to the website of Agence France Trésor, the principal method of issuing French government securities since 1985 has been to bid price auctions in which primary dealers participate. According to the website of the German Finance Agency, more than 90% of the Bunds are auctioned to primary dealers.
8 Conclusion

During the last decade, many central banks realized that their short-term policy rates were at an effective zero lower bound. In response, they embarked on QE to lower long-term government bond yields and ease the funding conditions in the economy. When central banks buy long-term government bonds for QE, they remove investment risk and transaction services of these bonds from the market. However, many central banks, such as the Federal Reserve, lend some of their bonds back to the market to mitigate frictions in the financial market.

This paper is the first to consider a trade-off that a central bank faces when lending its bonds. By lending its bonds, a central bank increases gains from trades in the bond market and other related markets. On the other hand, by not lending bonds and removing more transaction services from the market, a central bank can further lower long-term rates in the economy.
9 Appendix

9.1 Why Insurance Companies and Pension Funds Cannot Easily Monetize Repo Specialness Premia

Banks intermediate most repo trades in Europe (Duffie, 2018). Because only banks can join electronic platforms such as BrokerTec, the only feasible way for insurers or pension funds to repo their bonds is through bilateral repo with banks. Recently, regulatory drives have made banks increasingly reluctant to intermediate repo and reverse repo transactions for nonbanks (Hill, 2017b). One crucial factor is the Basel III Leverage Ratio requirement. Basel III forces banks to maintain a leverage ratio greater than 3%, which is the ratio of Tier 1 capital to the total assets (Hill, 2017b). The leverage ratio requirement forces banks to economize on their balance sheets (Hill, 2017b). Consequently, the regulation strongly discourages banks to remain in the repo intermediation business, which brings them only small profits at the expense of a large expansion of their balance sheets (Hill, 2017b).

Banks began to show signs of retreat from the repo intermediation business in 2015 (ICMA, 2015). One exception is when banks net repo and reverse repo transactions (Maraffino, 2017) to avoid expanding their balance sheets. Banks often net repos and reverse repo by registering the trades at central counterparties (CCPs). To register any transaction at CCPs, both parties in the transaction need to be members of the CCP (Maraffino, 2017). Because membership is costly, not all financial institutions belong to CCPs; only those with a constant flow of two-way business (repos and reverse repos) have an incentive to become members of CCPs (ICMA, 2019). This excludes insurance companies (AXA, 2017).

For this reason, CCP membership is extended mostly to banks (ICMA, 2019). The repo desks of banks do not think highly of insurers and pension funds without CCP membership. To persuade the repo desk that transactions are profitable, insurers and pension funds need to accept unfavorable rates (Maraffino, 2017) or provide other profitable business opportunities in a bundle (ICMA, 2015).
It is possible for insurers and pension funds to search for counterparties in the bilateral repo market independently. At the same time, they do not have the expertise to assess the counterparty’s credit risk, comply with legal requirements, or negotiate with a wide range of nonbank participants (Hill, 2017b). Thus, many buy-side firms rely heavily on bank-based intermediation (Hill, 2017b).

In summary, repos are more costly for nonbanks than for banks for two reasons. First, nonbanks must ask banks to intermediate repos. Second, the leverage ratio regulation makes it costly for banks to offer repos for nonbanks.

9.2 Supply of Bonds by the Federal Reserve and the Bank of Canada

The Federal Reserve Bank of New York initiated the Fixed-Rate Overnight Reverse Repo (RRP) facility in September 2013. This allowed a wide range of financial institutions including nonbanks to reverse repo Treasuries from the New York Fed. Each institution could borrow Treasuries up to 30 billion dollars each day at the time. As of September 2021, each investor can borrow up to 160 billion dollars. Unlike its counterparts in Europe, the RRP facility does not limit the overall size of the operation, at least since December 2015. The New York Fed is willing to lend all bonds in its System Open Market Account (SOMA) portfolio to the extent possible.

The Fed RRP facility is much more accessible than the securities lending facility of the Eurosystem. For example, unlike the RRP facility, the Eurosystem cannot repo more than 75 billion euros of its PSPP-eligible bonds through its securities lending facility (Maraffino, 2017). Maraffino (2016) notes that introducing a facility akin to the RRP facility may considerably alleviate any problem associated with the reduced supply of bond collateral in the European repo market.

Moreover, the Federal Reserve has been operating a securities lending program since

\[\text{See } \url{https://libertystreeteconomics.newyorkfed.org/2016/08/a-closer-look-at-the-federal-reserves-securities-lending-program.html} \text{ for more details.}\]
1969, which allows primary dealers to borrow specific securities by positing any Treasury GC.³⁶ Investors borrow on-the-run securities by posting other Treasury GC.³⁷ Because on-the-run securities are far more special than off-the-run securities in the repo market, this program is likely to have reduced the repo specialness premium of on-the-run Treasuries (Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020).

From the market participant’s perspective, the securities-lending program of the Federal Reserve is more attractive than the European counterparts (Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020). The minimum lending fee of the Fed facility is five basis points as of 2016 (Fleming, Keane, Schurmeier, and Weiss, 2016). In contrast, most national central banks of the Eurosystem conduct repo on government bonds through their respective securities lending facilities at repo rates of at least 10 basis points lower than the prevailing market GC repo rate (Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020). Because the securities lending fee is economically equivalent to the repo specialness premium, Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) conclude that the Fed facility offers more favorable pricing than the European facilities.

Even well before the Bank of Canada began its QE, it had been consistently purchasing debt instruments of the federal government of Canada. As of 2015, the majority of the asset portfolio of the Bank of Canada—which is worth about 94 billion Canadian dollars—consists of bonds and bills of the government of Canada (Patterson, 2015). At the same time, investors use federal government bonds to collateralize most repo transactions in Canada. Thus, the Bank of Canada is aware that its sizable purchase of federal government bonds can reduce the float size in the private market and negatively affect the repo market liquidity.

The Bank of Canada took several measures to address the potential dry-up of liquidity in the repo market. For example, the bank conducted repo on federal government bonds when the GC repo market rate was below the target rate of the bank.³⁸ This measure contrasts

³⁶ According to the New York Fed website, a transaction needs “to be collateralized with Treasury bills, notes, bonds, or inflation-indexed securities.”
³⁸ https://www.bankofcanada.ca/markets/market-operations-liquidity-provision/framework-market-
with ECB policy. In particular, the ECB did not take action when the German GC repo rate became substantially lower than the deposit facility rate.

Moreover, through its securities lending facility, the Bank of Canada lends dealers up to 50 percent of its bonds. In return for borrowing federal government bonds, primary dealers can post a wide range of assets such as provincial government bonds, municipal government bonds, banker’s acceptances, commercial papers, or covered bonds. Primary dealers can gain access to federal government bonds—which is the most widely used collateral in the Canadian repo market—in exchange for other less widely used assets. Therefore, this facility can mitigate problems associated with reduced bond collateral supply in the repo market.

9.3 The Securities Lending Facility of the Eurosystem

Although the Eurosystem allows investors to borrow government bonds through the securities lending facility, many structural factors prevent the facility from effectively addressing bond collateral scarcity in the repo market. One structural limitation is that the ECB and the national central banks in the Eurosystem operate their securities lending facilities in a decentralized manner. They do not actively coordinate on how each national central bank and the ECB sets the rules for the lending facilities.

The lending facility of each national central bank is crucial for investors who wish to borrow government bonds issued in that country. Under the PSPP, each national central bank is responsible for the purchase of government bonds in its jurisdiction. Although the ECB can buy government bonds from any country, its purchase is limited to only 8% of the total purchase amount under the PSPP. Hence, the lending facility of the ECB does not

40 This limit was raised to 10% on April 19, 2016. See DECISION (EU) 2015/774 OF THE EUROPEAN CENTRAL BANK of 4 March 2015 on a secondary markets public sector asset purchase programme (ECB/2015/10) and DECISION (EU) 2016/702 OF THE EUROPEAN CENTRAL BANK of 18 April 2016
have a large stock of bonds. Therefore, for investors to borrow government bonds from a particular country, they need to approach the national central bank in that country.

Because the Eurosystem is operating these lending facilities in a decentralized manner, each national central bank has unique policies for lending bonds to investors. National central banks often communicate directly with investors to negotiate [Maraffino, 2015a]. National central banks determine (1) which investors are allowed to use lending facilities, (2) how many bonds they can borrow, (3) for how long they can borrow, (4) which collateral investors have to post, and (5) how much fees investors have to pay for borrowing bonds.

Until December 2016, investors had to bring another PSPP-eligible bond to borrow a government bond from the Eurosystem. Therefore, the bond lending facilities of national central banks did not change the overall quantity of bonds circulating in the market [Hill, 2017b].

In December 2016, the Eurosystem started allowing investors to borrow bonds while posting cash collateral at the securities lending facility. [1] Investors conducted reverse-repo transactions with the Eurosystem. Even this cash collateral option though could not fully mitigate the scarcity of bond collateral in the market, because securities lending facilities had many other restrictions. For example, the total amount of bonds to be lent to the market against cash collateral was capped at 50 billion euros. Additionally, only six national central banks of the Eurosystem and the ECB lent bonds against cash collateral. Those six national central banks were the National Bank of Belgium, the Deutsche Bundesbank, the Central Bank of Ireland, Banco de Espana, the Banque de France, and De Nederlandsche Bank. As of September 2021, the Banca d’Italia, Banka Slovenije, and Suomen Pankki – Finlands Bank also lend bonds against cash collateral. [2]

The 50 billion euros quota was distributed across individual national central banks in pro-

---

[1] See the press release of the ECB “Eurosystem introduces cash collateral for PSPP securities lending facilities” on December 8, 2016.


49
portion to the government bonds that each national central bank held under the PSPP. As a result, the total amount of German bonds that investors could borrow from the Bundesbank was capped at around 12 billion euros, which was considered “punitive” by investors (McGuire et al., 2017). On March 23, 2018, the Eurosystem raised this cap to 75 billion euros.

9.3.1 The Details about the Operations of Individual Lending Facilities

Austria

The Oesterreichische Nationalbank (OeNB) has been lending its bonds since February 1, 2016. However, there is no public information about the pricing and borrowing limit.

Belgium

The National Bank of Belgium started lending its bonds in April 2015. The fee was between 25 to 50 basis points at the time (Maraffino, 2015b). However, borrowers had to give to the National Bank of Belgium bond collateral with credit ratings at least as high as Belgian government bonds (Sanderson, 2015). In December 2016, the National Bank of Belgium started lending bonds against cash collateral.

As of September 2021, the fee for borrowing bonds against bond collateral is 10 basis points. When borrowing bonds against cash collateral, the applicable repo rate is the ECB deposit facility rate minus 20 basis points or the market repo rate, whichever is lower.

Finland

The Bank of Finland also started lending its bonds against bond collateral in April 2015. However, the collateral had to be bonds with credit ratings at least as high as that of Belgium.

44See the press release of the ECB “Decisions taken by the Governing Council of the ECB (in addition to decisions setting interest rates)” on March 23, 2018.
government bonds (Sanderson 2015). The Bank of Finland has been lending its bonds against cash collateral since December 15, 2016. 45 The repo rate for this cash collateral option was the rate of the deposit facility minus 30 basis points or the prevailing market repo rate, whichever is lower.

As of September 2021, when borrowing a bond from the Bank of Finland against cash collateral, an investor conducts a repo at a rate that is the ECB deposit facility rate minus 20 basis points or the market repo rate, whichever is lower.

France

On April 2, 2015, the Banque de France started lending its bonds against bond collateral through its securities lending facility. 46 The fee was 25 basis points. The borrowing limit was set to 200 million euros per counterparty and per bond. Since December 15, 2016, the Banque de France has also been lending its bonds against cash collateral with the same operational limits (i.e., borrowing limit per counterparty).

Germany

In April 2015, the Bundesbank started lending bonds against bond collateral through Clearstream Banking Luxembourg. The cost of borrowing bonds from the Bundesbank was set at 135 basis points (Maraffino 2015a). On November 24, 2016, the Financial Times reported that in order to borrow a German bond from the Bundesbank, an investor needed to post another German bond as collateral (Jones, McCrum, Hale, and Moore 2016).

The Bundesbank started lending bonds against cash collateral on December 15, 2016. However, the Bundesbank facility continued to adhere to the following restrictions even after December 2016.

- The borrower needs to have “a credit line with the Bundesbank” (Hill 2017b).

45 See the press release “Eurosystem introduces cash collateral for PSPP securities lending facilities” on December 8, 2016.
46 See the press release “Standard characteristics of Banque de France securities lending scheme” on April 2, 2015.
• The contracts for transactions need to be based on the European Master Agreement (EMA). Nevertheless, the norm in the private market is to use either the Global Master Repurchase Agreement (GMRA) for repo or the General Master Securities Lending Agreement (GMSLA) for securities lending [Hill, 2017b]. The use of different legal contracts increase the operational cost of bond borrowers.

• Investors cannot automatically roll over the repo contract with the Bundesbank. At maturity, investors have to deliver the bonds to the Bundesbank and then re-start the contract.

• No transaction can be larger than 200 million euros [Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020].

• Investors can reverse-in bonds only at rates that are significantly less favorable than the market prevailing rates [Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020].

Ireland

The Central Bank of Ireland has been lending bonds against bond collateral since April 2015. It started lending bonds against cash collateral in December 2016. As of September 2021, the Central Bank of Ireland requires bond collateral to have remaining maturities shorter than 10 years. The fee is 5 basis points for lending against bond collateral. When lending against cash, the repo rate is the deposit facility rate minus 20 basis points or the prevailing market repo rate, whichever is lower.47

Italy

The Bank of Italy started lending its bonds against bond collateral on May 11, 2015.48 The fee was set at 10 basis points. As of September 2021, the Bank of Italy also lends bonds against cash collateral.

47See https://www.centralbank.ie/monetary-policy/policy-implementation/asset-purchase-programmes/securities-lending
48See the press release of the Bank of Italy “The Bank of Italy’s securities lending programme” on May 11, 2015.
Lithuania

As of September 2021, the Bank of Lithuania lends its bonds against bond collateral only. The fee is at least 5 basis points. Each counterparty can borrow up to 2.5 percent of the amount outstanding of a single issue or 200 million euros, whichever is lower. 49

Luxembourg

As of September 2021, the Banque centrale du Luxembourg (BCL) lends its bonds against bond collateral only. The fee is 5 basis points or the prevailing market lending fee, whichever is higher. 50

Malta

As of September 2021, the Central Bank of Malta does not lend its bonds. The bank cites the lack of market demand as a reason.51

The Netherlands

De Nederlandsche Bank NV (DNB) has been lending bonds against bond collateral since April 2015. It started lending bonds against cash collateral in December 2016. As of September 2021, bond collateral has to be a government bond in the European Union with credit ratings equal to or higher than AA.52 The lending fee for bond collateral is 5 basis points. The lending fee for cash collateral is between 5 and 25 basis points.

Portugal

Banco de Portugal has been lending its bonds against bond collateral since April 7, 2015.53

49 https://www.lb.lt/en/mpi-securities-lending
51 https://www.centralbankmalta.org/app
52 See the DNB website https://www.dnb.nl/en/sector-information/financial-markets/qe-and-securities-lending/
Slovenia

As of September 2021, the Bank of Slovenia lends its bonds against bond collateral or cash collateral. The fee for lending against bond collateral is at least 5 basis points. The repo rate for lending against cash collateral is the ECB deposit facility rate minus 20 basis points.\(^{54}\) The collateral has to have credit ratings of at least BBB-/Baa3.

Spain

Banco de Espana has been lending its bonds against bond collateral since April 2015. As of September 2021, it lends its bonds against bond collateral or cash collateral. The fee for lending against bond collateral is 5 basis points or the market rate, whichever is higher. The repo rate for lending against cash collateral is the ECB deposit facility rate minus 20 basis points or the market repo rate, whichever is lower.\(^{55}\)

The ECB

The ECB began lending its bonds against bond collateral on April 2, 2015.\(^{56}\) The fee was 40 basis points or the market rate, whichever was higher (Maraffino, 2015b). Each counterparty could borrow up to the lower of 2.5% of the outstanding amount and 200 million euros (Maraffino, 2015b). Since April 4, 2016, the ECB has lowered the lending fee to 30 basis points or the market rate, whichever is lower (Nelson, 2016).

On December 15, 2016, the ECB began lending bonds against cash collateral. The repo rate was set to be the rate of the deposit facility minus 30 basis points or the prevailing market repo rate, whichever was lower.\(^{57}\) As of September 2021, the repo rate for borrowing against cash collateral is the deposit facility rate minus 20 basis points or the market repo rate, whichever is lower. The fee for borrowing against bond collateral is 5 basis points. The

---


\(^{55}\)See the website of the Banco de Espana.

\(^{56}\)Source: the monetary policy meeting account of the ECB on May 21, 2015.

\(^{57}\)See the press release of the ECB “Eurosystem introduces cash collateral for PSPP securities lending facilities” on December 8, 2016.
borrowing limit per counterparty is 200 million euros or 2.5% of the outstanding amount, whichever is lower.\(^{58}\)

**Other National Central Banks**

As of September 2021, Eesti Pank (Estonia), the Central Bank of Cyprus, the Bank of Greece, Latvijas Banka (Latvia), and the National Bank of Slovakia are also lending their bonds. However, there is no information available about the pricing or the borrowing limits of their facilities.

### 9.3.2 Market Reaction

After about a month after it started the PSPP, the Eurosystem disclosed the details of its plan to run the securities lending facilities in April 2015. However, the market was very disappointed. For example, a Bloomberg article on April 8, 2015 reported that “securities lending details don’t inspire much confidence that repo specialness will be limited” (Julius, 2015).

Maraffino (2015b) cites the following reasons. First, by requiring investors to bring another bond, the lending facilities would not increase the aggregate quantity of bond collateral circulating in the market. Second, the rates charged on investors were punitive. Third, there was also a punitive cap on the amount of bonds investors could borrow.

When the Eurosystem fully disclosed its plan to lend bonds against cash collateral on December 8, 2016, investors were still disappointed. A Reuters article on that day cited two reasons (Canepa, 2016). First, the 50 billion euros cap was considered to be too low. Second, in exchange for borrowing bonds from the Eurosystem, investors had to deposit cash at negative 70 basis points or lower, which was considered highly punitive by investors.

9.3.3 The Eurosystem’s Lending of Bonds

Figure 10 shows the loan balance of the bond-lending facilities of the Eurosystem as a fraction of their bond holdings.

Figure 10 The Fraction of Bonds Lent by the Securities Lending Facilities of the Eurosystem

Notes: The graph shows the aggregate nominal amount of bonds that the ECB and the national central banks of the Eurosystem lent to the market as a fraction of their bond holdings over time. The blue line captures lending against bond collateral. The red line reflects lending against cash collateral. Data source: ECB
9.4 **Constraint on the Size of the QE Programs of the ECB**

The QE programs in Europe have been legally controversial because some legal scholars interpreted the purchase by the Eurosystem of bonds of member states as monetary financing ([Nyborg, 2017](#)). The Treaty of the Functioning of the European Union (TFEU) explicitly prohibits monetary financing. In particular, Germans have been adamantly opposed to monetary financing because it does not favor the fiscal support of peripheral member countries ([Brunnermeier, James, and Landau, 2016](#)).

To safeguard the legality of the QE program, the ECB introduced the following constraints when it announced the program in March 2015 ([Nyborg, 2017](#)).

- The ECB can never purchase sovereign bonds in the primary market.
- Initially, the ECB stated that it would not buy more than 25% of the outstanding amount of any individual security. Six months later, the ECB raised the limit to 33% as long as the additional bond purchases did not make ECB the blocking minority during the restructuring process.\(^{60}\)
- The ECB will not purchase more than 33% of the outstanding debt of any issuer.
- The ECB will purchase a bond only after a certain number of days after its issuance. However, the ECB will not disclose the waiting period. By holding off purchasing bonds during the blackout period, the ECB enables private investors to negotiate bond prices.

The purchase limit of 33% helps the ECB avoid a legal challenge for two reasons. First, the limit allows the ECB to not become the blocking minority in case the issuer defaults. After the Greek debt crisis, the European Union countries signed the European Stability

---

Mechanism (ESM) Treaty for future sovereign debt crises. This treaty introduced the collective action clause (CAC) for all sovereign bonds issued after 2013. Under the CAC, a distressed sovereign can begin a restructuring plan only if it obtains approval from more than two-thirds of its bondholders (Martinelli, 2016). By not requiring a distressed sovereign to satisfy all bondholders, the CAC aimed to make the restructuring processes more flexible.

The blocking minority is a group of investors that own a sufficiently large fraction of bonds, which they use to block a restructuring plan (Martinelli, 2016). Under the CAC, an investor becomes the blocking minority if they own more than one-third of all debts of a distressed issuer (Martinelli, 2016).

If the ECB became the blocking minority of a distressed member country, it would be extremely difficult to comply with the prohibition regulation on monetary financing (Martinelli, 2016). A sovereign would profit at the expense of the ECB if the ECB agreed to a restructuring plan, which would directly violate the Maastrict Treaty (Martinelli, 2016). At the same time, by not agreeing to a restructuring plan, the ECB might perpetuate a sovereign debt crisis. To avoid dealing with such a dilemma, the ECB is against becoming the blocking minority.

Second, if the ECB committed to purchasing a predominant share of sovereign bonds, it could force private investors to act as mere intermediaries between the ECB and the fiscal government. For example, suppose the ECB committed to purchasing 99% of all sovereign bonds in the secondary market. Investors in the primary market would know that with 99% probability, they could resell the purchased bonds to the ECB. Private investors would then become a pass-through, and the ECB alone would set the prices of sovereign bonds. Economically, governments would be able to finance themselves as if the ECB was directly purchasing their bonds. By setting the purchasing limit to 33% of the bonds issued, the ECB ensures that it will not likely set the government bond prices alone. Ensuring the price discovery process in the sovereign bond market has been a contentious issue when the legality of the PSPP was challenged in the German constitutional court (BVerfG (2020)).

The PSPP has been under legal challenge since its inception in 2015. Right-wing polit-
cians in Germany sued the ECB for implementing illegal QE programs. On December 11, 2018, the European Court of Justice ruled that the ECB is not violating the regulation that prohibits monetary financing. However, on May 5, 2020, the German Federal Constitutional Court ruled that the PSPP might be illegal. The court asked the Deutsche Bundesbank to submit further information.

9.5 Portfolio Allocation Decisions of Life Insurance Companies

Life insurers indeed face strict regulations on their choices of investment strategies. At the same time, anecdotal evidence shows that European life insurers recently substituted ultra-low-yielding government bonds in their portfolios with alternative higher yielding assets. A significant fraction of European insurers have sold products with guaranteed returns, which has increased pressure on them to generate sufficiently high returns from their investments and avoid insolvency.

The Securities Holdings Statistics data show that insurance companies recently reduced their holdings of euro-denominated investment-grade corporate bonds. Much of that decline is attributed to the redemption of bonds purchased by insurance companies purchased in the past. The manner in which insurance companies invest cash obtained from newly underwritten policies reveals a shift from government bonds towards investment-grade corporate bonds.

---

61See the press release No 192/18 from the Court of Justice of the European Union (the Judgement in Case C-493/17).
### 9.6 List of Variables in the Portfolio Rebalancing Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Exogenous?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D$</td>
<td>The coupon rate of a government bond and a corporate bond.</td>
<td>Y</td>
</tr>
<tr>
<td>$\tau_\eta$</td>
<td>A stopping time for the default of corporate bonds.</td>
<td>Y</td>
</tr>
<tr>
<td>$\Lambda$</td>
<td>The loss given default for corporate bonds.</td>
<td>Y</td>
</tr>
<tr>
<td>$N_t$</td>
<td>A Poisson process modeling the default of corporate bonds.</td>
<td>Y</td>
</tr>
<tr>
<td>$M$</td>
<td>Repo specialness of a government bond.</td>
<td>N</td>
</tr>
<tr>
<td>$r$</td>
<td>Short-term interest rate. The policy rate of the central bank.</td>
<td>Y</td>
</tr>
<tr>
<td>$W_0$</td>
<td>The financial wealth that a newly-born risk-neutral bank is endowed with.</td>
<td>Y</td>
</tr>
<tr>
<td>$W_{it}$</td>
<td>The financial wealth of nonbank $i$ at time $t$.</td>
<td>N</td>
</tr>
<tr>
<td>$\bar{W}_t$</td>
<td>The aggregate financial wealth of all nonbanks at time $t$.</td>
<td>N</td>
</tr>
<tr>
<td>$\chi$</td>
<td>The rate at which banks exit from the market.</td>
<td>Y</td>
</tr>
<tr>
<td>$n$</td>
<td>The mass of new nonbanks that enter the market per unit of time.</td>
<td>Y</td>
</tr>
<tr>
<td>$\theta_{ict}$</td>
<td>The unit of corporate bonds that nonbank $i$ holds at time $t$.</td>
<td>N</td>
</tr>
<tr>
<td>$\theta_{igt}$</td>
<td>The unit of government bonds that nonbank $i$ holds at time $t$.</td>
<td>N</td>
</tr>
<tr>
<td>$\theta_{jct}$</td>
<td>The unit of corporate bonds that nonbank $j$ holds at time $t$.</td>
<td>N</td>
</tr>
<tr>
<td>$\theta_{jgt}$</td>
<td>The unit of government bonds that nonbank $j$ holds at time $t$.</td>
<td>N</td>
</tr>
<tr>
<td>$P_c$</td>
<td>The price of a corporate bond.</td>
<td>N</td>
</tr>
<tr>
<td>$P_g$</td>
<td>The price of a government bond.</td>
<td>N</td>
</tr>
<tr>
<td>$\tau_\chi$</td>
<td>A stopping time modeling the nonbanks’ exit from the market.</td>
<td>Y</td>
</tr>
<tr>
<td>$z$</td>
<td>A nonbank receives only $zM$ per unit of time from supplying a bond to the repo market.</td>
<td>Y</td>
</tr>
<tr>
<td>$\beta$</td>
<td>The subjective discount factor for nonbanks and banks.</td>
<td>Y</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td>Value</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>$C_{it}, C_{jt}$</td>
<td>The consumption stream for nonbanks and banks, respectively.</td>
<td>N</td>
</tr>
<tr>
<td>$F$</td>
<td>Investors other than the central banks hold $F$ units of government bonds.</td>
<td>Y</td>
</tr>
<tr>
<td>$S_c$</td>
<td>The supply of corporate bonds.</td>
<td>Y</td>
</tr>
<tr>
<td>$Q_{g, ECB}$</td>
<td>The central bank supplies $Q_{g, ECB}$ government bonds to the repo market.</td>
<td>Y</td>
</tr>
<tr>
<td>$Q_{short}$</td>
<td>The mass of short-tellers.</td>
<td>Y</td>
</tr>
<tr>
<td>$f(M)$</td>
<td>The utilization ratio.</td>
<td>N</td>
</tr>
</tbody>
</table>

### 9.7 Proof of Proposition 1

**Lemma 1.** Suppose the no-shorting constraint of nonbank $i$ does not bind. Then, equations (19) and (20) show the optimal holdings of government bonds and corporate bonds.

\[
\theta_{ict} = \left\{ \frac{1}{\Lambda P_c} - \eta \left( D - \frac{P_c}{P_g} (D + zM) \right)^{-1} \right\} W_{it} \tag{19}
\]

\[
\theta_{igt} = \left\{ \frac{\Lambda - 1}{\Lambda P_g} - \eta \frac{P_c}{P_g} D - \frac{P_c}{P_c} \{D + zM\} \right\} W_{it} \tag{20}
\]

**Proof.** Conjecture the following value function. $A$ and $\alpha$ are parameters to be determined.

\[
V(W_{it}) = \frac{\alpha}{\beta} lnW_{it} + A \tag{21}
\]

Equation (22) is the Hamilton–Jacobi–Bellman (HJB) equation, where $D$ is the infinitesimal generator; $v^c_{it}$ is a Lagrange multiplier for the budget constraint; and $v^g_{it}$ and $v^p_{it}$ are Lagrange multipliers for the no-shorting constraints of corporate bonds and government bonds, respectively.
\[ DV(W_{it}) - \beta V(W_{it}) + lnC_t + v^w_{it}(W_{it} - \theta_{ict}P_c - \theta_{igt}P_g) + v^c_{it}\theta_{ict} + v^g_{it}\theta_{igt} \] (22)

Using my conjecture of the value function above, I can rewrite the HJB equation as follows.

\[
\frac{\alpha}{\beta W_t} (-C_{it} + (\theta_{ict} + \theta_{igt}) D + \theta_{igt}zM) + \chi \left( lnW_{it} - \frac{\alpha}{\beta} lnW_{it} - A \right) \\
+ \eta \frac{\alpha}{\beta} \{ ln(W_{it} - \theta_{ict}AP_c) - lnW_{it} \} - \beta \left( \frac{\alpha}{\beta} lnW_{it} + A \right) + lnC_{it} \\
+ v^w_{it}(W_{it} - \theta_{ict}P_c - \theta_{igt}P_g) + v^c_{it}\theta_{ict} + v^g_{it}\theta_{igt} = 0 
\] (23)

An investor with log utility consumes a constant fraction of their wealth per unit of time. That is, \( C_{it} = \beta W_{it} \). The first-order conditions for \( \theta_{ict} \) and \( \theta_{igt} \) are given as equations (24) and (25). Equations (26) and (27) reflect complementary slackness conditions.

\[
\frac{\alpha}{\beta W_t} D + \eta \frac{\alpha}{\beta W_t - \theta_{ict}AP_c} - v^w_{it}P_c + v^c_{it} = 0 
\] (24)

\[
\frac{\alpha}{\beta W_t} \{ D + zM \} - v^w_{it}P_g + v^g_{it} = 0 
\] (25)

\[
v^c_{it}\theta_{ict} = 0 
\] (26)

\[
v^g_{it}\theta_{igt} = 0 
\] (27)

When no-shorting constraints do not bind, Lagrange multipliers are all equal to zero. Thus, equation (28) pins down \( v^w_{it} \).

\[
v^w_{it} = \frac{\alpha}{\beta W_t P_g} \{ D + zM \} 
\] (28)

62
I substitute equation (28) into equation (24) to solve for $\theta_{ict}$, and the budget constraint is used to solve for $\theta_{igt}$.

Lemma 1 implies that the market-clearing condition for the corporate bond market is the one shown in equation (29). Let $Q_{c,bank} = \int_j \theta_{jct} dj$ and $Q_{g,bank} = \int_j \theta_{jgt} dj$ denote the aggregate quantities of corporate bonds and government bonds held by risk-neutral banks, respectively. Similarly, define $Q_{c,nonbank} = \int_i \theta_{ict} di$ and $Q_{g,nonbank} = \int_i \theta_{igt} di$ for nonbanks. Because of the shorting constraint, $Q_{c,bank} \geq 0$, risk-neutral banks hold positive amounts of corporate bonds only if $P_c \leq D_r + \eta \Lambda$.

The market-clearing condition for the repo market is shown in equation (30).

Equation (31) provides the market-clearing condition for the government bond cash market.

By combining equations (30) and (31), I obtain

$$Q_{g,ECB} + F = [1 - f(M)] \cdot Q_{g,nonbank}$$
I integrate both sides of the nonbank budget constraint to obtain equation (33).

\[
\int \theta_{ict} P_c + \theta_{igt} P_g \, di = \int W_i \, di
\]

\[
Q_{c,\text{nonbank}} P_c + Q_{g,\text{nonbank}} P_g = \frac{nW_0}{\chi}
\]

Equation (33) is then substituted into equation (32).

\[
Q_{g,\text{ECB}} + F = [1 - f(M)] \cdot \frac{1}{P_g} \left[ \frac{nW_0}{\chi} - Q_{c,\text{nonbank}} P_c \right]
\]

Equations (35) to (39) jointly determine the corporate bond price \( P_c \) and repo specialness \( M \) in equilibrium in which the shorting constraints of nonbanks do not bind.

\[
\frac{nW_0}{\chi} \left\{ \frac{1}{\bar{P}_c} - \eta \left( D - \frac{P_c r}{D + M} (D + z M) \right)^{-1} \right\} = Q_{c,\text{nonbank}}
\]

\[
Q_{c,\text{nonbank}} + Q_{c,\text{bank}} = S_c
\]

\[
Q_{c,\text{bank}} \left( P_c - \frac{D}{r + \eta \Lambda} \right) = 0, Q_{c,\text{bank}} \geq 0, P_c \geq \frac{D}{r + \eta \Lambda}
\]

\[
Q_{g,\text{ECB}} + F = [1 - f(M)] \cdot \frac{1}{P_g} \left[ \frac{nW_0}{\chi} - Q_{c,\text{nonbank}} P_c \right]
\]

\[
\frac{nW_0}{\chi} - Q_{c,\text{nonbank}} P_c \geq 0
\]

Denote \( \frac{nW_0}{\chi} \) as \( W^* \). Define \( M^* \).

\[
M^* = \frac{-\frac{n\Lambda}{r + \eta \Lambda} D \left( \frac{r + \eta \Lambda}{D \Lambda} - \frac{S_c}{W^*} \right) + \eta}{\frac{(1-z)r + \eta \Lambda}{r + \eta \Lambda} \left( \frac{r + \eta \Lambda}{D \Lambda} - \frac{S_c}{W^*} \right) - \frac{\eta}{D}}
\]
Lemma 2. If \( Q_{g, ECB} + F < [1 - f(M^*)] \cdot \frac{r}{D + M^*} \left[ \frac{nW_0}{\chi} - S_c \frac{D}{r + \eta \Lambda} \right] \), risk-neutral banks do not own corporate bonds in any equilibria.

Proof. The proof is derived by contradiction. Suppose risk-neutral banks own corporate bonds in an equilibrium; then, \( P_c = \frac{D}{r + \eta \Lambda} \). Equations (35) and (36) imply inequality (41).

\[
\frac{nW_0}{\chi} \left\{ \frac{r + \eta \Lambda}{AD} - \frac{\eta}{D - \frac{D}{r + \eta \Lambda} D + M(D + zM)} \right\} < S_c
\]  

(41)

If \( M = M^* \), the left-hand side of equation (41) is exactly equal to \( S_c \). Because that side of the equation is increasing in \( M \), \( M \) is smaller than \( M^* \).

The expression \([1 - f(M)] \cdot \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c \frac{D}{r + \eta \Lambda} \right]\) is decreasing in \( M \). Therefore,

\[
[1 - f(M)] \cdot \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - Q_{c, onbank} \frac{D}{r + \eta \Lambda} \right] > [1 - f(M)] \cdot \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c \frac{D}{r + \eta \Lambda} \right]
\]

\[
> [1 - f(M^*)] \cdot \frac{r}{D + M^*} \left[ \frac{nW_0}{\chi} - S_c \frac{D}{r + \eta \Lambda} \right] > Q_{g, ECB} + F
\]

This lemma assumes the last inequality. Thus, for any value of \( M \) that causes banks to own corporate bonds, the repo market cannot clear. Contradiction.

Then, I can reduce the conditions for a no-shorting equilibrium.

\[
\frac{nW_0}{\chi} \left\{ \frac{1}{AP_c} - \eta \left( D - \frac{P_c r}{D + M(D + zM)} \right)^{-1} \right\} = S_c
\]

(42)

\[
P_c > \frac{D}{r + \eta \Lambda}
\]

(43)
\[ Q_{g, ECB} + F = [1 - f(M)] \cdot \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c P_c \right] \quad (44) \]

\[ 1 - P_c \left\{ \frac{1}{\Lambda P_c} - \eta \left( D - \frac{P_c r}{D + M} (D + zM) \right)^{-1} \right\} \geq 0 \quad (45) \]

Equation (42) is a quadratic equation in \( P_c \). I need to determine which root is a corporate bond price in an equilibrium.

\[ P_c = \frac{r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \pm \sqrt{\left( r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \right)^2 - \frac{4S_c}{W^*} \Lambda r \frac{D + zM}{D + M} D}}{2 \frac{S_c}{W^*} \Lambda r \frac{D + zM}{D + M}} \quad (46) \]

**Lemma 3.** \( P_c = \frac{r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \pm \sqrt{\left( r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \right)^2 - \frac{4S_c}{W^*} \Lambda r \frac{D + zM}{D + M} D}}{2 \frac{S_c}{W^*} \Lambda r \frac{D + zM}{D + M}} \) cannot be a corporate bond price in a no-shorting equilibrium.

**Proof.** Rewrite the inequality (45).

\[ \frac{1}{\Lambda} - \eta \frac{D}{D + M} - \frac{P_c}{D + M} (D + zM) \leq 1 \]

Because \( \Lambda \) is smaller than 1, for this inequality to hold, \( D - \frac{P_c r}{D + M} (D + zM) \) must be positive. That is, \( P_c \) must be smaller than \( \frac{D(D + M)}{r(D + zM)} \).

Suppose \( P_c = \frac{r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \pm \sqrt{\left( r \frac{D + zM}{D + M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D \right)^2 - \frac{4S_c}{W^*} \Lambda r \frac{D + zM}{D + M} D}}{2 \frac{S_c}{W^*} \Lambda r \frac{D + zM}{D + M}} \) is the corporate bond price.
Then, $P_c = \frac{r \frac{D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D}{\frac{2S_c}{W^*} \Lambda r \frac{D+zM}{D+M}} + \sqrt{\left(\frac{r \frac{D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D}{\frac{2S_c}{W^*} \Lambda r \frac{D+zM}{D+M}}\right)^2 - \frac{4S_c}{W^*} \Lambda r \frac{D+zM}{D+M} D} < \frac{D(D+M)}{r(D+zM)}$

$$\iff \left(\frac{r D+zM}{D+M} + \eta \Lambda - \frac{S_c}{W^*} \Lambda D\right)^2 > \left(\frac{r D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D\right)^2 - 4 \frac{S_c}{W^*} \Lambda r \frac{D+zM}{D+M} D$$

$$\iff \frac{D+zM}{D+M} > \frac{D+zM}{D+M} + \eta \Lambda$$

Contradiction.

Therefore, if a no-shorting equilibrium exists, a corporate bond price must be the negative root of the quadratic equation (46).

$$P_c = \frac{r \frac{D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D}{\frac{2S_c}{W^*} \Lambda r \frac{D+zM}{D+M}} - \sqrt{\left(\frac{r \frac{D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D}{\frac{2S_c}{W^*} \Lambda r \frac{D+zM}{D+M}}\right)^2 - \frac{4S_c}{W^*} \Lambda r \frac{D+zM}{D+M} D}$$

(47)

The negative root satisfies the inequality (45).

$$1 - P_c \left\{ \frac{1}{\Lambda P_c} - \eta \left( D - \frac{P_c r}{D+M}(D+zM) \right)^{-1} \right\} \leq 0 \iff$$

$$\frac{r \frac{D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D}{\frac{2S_c}{W^*} \Lambda r \frac{D+zM}{D+M}} - \sqrt{\left(\frac{r \frac{D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D}{\frac{2S_c}{W^*} \Lambda r \frac{D+zM}{D+M}}\right)^2 - \frac{4S_c}{W^*} \Lambda r \frac{D+zM}{D+M} D} < \frac{D(D+M)}{r(D+zM)}$$

$$\iff \left(\frac{r D+zM}{D+M} + \frac{S_c}{W^*} \Lambda D\right)^2 < \left(\frac{r D+zM}{D+M} + \eta \Lambda + \frac{S_c}{W^*} \Lambda D\right)^2 - 4 \frac{S_c}{W^*} \Lambda r \frac{D+zM}{D+M} D$$

$$\iff \frac{D+zM}{D+M} < \frac{D+zM}{D+M} + \eta \Lambda$$
Define two bivariate functions $D_g(\cdot, \cdot)$ and $D_c(\cdot, \cdot)$. Define two new functions $d_g(\cdot)$ and $d_c(\cdot)$ such that $D_c(d_c(M), M) = S_c$ and $D_g(d_g(M), M) = Q_{g, ECB} + F$. Since $D_g(P_c, M) = Q_{g, ECB} + F$ is a linear equation of $P_c$, one can always solve for $P_c$. Therefore, the existence of function $d_g(\cdot)$ is guaranteed.

\[
D_c(P_c, M) = \frac{nW_0}{\chi} \left\{ \frac{1}{\Lambda P_c} - \frac{D}{D + M} \left( D + zM \right) \right\}^{-1}
\]  
(48)

\[
D_g(P_c, M) = \left[ 1 - f(M) \right] \cdot \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c P_c \right]
\]  
(49)

The existence of function $d_c(\cdot)$ is guaranteed if the discriminant of the quadratic equation (42) is always nonnegative.

\[
\left( \frac{r}{D + M} + \frac{S_c}{W^*_\Lambda D} \right)^2 - 4 \frac{S_c}{W^*_\Lambda} \frac{D + zM}{D + M} D > 0
\]

\[
\left( \frac{r}{D + M} - \frac{S_c}{W^*_\Lambda D} \right)^2 + \eta^2 \Lambda^2 + 2\eta \Lambda \left( \frac{r}{D + M} + \frac{S_c}{W^*_\Lambda D} \right) > 0
\]

Therefore, function $d_c(\cdot)$ always exists. Equations (50), (51), (52) characterize a no-shorting equilibrium.

\[
D_c(d_c(M), M) = S_c
\]  
(50)

\[
P_c > \frac{D}{r + \eta \Lambda}
\]  
(51)

\[
D_g(d_g(M), M) = Q_{g, ECB} + F
\]  
(52)

**Lemma 4.** Suppose a no-shorting equilibrium exists. The corporate bond price $P_c$ in a no-shorting equilibrium is increasing in repo specialness $M$. 

68
Proof.

\[
\frac{\partial D_c}{\partial P_c} = \frac{nW_0}{\chi} \left\{ -\frac{1}{\Lambda P_c^2} - \eta \frac{r}{D + M} \right\} < 0
\]

\[
\frac{\partial D_c}{\partial M} = -\frac{nW_0}{\chi} \eta \frac{P_c(D + zM)}{(D - \frac{P_c}{D + M}(D + zM))^2} > 0
\]

By the implicit function theorem, \( \frac{d}{dM} d_c(M) > 0 \).

To prove the unique existence of a no-shorting equilibrium, it suffices to show the unique existence of \((M, P_c)\) that satisfies the following system of equations (50), (51), and (52).

**Lemma 5.** The system of equations (50), (51), and (52) has a unique solution.

Proof.

\[
\frac{\partial D_g}{\partial P_c} = -S_c[1 - f(M)] \cdot \frac{r}{D + M} < 0
\]

\[
\frac{\partial Q_g}{\partial M} = -f(M) \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c P_c \right] + [1 - f(M)] \cdot \frac{r}{(D + M)^2} \left[ \frac{nW_0}{\chi} - S_c P_c \right] = -f'(M) \frac{r}{D + M} \left[ \frac{nW_0}{\chi} - S_c P_c \right] - \frac{Q_{g,ECB} + F}{D + M} < 0
\]

Therefore, by the implicit function theorem, \( \frac{d}{dM} d_g(M) < 0 \). By substituting \( f(0) = 0 \) and \( M = 0 \) into \( D_g(P_c, M) = F + Q_{g,ECB} \), I can solve for \( d_g(0) \).

\[
Q_{g,ECB} + F = \frac{r}{D} \left[ \frac{nW_0}{\chi} - S_c d_g(0) \right]
\]

\[
d_g(0) = \frac{1}{S_c} \left\{ \frac{nW_0}{\chi} - \frac{D}{r} \left( Q_{g,ECB} + F \right) \right\}
\]
If the condition created for this proposition holds, $d_g(0)$ is positive.

$$Q_g,ECB + F < [1 - f(M^*)] \cdot \frac{r}{D + M^*} \left[ \frac{nW_0}{\chi} - \frac{S_c D}{r + \eta \Lambda} \right] < \frac{r \cdot nW_0}{D \cdot \chi}$$

$$\Leftrightarrow \frac{nW_0}{\chi} - \frac{D}{r} (Q_g,ECB + F) > 0$$

Substitute $M = 0$ into equation [50] to obtain $d_c(0)$, which is positive.

$$d_c(0) = \frac{r + \eta \Lambda + \frac{S_c \Lambda D - \sqrt{(r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda})^2 - \frac{4 S_c \Lambda r D}{W^* \Lambda r}}}{2 S_c \Lambda r}$$

(54)

Check that $d_c(0)$ is larger than $\frac{D}{r + \eta \Lambda}$.

$$d_c(0) = \frac{r + \eta \Lambda + \frac{S_c \Lambda D - \sqrt{(r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda})^2 - \frac{4 S_c \Lambda r D}{W^* \Lambda r}}}{2 S_c \Lambda r} > \frac{D}{r + \eta \Lambda}$$

$$\Leftrightarrow r + \eta \Lambda + \frac{S_c \Lambda D - \sqrt{(r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda})^2 - \frac{4 S_c \Lambda r D}{W^* \Lambda r}}}{r + \eta \Lambda} > \frac{D}{r + \eta \Lambda} \frac{2 S_c \Lambda r D}{W^* \Lambda r}$$

$$\Leftrightarrow r + \eta \Lambda + \frac{S_c \Lambda D - \sqrt{(r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda})^2 - \frac{4 S_c \Lambda r D}{W^* \Lambda r}}}{r + \eta \Lambda} > \frac{D}{r + \eta \Lambda} \frac{2 S_c \Lambda r D}{W^* \Lambda r}$$

$$\Leftrightarrow \frac{4 S_c \Lambda r D}{W^* \Lambda r} \left( r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda} \right)^2 - \left( r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda} \right)^2$$

$$\Leftrightarrow \frac{4 S_c \Lambda r D}{W^* \Lambda r} > \frac{S_c \Lambda r D}{2 \frac{2r}{r + \eta \Lambda} \left( 2r + 2 \frac{2r + 2 \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda}}{r + \eta \Lambda} \right)}$$

$$\Leftrightarrow r + \eta \Lambda > r + \eta \Lambda + \frac{S_c \Lambda D}{r + \eta \Lambda} \frac{\eta \Lambda}{r + \eta \Lambda}$$

70
Because \( d_c(\cdot) \) is an increasing function, \( d_c(M) > \frac{D}{r+\eta} \) for \( \forall M > 0 \). The corporate bond price is always higher than the fundamental value.

Check that \( d_c(0) \) is smaller than \( d_g(0) \).

\[
d_c(0) < d_g(0) \iff \frac{r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D}{W^*} - \sqrt{\left(r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D\right)^2 - \frac{4S_c}{W^*} \Lambda r D} < \frac{1}{S_c} \left\{ W^* - \frac{D}{r} (Q_{g,ECB} + F) \right\}
\]

\[
\therefore \frac{2S_c D}{r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D + \sqrt{\left(r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D\right)^2 - \frac{4S_c}{W^*} \Lambda r D}} < \frac{2}{W^*} \Lambda r \left\{ W^* - \frac{D}{r} (Q_{g,ECB} + F) \right\}
\]

\[
\therefore 2S_c D < \left\{ W^* - \frac{D}{r} (Q_{g,ECB} + F) \right\} \left\{ r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D + \sqrt{\left(r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D\right)^2 - \frac{4S_c}{W^*} \Lambda r D} \right\}
\]

Note that \( \left(r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D\right)^2 - \frac{4S_c}{W^*} \Lambda r D = \left(r + \frac{S_c}{W^*} \Lambda D\right)^2 + \eta^2 \Lambda^2 + 2\eta\Lambda \left(r + \frac{S_c}{W^*} \Lambda D\right) - \frac{4S_c}{W^*} \Lambda r D = \left(r - \frac{S_c}{W^*} \Lambda D\right)^2 + \eta^2 \Lambda^2 + 2\eta\Lambda \left(r - \frac{S_c}{W^*} \Lambda D\right) = \left(r - \frac{S_c}{W^*} \Lambda D + \eta\Lambda\right)^2 \).

\[
d_c(0) < d_g(0) \iff 2S_c D < \left\{ W^* - \frac{D}{r} (Q_{g,ECB} + F) \right\} \left(r + \eta\Lambda + \frac{S_c}{W^*} \Lambda D + r - \frac{S_c}{W^*} \Lambda D + \eta\Lambda\right)
\]

\[
\therefore S_c D < \left\{ W^* - \frac{D}{r} (Q_{g,ECB} + F) \right\} (R + \eta\Lambda) \iff S_c \frac{D}{r + \eta\Lambda} + \frac{D}{r} (Q_{g,ECB} + F) < W^*
\]

\[
\therefore Q_{g,ECB} + F < \frac{D}{D + M^*} \left(W^* - S_c \frac{D}{r + \eta\Lambda}\right) \iff Q_{g,ECB} + F < \left[1 - f(M^*)\right] \cdot \frac{r}{D + M^*} \left[\frac{nW_0}{\chi} - S_c \frac{D}{r + \eta\Lambda}\right]
\]

Lastly, derive \( \lim_{M \to \infty} d_g(M) \). Rewrite equation (49).

71
\[
d_d(M) = \frac{1}{S_c} \left( W^* - \frac{Q_{g, ECB} + F D + M}{1 - f(M)} \right)
\]

Therefore, \( \lim_{M \to \infty} d_d(M) = -\infty \).

d_d(\cdot) \) is a continuous and strictly decreasing function such that \( \lim_{M \to \infty} d_d(M) = -\infty \) and \( d_d(0) > d_c(0) > \frac{D}{r + \eta M} \), whereas \( d_c(\cdot) \) is a continuous and strictly increasing function such that \( d_c(0) < d_d(0) \). Define a new function \( d^*(M) = d_c(M) - d_d(M) \). \( d^*(\cdot) \) is a continuous and increasing function of \( M \) such that \( d^*(0) < 0 \) and \( \lim_{M \to \infty} d^*(M) > 0 \). By the intermediate value theorem, there exists a unique positive number \( M^* \) such that \( d_c(M^*) = d_d(M^*) \). That positive number \( M^* \) uniquely determines the value of \( P_c \) through equation (47). ■

9.8 Proof of Proposition 2

By Proposition 1, for any value of \( Q_{g, ECB} \) that satisfies the condition of this proposition, there exists a unique pair of equilibrium \( P_c \) and \( M \) that solves equations (55) and (56).

\[
P_c = \frac{r D + z M}{D + M} + \frac{S_c W^* \Lambda D}{D + M} - \sqrt{\left( \frac{r D + z M}{D + M} + \frac{S_c W^* \Lambda D}{D + M} \right)^2 - \frac{4 S_c W^* \Lambda r D + z M}{D + M} D} = d_c(M) \tag{55}
\]

\[
[1 - f(M)] \cdot \frac{r}{D + M} \left[ \frac{n W_0}{\chi} - S_c P_c \right] = Q_{g, ECB} + F \tag{56}
\]

I differentiate both equations with respect to \( Q_{g, ECB} \).

\[
\frac{\partial P_c}{\partial Q_{g, ECB}} = d'_c(M) \frac{\partial M}{\partial Q_{g, ECB}} \tag{57}
\]
\[
\left[ -f'(M) \frac{r}{D + M} - (1 - f(M)) \frac{r}{(D + M)^2} \right] \frac{\partial M}{\partial Q_{ECB}} \left[ \frac{nW_0}{\chi} - S_c P_c \right] - \left[ 1 - f(M) \right] \cdot \frac{r}{D + M} S_c \frac{\partial P_c}{\partial Q_{ECB}} = 1
\]

(58)

I substitute equation (57) into equation (58)

\[
\left\{ -f'(M) \frac{r}{D + M} - (1 - f(M)) \frac{r}{(D + M)^2} \right\} \left( \frac{nW_0}{\chi} - S_c P_c \right) - \left[ 1 - f(M) \right] \frac{r}{D + M} S_c d'_c(M) \frac{\partial P_c}{\partial Q_{ECB}} = 1
\]

Because \( \left\{ -f'(M) \frac{r}{D + M} - (1 - f(M)) \frac{r}{(D + M)^2} \right\} \left( \frac{nW_0}{\chi} - S_c P_c \right) - \left[ 1 - f(M) \right] \frac{r}{D + M} S_c d'_c(M) \) is negative, \( \frac{\partial P_c}{\partial Q_{ECB}} \) is positive. \( \frac{\partial M}{\partial Q_{ECB}} = \frac{1}{S_c(M)} \frac{\partial P_c}{\partial Q_{ECB}} \) is positive as well.

9.9 Quantifying the impact of the ECB’s Decision Not to Lend Bonds on Gains from Trade

The model is based on that of Vayanos and Weill (2008). The model contains only one bond, which can be thought of as a core government bond, such as a German Bund. Figure 11 shows the complete life cycle of an investor. As discussed in Duffie, Garleanu, and Pedersen (2005), every investor in my model has a time discount rate equal to the risk-free rate. Investors are risk-neutral and maximize the present value of their consumption stream. For example, equation (59) shows the value function of an idle investor. I conjecture that the value function is linear in wealth \( W_t \). Because the discount rate is equal to the risk-free rate, the investor is not concerned with the timing of their consumption. Thus, without loss of generality, I let \( dC_t = rW_t dt \) (Duffie, Garleanu, and Pedersen, 2005). As in He and Xiong (2012), bonds mature stochastically with rate \( \psi \). When a bond matures, the holder receives the principal 1. A short-seller needs to pay 1 to the owner. An investor that does not own a bond exits the market with zero payoff. Bonds mature independently of one another.
\[ J_0(W_t) = W_t + V(0) \]

\[
= \sup_c \mathbb{E}_t \left[ \int_{u=t}^{t+\min(\tau_L, \tau_H, \tau_\psi)} e^{-r(u-t)} dC_u + e^{-r \cdot \min(\tau_L, \tau_H, \tau_\psi)} \left\{ \frac{\rho_L V(\bar{b}) + \rho_s V(bo)}{\rho_L + \rho_s + \psi} + W_{t+\min(\tau_L, \tau_H, \tau_\psi)} \right\} \right] \tag{59}
\]

such that

\[ dW_t = rW_t dt - dC_t \]

In this equation, \( \tau_L, \tau_H, \) and \( \tau_\psi \) are stopping times with rates \( \rho_L, \rho_H, \) and \( \psi, \) respectively. With rate \( \rho_L, \) the investor transitions to the \( \"\bar{b}\" \) state and searches for a seller in the cash market. With rate \( \rho_H, \) it transitions to the \( \"bo\" \) state and searches for a lender in the repo market. With rate \( \psi, \) the bond matures. Then, I can further simplify the investor’s problem as follows.

\[ V(0) = \mathbb{E}_t \left[ e^{-r \cdot \min(\tau_L, \tau_H, \tau_\psi)} \left\{ \frac{\rho_L V(\bar{b}) + \rho_s V(bo)}{\rho_L + \rho_s + \psi} \right\} \right] \tag{60} \]

The HJB equation is as follows.

\[ rV(0) = \rho_L \{ V(\bar{b}) - V(0) \} + \rho_s \{ V(bo) - V(0) \} + \psi \{ 0 - V(0) \} \tag{61} \]

The complete list of HJB equations for all states is given below. \( v \) and \( \lambda \) are the contact rates in the repo market and the cash market, respectively, and \( S = \{ bns, cns, s \} \) is the set of all possible states of investors that go to the cash market to sell a bond. Likewise, \( B = \{ \bar{b}, bnb, cnb \} \) is the set of states in which an investor purchases a bond in the cash market. Let \( P(\sigma_b, \sigma_s) \) denote the transaction price of a bond when a buyer of type \( \sigma_b \) and a seller of type \( \sigma_s \) meet.
Suppose a long investor recalls a bond from a short investor who sold the bond in the cash market. To return a bond, the short investor needs to purchase the bond. However, since the cash market is an over-the-counter market, such a purchase requires time. As in Vayanos and Weill (2008), I assume that the short investor returns the cash equivalent to the market price of a bond. Let $C$ denote the amount of cash that the short investor returns to the long investor if the bond is not in hand. Since the transaction price of a bond depends on the types of buyers and sellers, I take the trade volume-weighted average value of prices as shown in equation (75).

Let $w$ denote the lending fee that borrowers and lenders negotiate in the bilateral repo market. As in my main theoretical model of portfolio rebalancing, I assume that a borrower pays $w$ per unit of time to the lender. Let $w_{CB}$ denote the lending fee that the central bank charges to the borrower. $\delta$ is the coupon rate of a bond. Borrowers meet with the central bank at rate $\eta$. This delay in concluding a trade with the central bank could represent the restrictive operation of the ECB’s securities lending facility.

\[
r V(\bar{b}) = k_L[V(0) - V(\bar{b})] + \lambda \mu(S)[V(\bar{\ell}) - V(\bar{b})] - \sum_{\sigma_s \in S} \lambda \mu(\sigma_s)P(\bar{b}, \sigma_s) + \psi[0 - V(\bar{b})] \tag{62}
\]

\[
r V(\bar{\ell}) = x_L - y + \delta + k_L[V(\bar{s}) - V(\bar{\ell})] + v \cdot \mu(bo)[V(hns) - V(\bar{\ell})] \tag{63}
\]

\[
r V(\bar{s}) = -y + \delta + \lambda \mu(b)[V(0) - V(\bar{s})] + \sum_{\sigma_b \in B} \lambda \mu(\sigma_b)P(\sigma_b, \bar{s}) + \psi[1 - V(\bar{s})] \tag{64}
\]

\[
r V(bo) = v \cdot \mu(\bar{\ell}) \cdot [V(bns) - V(bo)] + \eta[V(cns) - V(bo)] + k_s[V(0) - V(bo)] + \psi[0 - V(bns)] \tag{65}
\]
Figure 11 The Life Cycle of a Bond Investor

Notes: In the figure, $\mu(\cdot)$ denotes the mass of investors of a given type, and $V(\cdot)$ denotes the value function of an investor of a given type. The blue arrow indicates that the investor changed its type because of a preference shock. The red arrow indicates that the investor traded in the repo market and transitioned to another state. The green arrow indicates that the investor traded in the cash market and transitioned to another state. The dashed arrow indicates that the investor changed its type because of its counterparty. The expression next to each arrow is the rate at which an investor transitioned along that line. The red text next to each box shows the flow of the benefit or cost for an investor. For example, an investor in the “s” state receives coupon $\delta$ per unit of time but at the same time incurs the cost $y$ per unit of time.
\begin{align*}
\bar{r}V(bns) &= k_L[V(bo) - V(bns)] + k_s[V(0) - V(bns)] + \lambda \mu(b)[V(bnn) - V(bns)] \\
&\quad + \sum_{\sigma_b \in B} \lambda \mu(\sigma_b, bns) + \psi[0 - V(bns)] \\
\bar{r}V(bnn) &= -w - \delta + x_s - y + k_L[V(bo) - V(bnn)] + k_s[V(bnb) - V(bnn)] + \psi[-1 - V(bnn)] \\
\bar{r}V(bnb) &= -w - \delta - y + \lambda \mu(S)[V(0) - V(bnb)] + k_L[V(0) - V(bnb) - C] \\
&\quad - \sum_{\sigma_s \in S} \lambda \mu(\sigma_s)P(bnb, \sigma_s) + \psi[-1 - V(bnb)] \\
\bar{r}V(cns) &= -w_{CB} + \lambda \mu(b)[V(cn) - V(cns)] + k_s[V(0) - V(cns)] \\
&\quad + \sum_{\sigma_b \in B} \lambda \mu(\sigma_b, cns) + \psi[0 - V(cns)] \\
\bar{r}V(cn) &= -w_{CB} - \delta + x_s - y + k_s[V(cn) - V(cn)] + \psi[-1 - V(cn)] \\
\bar{r}V(cn) &= -w_{CB} - \delta - y + \lambda \mu(S)[V(0) - V(cn)] - \sum_{\sigma_s \in S} \lambda \mu(\sigma_s)P(cn, \sigma_s) + \psi[-1 - V(cn)] \\
\bar{r}V(hns) &= x_L - y + \delta + w + k_s[V(\bar{\ell}) - V(hns)] + k_L[V(\bar{s}) - V(hns)] \\
&\quad + \lambda \mu(b)[V(hnn) - V(hns)] + \psi[1 - V(hns)] \\
\bar{r}V(hnn) &= x_L - y + \delta + w + k_L[V(0) - V(hnn) + C] + k_s[V(hnb) - V(hnn)] + \psi[1 - V(hnn)] \\
\bar{r}V(hnb) &= x_L - y + \delta + w + \lambda \mu(S)[V(\bar{\ell}) - V(hnb)] + k_L[V(0) - V(hnb) + C] + \psi[1 - V(hnb)] \\
\end{align*}

\begin{equation}
C = \frac{\sum_{\sigma_b} \sum_{\sigma_s} P(\sigma_b, \sigma_s) \mu(\sigma_b) \mu(\sigma_s)}{\sum_{\sigma_b} \sum_{\sigma_s} \mu(\sigma_b) \mu(\sigma_s)}
\end{equation}

Let $\sigma(S)$ and $\sigma(b)$ denote the total mass of sellers and buyers in the cash market.
\[ \mu(S) = \mu(\bar{s}) + \mu(bns) + \mu(hns) \quad (76) \]

\[ \mu(b) = \mu(\bar{b}) + \mu(bnb) + \mu(cnbs) \quad (77) \]

The stationary equilibrium mass of investors of each type satisfies the following system of equations. For each state, the inflow equals the outflow.

\[ \mu(hns) = \mu(bns) = \frac{v\mu(bo)\mu(\bar{\ell})}{k_L + k_S + \lambda\mu(b)} \quad (78) \]

\[ \mu(hnn) = \mu(bnn) = \frac{\lambda\mu(b) v\mu(bo)\mu(\bar{\ell})}{k_L + k_S} \quad (79) \]

\[ \mu(bnb) = \mu(hnb) = \frac{k_S \lambda\mu(b) v\mu(bo)\mu(\bar{\ell})}{k_L + k_S} \quad (80) \]

\[ \eta \cdot \mu(bo) = \mu(cns) \cdot \{k_S + \lambda\mu(b)\} \quad (81) \]

\[ \lambda \cdot \mu(cns) \cdot \mu(b) = k_s \cdot \mu(cnn) \quad (82) \]

\[ k_s \cdot \mu(cnn) = \lambda \cdot \mu(cnbs) \mu(S) \quad (83) \]

\[ \rho_S \mu(0) + k_L \mu(bnn) + k_L \mu(bns) = \eta \cdot \mu(bo) + v\mu(\bar{\ell})\mu(bo) + k_S \mu(bo) \quad (84) \]

\[ \mu(\bar{b}) = \frac{\rho_l \mu(0)}{k_L + \lambda\mu(S)} \quad (85) \]

\[ \mu(\bar{s}) = \frac{k_L \mu(\bar{\ell}) + k_L \mu(hns)}{\lambda\mu(b)} \quad (86) \]

\[ \lambda\mu(S)\mu(\bar{b}) + k_s\mu(\bar{b}) + \lambda\mu(S)\mu(nb) = v\mu(bo)\mu(\bar{\ell}) + k_L \mu(\bar{\ell}) \quad (87) \]

Additionally, the mass of all investors must sum to an exogenously specified parameter.
Lastly, the investors’ net holdings of bonds are equal to an exogenous parameter $m_S$. This condition is the market-clearing condition for the cash market.

$$
\mu(\bar{\ell}) + \mu(S) = m_s
$$  \hspace{1cm} (89)

When a buyer and a seller meet in the cash market, they determine the transaction price through bargaining. Let $\Phi$ denote the bargaining power of a buyer vis-à-vis a seller. The buyer obtains a fraction $\Phi$ of the total gain from the trade. [Duffie, Gârleanu, and Pedersen (2007)] reported a microfoundation for equation (90) based on the Nash bargaining theory.

$$
V(\bar{\ell}) - V(\bar{b}) - P(\bar{b}, s) = \Phi\{V(\bar{\ell}) - V(\bar{b}) + V(0) - V(s)\}
$$  \hspace{1cm} (90)

$$
V(\bar{\ell}) - V(\bar{b}) - P(\bar{b}, bns) = \Phi\{V(\bar{\ell}) - V(\bar{b}) + V(cnn) - V(bns)\}
$$  \hspace{1cm} (91)

$$
V(\bar{\ell}) - V(\bar{b}) - P(\bar{b}, cns) = \Phi\{V(\bar{\ell}) - V(\bar{b}) + V(bnn) - V(cns)\}
$$  \hspace{1cm} (92)

When a lender and a borrower meet in the repo market, they determine the lending fee through bargaining. Let $\theta$ denote the bargaining power of a lender vis-à-vis a borrower.
\[ V(hns) - V(\bar{\ell}) = \theta \{ V(hns) - V(\bar{\ell}) + V(bns) - V(bo) \} \]  

(99)

The central bank charges the borrower a lending fee so that the central bank captures half of the surplus.

\[ \frac{W_{CB}}{r + k_S} = \frac{1}{2} (V(cns) - V(bo)) \]  

(100)

When a buyer and a seller meet, they will trade only if the total gain from the trade is positive. The right-hand side of equations (90) to (98) should be positive. Trades in the bilateral repo market can occur only if \( V(hns) - V(\bar{\ell}) + V(bns) - V(bo) \) is positive. A short investor borrows a bond from the central bank only if \( V(cns) - V(bo) \) is positive.

**Definition 2** Let \( \sigma \) denote the type of an investor (e.g., bns). Let \( \sigma_s \) and \( \sigma_b \) denote types of sellers and buyers, respectively. A joint equilibrium of the cash market and the repo market are the set of bond prices \( \{ P(\sigma_b, \sigma_s) \} \), a lending fee in the bilateral repo market \( w \), a lending fee that the central bank charges to a borrower \( w_{CB} \), investor masses \( \{ \mu(\sigma) \} \), and value functions \( \{ V(\sigma) \} \) such that:

- Each investor’s value function satisfies the HJB equations (62) through (74);
- The mass of investor of each type satisfies equations (78) through (87);
- The mass of investors sum to \( m_I \) as shown in equation (88);
- The total amount of bonds investors hold is equal to \( m_S \) as shown in equation (89);
- Buyers and sellers in the cash market determine bond prices \( \{ P(\sigma_b, \sigma_s) \} \) as shown in equations (90) through (98);
- Borrowers and lenders in the bilateral repo market determine the lending fee \( w \) as shown in equation (99);
- The central bank charges a lending fee \( w_{CB} \) on borrowers as shown in equation (100); and
• The incentive compatibility conditions hold. Borrowers and lenders want to trade in the repo market. Borrowers want to borrow bonds from the central bank, and buyers and sellers want to trade in the cash market.

I numerically solve for an equilibrium. Tables 9, 10, and 11 describe my calibration process. As in Vayanos and Weill (2008), I make the mass of buyers in the model strictly larger than the total quantity of bonds circulating in the market. de Roure, Moench, Pelizzon, and Schneider (2019) reported that the average transaction size in the Bund market is 6 million euros. Thus, one unit mass in my model corresponds to 6 million euros. The unit of time in my model is one year. I use data between October 1, 2018, and March 31, 2019, whenever possible. My BrokerTec and MiFid2 data are both available during this period.

For the risk-free rate, I use the 10-year overnight indexed swap (OIS) rate. The ideal choice of the risk-free rate would be an overnight secured interbank money market rate or the ECB deposit facility rate, both of which are negative. Negative risk-free rates imply a negative subjective discount rate in my model. When the discount rate is negative, the objective function in the HJB equation is ill-defined. Therefore, I use a 10-year OIS rate, which is positive. I find that the calibration result is not sensitive to the choice of the risk-free rate.
### Table 9 Calibration of Quantity Variables in the Search-Based Model of the Bond Market

<table>
<thead>
<tr>
<th>Definition</th>
<th>Calibration</th>
<th>Data source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$ The contact rate between investors in the cash market</td>
<td>Target the cash market trade volume</td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>$\nu$ The contact rate between investors in the bilateral repo market</td>
<td>Match the utilization rate in the government bond lending market</td>
<td>Aggarwal, Bai, and Laeven (2020)</td>
<td>0.0001</td>
</tr>
<tr>
<td>$\rho_H$ The rate at which an idle investor gets a preference shock and wants to buy a bond</td>
<td>A higher value increases the trade volume in the cash market.</td>
<td>Mifid2 RTS27 reports from the largest dealers and trading platforms in Europe</td>
<td>0.25</td>
</tr>
<tr>
<td>$\rho_L$ The rate at which an idle investor gets a preference shock and wants to short-sell a bond</td>
<td>A higher value increases the trade volume in the repo market.</td>
<td>BrokerTec data and ICMA Survey</td>
<td>0.0590</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
<td>Formula</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>$m_S$</td>
<td>The free float of government bonds from core eurozone countries</td>
<td>$\text{First, obtain the total outstanding amounts of core eurozone government bonds. Then subtract the amount that the ECB purchased for the PSPP.}$</td>
<td></td>
</tr>
<tr>
<td>$m_I$</td>
<td>The total mass of investors</td>
<td>$\text{The outstanding amounts of all euro-denominated bonds issued by euro-area residents}$</td>
<td></td>
</tr>
<tr>
<td>$k_L$</td>
<td>The rate at which a long investor gets a preference shock and wants to unwind the position</td>
<td>$\text{The turnover rate of off-the-run government bonds (Corradin and Maddaloni, 2020)}$</td>
<td></td>
</tr>
<tr>
<td>$k_S$</td>
<td>The rate at which a short investor gets a preference shock and wants to unwind the position</td>
<td>$\text{The turnover rate of on-the-run government bonds (Corradin and Maddaloni, 2020)}$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_S$</td>
<td>3,282 billion euros</td>
<td>ECB website</td>
</tr>
<tr>
<td>$m_I$</td>
<td>14,520 billion euros</td>
<td>ECB website</td>
</tr>
<tr>
<td>$k_L$</td>
<td>0.687</td>
<td>MiFid2 RTS27 report</td>
</tr>
<tr>
<td>$k_S$</td>
<td>13.308</td>
<td>MiFid2 RTS27 report</td>
</tr>
</tbody>
</table>
The contact rate between a short investor and the central bank

The quantity of bonds that the ECB lends through the securities lending facility

Notes: For the trading volume in the cash market, I used MIFID2 RTS27 reports from ABN AMRO, Bank of America, Barclays, BGC, BNP Paribas, BrokerTec, Citi, Credit Agricole, Danske Bank, Deutsche Bank, DZ Bank, Goldman Sachs, HSBC, ING, Jefferies, JP Morgan, Mizuho International, Morgan Stanley, MTS, Natwest, Nomura, Rabobank, Societe Generale, TradeWeb, UBS, and Unicredit.

Table 10 Calibration of Price Variables in the Search-Based Model of the Bond Market

<table>
<thead>
<tr>
<th>Definition</th>
<th>Calibration</th>
<th>Data source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_L )</td>
<td>The flow of benefit for long investors</td>
<td>The basis spread between 10-year core sovereign bond yields and 10-year OIS rate</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>( x_S )</td>
<td>The flow of benefit for short investors</td>
<td>Repo specialness of core sovereign bonds</td>
<td>BrokerTec</td>
</tr>
<tr>
<td>( y )</td>
<td>The cost of carrying long or short positions</td>
<td>The basis spread between 10-year core sovereign bond yields and 10-year OIS rate</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>( r )</td>
<td>The risk-free rate</td>
<td>10-year OIS rate.</td>
<td>Bloomberg</td>
</tr>
</tbody>
</table>
Table 11 Calibration of Other Variables in the Search-Based Model of the Bond Market

<table>
<thead>
<tr>
<th>Definition</th>
<th>Calibration</th>
<th>Data source</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$ The average coupon rate</td>
<td>Match the coupon rates of core sovereign bonds</td>
<td>Thomson Reuters Eikon</td>
<td>1.612%</td>
</tr>
<tr>
<td>$\psi$ The rate at which bonds mature stochastically</td>
<td>Match the weighted-average maturity of core sovereign bonds</td>
<td>Eikon</td>
<td>$\frac{1}{8.594}$</td>
</tr>
<tr>
<td>$\phi$ The bargaining power of a buyer vis-à-vis a seller in the cash market</td>
<td>The basis spread between 10-year core sovereign bond yields and 10-year OIS rate</td>
<td>Bloomberg</td>
<td>0.7</td>
</tr>
<tr>
<td>$\theta$ The bargaining power of a lender vis-à-vis a borrower in the repo market</td>
<td>Repo specialness of core sovereign bonds</td>
<td>BrokerTec</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Table 12 summarizes the result of my calibration.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Model-Implied Value</th>
<th>Target Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade volume in the cash market</td>
<td>9.791 × 10^5 (in units of 6 million Euros)</td>
<td>5.697 × 10^5 (in units of 6 million Euros)</td>
</tr>
<tr>
<td>Trade volume in the repo market</td>
<td>8.389 × 10^5 (in units of 6 million Euros)</td>
<td>1.088 × 10^6 (in units of 6 million Euros)</td>
</tr>
<tr>
<td>Bonds that the central bank lends to investors</td>
<td>528.04 (in units of 6 million Euros)</td>
<td>523 (in units of 6 million Euros)</td>
</tr>
<tr>
<td>The yield-OIS basis for a 10-year sovereign bond</td>
<td>70.3 basis points</td>
<td>74.2 basis points</td>
</tr>
<tr>
<td>Specialness</td>
<td>15.74 basis points</td>
<td>15.1 basis points</td>
</tr>
<tr>
<td>Utilization rate</td>
<td>13.44%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Lending fee for the central bank facility</td>
<td>12.62 basis points</td>
<td>The exact value is unknown, but the Eurosystem follows the market rate.</td>
</tr>
</tbody>
</table>

Similar to [Hugonnier, Lester, and Weill (2020)](#), I define the investors’ aggregate gains from trade as the combined flow of benefits and costs for all investors in the model. I assume that the central bank sends the profit it makes from lending bonds back to the fiscal government. This assumption is in line with the practice of national central banks in the eurozone. Therefore, the lending fee that borrowers pay to the central bank is not a welfare cost. When computing gains from trade, I add the term $w_{cb}\{\mu(cns) + \mu(cnn) + \mu(cnb)\}$.  

86
\begin{equation}
Gain_t = (x_L - y)\{\mu(\bar{l}) + \mu(ns) + \mu(nn) + \mu(nb)\} \\
- y\{\mu(\bar{s}) + \mu(nb) + \mu(cn)\} + (x_s - y)\{u(nn) + u(cnn)\} \\
+ w_{cb}\{\mu(cn) + \mu(cn) + \mu(cn)\}
\end{equation}

I construct a counterfactual exercise by varying the value of \(\eta\), the rate at which borrowers meet with the central bank.

### 9.10 Alternative Measurement of the Bond-Lending Channel

My measurement of the bond-lending channel described in Section 5.4 used a one-time event on November 23, 2016. To complement this evidence, I also measure the response of corporate bond yields to repo-induced changes in sovereign bond yields using extended time-series data in daily frequency. My sample covers the period between March 1, 2013, and March 31, 2019. I use a variation of the Granular Instrumental Variable (GIV) method of Gabaix and Koijen (2020).

Equation (105) shows the reduced-form specification of my model, where \(y^c_{it}\) is the yield-to-maturity of a corporate bond \(i\) on day \(t\); \(y^g_{it}\) is the weighted-average yield-to-maturity of sovereign bonds on the same day; \(y^g_{jmct}\) is the yield-to-maturity of sovereign bond \(j\); and subscripts \(m\) and \(c\) are the maturity bucket and domicile country of the issuer, respectively.

As shown in equation (106), the kernel weight is exponentially decreasing in the absolute difference between the duration of a corporate bond \(D^c_{it}\) and the duration of a sovereign bond \(D^g_{jmct}\). \(\bar{X}_{it}\) is a vector of control variables, which include the duration of a corporate bond, the Euro Overnight Index Average (EONIA) rate, and the common factors driving the repo specialness of sovereign bonds.

To extract the idiosyncratic components of repo specialness, I follow the steps in Gabaix and Koijen (2020). My data come from BrokerTec.

**Step 1**: I run the following panel regression. \(s_{jmct}\) is the repo specialness of sovereign
bond \( j \) on day \( t \). Subscript \( m \) denotes the maturity bucket and subscript \( c \) reflects the domicile country of the issuer. I specify four maturity buckets: (1) from 0 to 2 years, (2) from 2 to 5 years, (3) from 5 to 10 years, and (4) from 10 to 20 years. There are 10 countries in my sample: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, and Spain. \( FE_c \) and \( FE_t \) are the country and time fixed effects, respectively. I obtain estimation residuals \( \hat{v}_{jmc} \).

\[
S_{jmc} = FE_c + FE_t + v_{jmc} \tag{102}
\]

**Step 2:** For each day, I run the following cross-sectional regression. \( Mat_{jmc} \) is the residual maturity of sovereign bond \( j \) on day \( t \). \( Core_{jmc} \) is an indicator variable that is 1 if and only if country \( c \) is one of the core countries. \( F^m_t \) and \( F^c_t \) are common latent factors.

\[
\hat{v}_{jmc} = Mat_{jmc} \cdot F^m_t + Core_{jmc} \cdot F^c_t + \epsilon_{jmc} \tag{103}
\]

The model assumes that a set of common unobserved factors drive the specialness premia of all sovereign bonds. For example, long-term bonds tend to have higher specialness premia than short-term bonds. Short-sellers concentrate on borrowing long-term bonds to bet against interest rate movements. The latent maturity common factor proxies this short-selling demand. The specialness of a long-term bond is more sensitive to this common factor than the specialness of a short-term bond. Therefore, I identify the slope parameter \( Mat_{jmc} \).

In a similar fashion, core sovereign bonds tend to be more special than peripheral sovereign bonds. The common latent factor \( F^c_t \) captures this pattern. After estimating specification (103), I obtain residuals \( \hat{v}_{jmc} \).

**Step 3:** I compute the weighted-average value of \( \hat{v}_{jmc} \) across all bonds with the same maturity bucket and the issuer country on a given day. \( Q_{jmc} \) is the repo trade volume for sovereign bond \( j \) on day \( t \). The estimation residual \( \hat{v}^*_{jmc} \) is the weighted-average idiosyncratic
component of the specialness of sovereign bonds with the maturity bucket \( m \) and the issuer country \( c \).

\[
\hat{\epsilon}_{mct} = \sum_j Q_{jmc} \hat{\epsilon}_{jmc} \quad \text{(104)}
\]

**Step 4:** I run a principal component analysis (PCA) on the panel of \( \hat{\epsilon}_{mct} \). The goal of PCA is to remove the common factors that might remain after Step 2. Let \( PC_{1t} \) and \( PC_{2t} \) denote the principal components with the two largest eigenvalues.

\[
y_{ct}^e = \beta_0 + \alpha \cdot y_{it}^* + \beta_X \cdot \bar{X}_{it} + u_{it} \quad \text{(105)}
\]

\[
y_{it}^* = \frac{\sum_{jmc} \exp \left( -\phi \cdot \left| D_{ct}^c - D_{jmc}^g \right| \right) \cdot y_{jmc}^g}{\sum_{jmc} \exp \left( -\phi \cdot \left| D_{ct}^c - D_{jmc}^g \right| \right)} \quad \text{(106)}
\]

The OLS estimation of this model is likely to exhibit omitted variable bias. To construct an instrument for \( y_{it}^* \), I compute the weighted-average value of the estimated idiosyncratic component \( \hat{\epsilon}_{jmc} \) to obtain my instrument \( Z_{it} \) \( \text{(107)} \).

\[
Z_{it} = \frac{\sum_{jmc} \exp \left( -\phi \cdot \left| D_{ct}^c - D_{jmc}^g \right| \right) \cdot \hat{\epsilon}_{jmc}}{\sum_{jmc} \exp \left( -\phi \cdot \left| D_{ct}^c - D_{jmc}^g \right| \right)} \quad \text{(107)}
\]

For the exclusion restriction to hold, the idiosyncratic component of the repo specialness \( \hat{\epsilon}_{jmc} \) needs to be orthogonal to any unobserved factor \( u_{it} \) driving corporate bond yields. Any plumbing issue specific to a bond could be responsible for the remaining variation in repo specialness \( \hat{\epsilon}_{jmc} \). Figure 12 shows an example of the time series of the instrument.

I consider all euro-denominated corporate bonds for which dealers’ Composite Bloomberg
Bond Trade (CBBT) executable quote data are available. I include a corporate bond in the sample only if its Moody’s rating is not below Aa3, its S&P rating is not below AA-, and its Fitch rating is not below AA-. Similarly, I consider all euro-denominated sovereign bonds with CBBT data available. Table 13 summarizes the data.

**Figure 12 Example of the Estimated Idiosyncratic Component of Specialness**

Notes: To obtain this time series, I regress $Z_{it}$ in equation (107) on the control variables in the model, as shown in equation (105), and I plot the time-series of the residuals from that regression. The exclusion restriction requires this time-series to be orthogonal to any unobserved factor driving corporate bond yields. This example is for a corporate bond with ISIN DE000NWB0329.

I estimate the model separately for each maturity bucket. Table 14 shows that the estimation result is consistent with that given in Section 5.4. For example, consider corporate bonds with durations between 5 and 10 years. If sovereign bond yields drop by a basis point exclusively because of their expected repo specialness, the corporate bond yields drop by 0.522 basis points. This result is not significant for corporate bonds with durations shorter than 5 years or longer than 10 years.
Table 13 Summary Statistics for the Daily Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate bond yields (%)</td>
<td>0.494</td>
<td>1.198</td>
<td>784,989</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>Sovereign bond yields (%)</td>
<td>0.440</td>
<td>0.925</td>
<td>232,804</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>The repo specialness of sovereign bonds (bp)</td>
<td>12.515</td>
<td>20.450</td>
<td>554,499</td>
<td>BrokerTec</td>
</tr>
<tr>
<td>The duration of sovereign bonds (years)</td>
<td>7.891</td>
<td>6.870</td>
<td>261,521</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>The duration of corporate bonds (years)</td>
<td>5.012</td>
<td>3.076</td>
<td>784,989</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>The EONIA rate (%)</td>
<td>-0.0294</td>
<td>0.191</td>
<td>353</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>The remaining maturity of sovereign bonds (years)</td>
<td>9.746</td>
<td>10.507</td>
<td>261,521</td>
<td>Eikon</td>
</tr>
</tbody>
</table>

9.11 Alternative Explanations of Bond Yield Movements on November 23, 2016

A potential concern is that the Reuters article could have prompted investors to change their beliefs about the ECB’s QE size or its policy rate in the future, which would affect bond yields (signaling channel). However, bond yield movements from revised investor beliefs may be less quantitatively important than the bond-lending channel of QE.

First, if investors did revise their beliefs about how long the ECB will conduct QE, government bond yields would have gone down, not up. Investors are likely to have anticipated the purchase of more bonds by the ECB. ECB policymakers have been concerned about the growing scarcity of bonds in the repo market and increasing specialness throughout the PSPP period (Mersch, 2017). This concern about frictions in the market might have de-
<table>
<thead>
<tr>
<th><strong>Table 14 Impact of Repo-Driven Change in Sovereign Bond Yields on Corporate Bond Yields</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
</tr>
<tr>
<td><strong>Sovereign bond yields (%)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>EONIA rate (%)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Linear time trend (days)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Duration (years)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Maturity factor</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Core country factor</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>The first principal component</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>The second principal component</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Fixed Effects</strong></td>
</tr>
<tr>
<td><strong>N</strong></td>
</tr>
<tr>
<td><strong>Cluster</strong></td>
</tr>
<tr>
<td><strong>Effective F-Statistics</strong></td>
</tr>
<tr>
<td><strong>Critical Value for 5% Nagar (1959) Bias</strong></td>
</tr>
<tr>
<td><strong>Critical Value for 10% Nagar (1959) Bias</strong></td>
</tr>
</tbody>
</table>

Notes: The table shows the 2SLS estimation of the linear model (105). I fixed $\phi = 5.16$. Column (1) uses corporate bonds with durations shorter than five years. Column (2) uses corporate bonds with durations between 5 years and 10 years. Column (3) uses corporate bonds with durations longer than 10 years. The effective F-statistics are from Olea and Pflueger (2013)’s test of weak instruments. I ran the regression in daily frequency. The sample period was March 1, 2013, to March 31, 2019. *, **, *** indicate statistical significance at 10%, 5%, and 1%, respectively. The numbers in parenthesis are standard errors.
terred the ECB from purchasing more bonds. However, a more accessible securities lending facility might have led investors to believe that the ECB would soon expand its bond purchases.

Bloomberg regularly conducts surveys asking professional forecasters for their predictions on how the ECB would conduct its QE going forward. Bloomberg conducted two surveys around the time of this event, the first on October 17, 2016, and the second on December 4, 2016. The surveys suggest that investors anticipated the purchase of more bonds by the ECB. Slightly more respondents anticipated that the ECB would extend the duration of QE in December than in October. In particular, 79% (76%) of the respondents in December (October) projected that the ECB would extend the duration of QE. An expectation of even more QE in the future is likely to push down bond yields. However, on November 23, 2016, the bond yields increased. Therefore, the data shows that the signaling channel is likely to have been less important than the bond-lending channel.

Second, if investors did change their forecasts of future policy rates, they would have lowered, not raised, their expectations of the ECB’s key policy rate in the future. In each press conference, the ECB repeatedly communicated that it would not raise its deposit facility rate before the end of its QE.\textsuperscript{64} If investors believed that the ECB could further extend its QE, they might have also believed the ECB would keep its policy rate low for a longer period of time. However, this channel predicts government bond yields to go down not up. Although an expectation of a lower policy rate in the future is likely to push down bond yields, this is not reflected in the data. Figures\textsuperscript{13,14} and \textsuperscript{15} show that euro OIS rates did not move significantly on November 23, 2016.

Third, many market participants did not interpret the news of a change in collateral policy as a signal that the ECB would change its broader monetary policy. For example, when interviewed by the Financial Times on November 23, 2016, Frederik Ducroze at Pitchet said, “This would be a technical adjustment to deal with scarcity issues [of bonds] and market tensions [but] nothing to do with the broader policy stance.”\textsuperscript{65}

\textsuperscript{64}See the second paragraph of the introductory statement to the ECB’s press conference on October 20, 2016.
\textsuperscript{65}See the Financial Times article on November 23, 2016 titled “Eurozone Bond Yields Jump on ECB Repo
Figure 13 Change in 1-Year Overnight Index Swap (OIS) rate on November 23, 2016

Notes: Data come from Bloomberg.
Figure 14 Change in 18-Month Overnight Index Swap (OIS) rate on November 23, 2016

Notes: Data come from Bloomberg.
Figure 15 Change in 2-Year Overnight Index Swap (OIS) rate on November 23, 2016

Notes: Data come from Bloomberg.
Figure 16 The Turnover Rate in the Repo Market and Age of the Bond

Notes: The sample consists of euro-denominated sovereign bonds issued in Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal, and Spain. The sample covers the period between March 1, 2013, and March 31, 2019. Data come from BrokerTec and Thomson Reuters Eikon. For each bond on a given day, I compute the turnover rate as the ratio of the trade volume on BrokerTec to the initial amount issued. Then, I compute the average value of the turnover rates across all bonds belonging to the same age bucket.
Notes: For each duration bucket, I compute the average changes in sovereign bond yields and corporate bond yields within 60 minutes of the Reuters article release. The transmission ratio is the ratio of the change in corporate bond yields to that in sovereign bond yields. Data come from Bloomberg.
Figure 18 Repo Specialness of German Bunds by Duration

Notes: I compute the average repo specialness premia of German Bunds by duration buckets. The sample period is the month of November 2016. Data come from BrokerTec.
Online Appendix for "The Bond-Lending Channel of Quantitative Easing"
9.13 Robustness Results for Section 5.4: Specification A

Please see the full version posted on my website https://heesuroh.com/.
9.14 Robustness Results for Section 5.4: Specification B

Please see the full version posted on my website https://heesuroh.com/.

9.15 Substitutability of Bonds Across the Yield Curve

D’Amico and King (2013) study the price impact of the purchases of Treasury securities by the Fed during the Large Scale Asset Purchases (LSAP) programs. I reproduce their empirical specifications below. $R_n$ is the holdings period return of security $n$ from March 18, 2009, to October 30, 2009. $q_{n,0}$ is the quantity of security $n$ purchased by the Fed, normalized by the outstanding amount of security $n$ and its near substitutes. Near-substitute bonds are bonds with maturities within 2 years of that of security $n$. $q_{n,1}$ is the normalized purchase quantity for the near-substitute bonds of security $n$. $\tau_n$ is the maturity of security $n$. Table 7 of D’Amico and King (2013) reports the 2SLS estimation results of this model. For Treasury bonds, they estimate $\gamma_0$ to be 0.68 and $\gamma_1$ to be 0.09.

$$R_n = \gamma_0 q_{n,0} + \gamma_1 q_{n,1} + \phi_0 + \phi_1 \tau_n + \phi_2 \tau_n^2 + \epsilon_n$$

(108)

Suppose that I can model the relative substitutability of Treasury bonds across the yield curve with my exponential kernel. Also, assume that, on average, the maturities of near-substitute bonds differ from the maturity of security $n$ by exactly one year. Then I can model the coefficients $\gamma_0$ and $\gamma_1$ as shown below. When the Fed purchases security $n$, the price impact for the near-substitutes of security $n$ is smaller than that for security $n$ by a factor of $\exp(-\phi)$

$$\gamma_1 = \gamma_0 \cdot \exp(-\phi \cdot 1)$$

(109)

By substituting $\gamma_0 = 0.68$ and $\gamma_1 = 0.09$ into Equation (109), I back out $\phi = 2.02$. 

102
References


Thibaut Piquard and Dilyara Salakhova. Substitution between secured and unsecured interbank markets, counterparty risk and the opportunity cost of collateral, 2018.


Yves Mersch. Legal aspects of the ECB ’ s response to the coronavirus ( COVID-19 ) pandemic – an exclusive but narrow competence. In Keynote speech by Yves Mersch, Member of the Executive Board of the ECB and Vice-Chair of the Supervisory Board of the ECB, at the ESCB Legal Conference, pages 1–6, Frankfurt am Main, 2020. European Central Bank.


Andy Hill. A post-mortem of the European repo market break-down over the 2016 year-end, 2017a. ISSN 0025-5769.


Andy Hill. The European Credit Repo Market, 2017b.

ICMA. Perspectives from the eye of the storm The current state and future evolution of the European repo, 2015.


Lynn Patterson. Fine-tuning the framework for the Bank’s market operations, 2015.

Giuseppe Maraffino. PSPP securities lending to mitigate repo squeeze, 2015a.


Giuseppe Maraffino. PSPP securities lending to mitigate repo squeeze, 2015b.


Francesco Canepa. Ecb to lend out bonds for cash to avoid market squeeze. Reuters, 12 2016.


Zoso Davies and Andreas Hetland. Low yields shape demand, 2017.

110


