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The Eurosystem's asset purchase programmes, securities lending and Bund specialness

Markus Baltzer
Kathi Schlepper
Christian Speck

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

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Non-technical summary

Research question

Since 2015, the Eurosystem has been purchasing government bonds within the framework of the public sector purchase programme (PSPP). The aim was to raise the low inflation rate at the time by easing financing conditions for enterprises and households. On aggregate, the Eurosystem purchased just under one-quarter of the outstanding German Federal securities (Bunds) as part of its monetary policy asset purchase programmes up to 2019. The lower free float led market participants to fear that market functioning might become impaired. Since that would ultimately also damage monetary policy transmission, the Eurosystem lends Bunds from its monetary policy portfolio via repurchase agreements (repos) in an effort to mitigate spells of market tension in certain Bunds or at times of particular market stress. This paper explores the influence of both Eurosystem asset purchases and securities lending on the repo market for German Bunds.

Contribution

We expand the existing body of literature on the price effect of asset purchase programmes in the repo market by adding a new "eligibility effect". This means that Federal securities that are eligible in principle but not purchased trade at a premium to those that are excluded in principle from the purchase programme because their remaining term to maturity or yield is too small, for example. Furthermore, this is among the first papers to quantify flow effects of securities lending based on individual lending operations in the euro area. The particular design of securities lending at the Bundesbank, with a fixed term, enables us to determine exogenous shocks on the free float.

Results

Our results show that the eligibility effect is stronger than the classic flow effect of actual purchases that has attracted the most attention in the existing body of literature. We also find that controlling for the eligibility effect reduces the classic flow effect. The eligibility effect was found to be particularly high in 2016-17, when a high purchase volume was implemented and the eligible asset universe was significantly constrained by a minimum yield requirement to long-term Bunds. Such a constraint of the eligible asset universe combined with a high purchase volume leads to an unintended tension in eligible market segments. The economically largest and statistically most significant effect among the securities lending variables concerns the return of securities lent out against cash collateral. Thus, the end of a securities lending operation of Bundesbank unwinds a temporary increase in the bond supply and increases the specialness of that particular

Bund. However, the economical low flow effects of securities lending are small. This becomes apparent when compared with the stock effects of asset purchases, the regulatory effects of window dressing around reporting dates, or hedging in the Futures market.

Nichttechnische Zusammenfassung

Fragestellung

Das Eurosystem kauft seit 2015 Staatsanleihen im Rahmen des public sector purchase programme (PSPP). Dieses sollte über lockere Finanzierungsbedingungen für Unternehmen und Haushalte die damals niedrige Inflation anheben. Insgesamt kaufte das Eurosystem im Rahmen seiner geldpolitischen Anleihekaufprogramme bis 2019 knapp ein Viertel der ausstehenden Bundeswertpapiere. Durch den gesunkenen Streubesitz befürchteten Marktteilnehmer, die Marktfunktionalität könne eingeschränkt werden. Da eine solche Entwicklung letztlich auch die geldpolitische Transmission beeinträchtigen würde, verleiht das Eurosystem Bundeswertpapiere aus seinem geldpolitischen Portfolio über Rückkaufsvereinbarungen, kurz Repos. Dadurch sollen temporäre Marktverspannungen in einzelnen Bundeswertpapieren oder zu Zeiten besonderen Marktstresses abgemildert werden. Dieses Papier untersucht den Einfluss sowohl der Anleihekäufe als auch der Wertpapierleihe des Eurosystems auf den Repomarkt für Bundeswertpapiere.

Beitrag

Wir erweitern die bestehende Literatur zum Preiseffekt von Anleihekaufprogrammen im Repomarkt um einen neuen Ankaufbarkeitseffekt. Dieser bedeutet, dass prinzipiell ankaufbare, aber nicht gekaufte Bundeswertpapiere teurer handeln als solche, die vom Ankaufprogramm ausgeschlossen sind, zum Beispiel, weil deren Restlaufzeit oder Rendite zu gering ist. Zudem ist unsere Studie unter den ersten, die Flusseffekte der Wertpapierleihe auf Grundlage einzelner Leiheoperationen im Euroraum quantifizieren. Die besondere Ausgestaltung der Wertpapierleihe in der Bundesbank mit fixer Laufzeit bietet hierbei die Möglichkeit, exogene Schocks auf den Streubesitz zu bestimmen.

Ergebnisse

Unsere Ergebnisse zeigen, dass der Ankaufbarkeitseffekt stärker ist als der klassische Flusseffekt tatsächlicher Käufe, der im Zentrum des Interesses der bestehenden Literatur steht. Zudem reduziert sich der klassische Flusseffekt, wenn für den Ankaufbarkeitseffekt kontrolliert wird. Ein besonders hoher Ankaufbarkeitseffekt ist in den Jahren 2016/2017 zu beobachten, als zum einen ein hohes Kaufvolumen realisiert wurde und zum anderen das ankaufbare Anleiheuniversum durch eine Mindestrenditevorgabe deutlich eingeschränkt war auf langlaufende Bundeswertpapiere. Durch solch eine Einschränkung der Ankaufbarkeit während hoher Ankaufvolumina kommen ungewollte Verspannungen in

ankaufbaren Marktsegmenten zum Ausdruck. Bei den Leiheoperationen tritt der ökonomisch größte und statistisch signifikanteste Effekt bei der Rendite von Anleihen auf, die gegen Cash-Sicherheiten (cash collateral) verliehen werden. Wird mit Ende des Wertpapierleihegeschäfts der Bundesbank eine temporäre Angebotsausweitung einer Anleihe wieder zurückgeführt, so erhöht sich deren Knappheitsprämie wieder. Allerdings sind die Flusseffekte bei der Wertpapierleihe ökonomisch vergleichsweise gering. Dies zeigt sich insbesondere, wenn sie mit den Bestandseffekten der Wertpapierkäufe sowie den regulatorischen Effekten zu Bilanzstichtagen oder dem Hedging am Futuremarkt verglichen werden.

DEUTSCHE BUNDESBANK DISCUSSION PAPER NO 39/2022

The Eurosystem's Asset Purchase Programmes, Securities Lending and Bund Specialness[1]

Markus Baltzer
Deutsche Bundesbank

Kathi Schlepper
Deutsche Bundesbank

Christian Speck
Deutsche Bundesbank

Abstract

The Eurosystem's asset purchase programmes reduced the free float of German Bunds. Market participants feared impaired market functioning in the Bund market and monetary policymakers unintended consequences for monetary policy transmission. We study the intended and unintended consequences of asset purchases in the repo market with Bund collateral. Bunds that are eligible for APP purchases carry a repo specialness premium even when they are not purchased. This "eligibility premium" is larger than the actual flow effect of purchases identified in previous research. Securities lending (SecL) operations have a flow effect, but its magnitude is even smaller than the flow effect of APP purchases. Therefore, the impact of SecL in the repo market is only of a quite limited extent. Furthermore, the effects of APP and SecL on repo specialness are relatively small compared to those caused by banks' balance sheets window dressing at quarter ends and by the hedging pressure for Bund Futures.

Keywords: Repos, Quantitative Easing, Securities Lending, Eurosystem, PSPP

JEL-Classification: E43, E58, G12, G28

[1] Contact addresses: Markus Baltzer, markus.baltzer@bundesbank.de, Kathi Schlepper, kathi.schlepper@bundesbank.de, Christian Speck, christian.speck@bundesbank.de. We are grateful for valuable comments to Benoît Nguyen (referee), Ulrich Grosch, Stephan Jank, Joachim Keller, Emanuel Mönch and Martin Wieland as well as seminar participants at Deutsche Bundesbank and European Central Bank. René Enzmann, Holger Spies and Bernd Wiesemann provided insights into the policy implementation. The views expressed in this paper are those of the authors and do not necessarily coincide with the views of the Deutsche Bundesbank or the Eurosystem.

1 Introduction

> *"One key principle underlying the implementation of the PSPP is the minimisation of unintended consequences. ... In other words, we may face a scarcity of bonds, but we won't face a shortage." Cœuré (2015)*

In this paper, we investigate asset scarcity and asset shortage in the market for repurchase agreements for Bunds[2] with a focus on the role of purchases under the Eurosystem's public sector purchase programme (PSPP) from 2015 to 2019 and the Eurosystem's securities lending (SecL) facility as a mitigation tool.

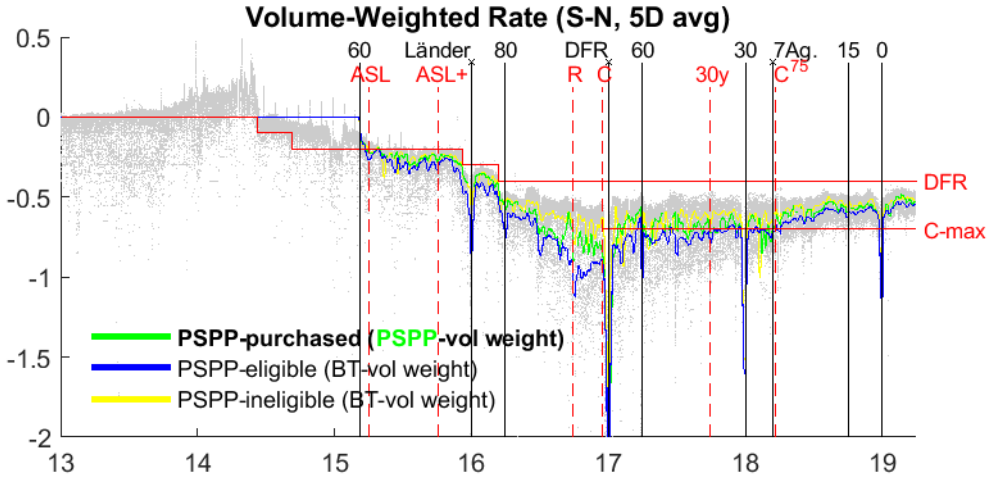
Asset purchases of the Eurosystem reduce the free float of Bunds, i.e. the quantity of outstanding bonds held by price-sensitive investors, which can generate asset scarcity and shortage effects. A price increase and yield decline due to scarcity is an intended effect of the PSPP in order to support monetary policy transmission.[3] However, large-scale asset purchases may have unintended side effects, for example if shortage leads to fails in Future contracts. The Bund market is considered to be most affected by the negative side effects of Eurosystem's asset purchases. Bunds are generally accepted by market participants as a risk-free (AAA-rated) benchmark for the *entire* euro area and play a key role for fixed income derivatives denominated in Euros. Since PSPP purchases are determined by a country's ECB capital key, PSPP purchases of Bunds are large relative to their amount outstanding.[4] Against this background, market participants were concerned about asset shortages and reduced market liquidity in the Bund market. The Eurosystem established a SecL facility which makes bonds in the PSPP portfolio temporarily available via repurchase agreements (repos). To support market liquidity without unduly curtailing normal repo market activity, the Eurosystem adheres to a pricing framework serving as an effective backstop.

The repo market lends itself well to studying the effect of asset scarcity and shortage because a repo is both a collateralised loan and a repurchase agreement for a specific asset. Repos markets are crucial to build short positions on the cash market and for the functioning of interest rate swap and bond Futures markets.[5] Our paper covers security-

[2] Our definition of "Bund" comprises all German Federal securities, not only the 10 and 30 year Bunds issued by the Federal government but as well Bobl, Schatz and Bubill. Likewise we will call all bond Futures from EUREX "Bund Future" irrespective of whether it is a Bund-, Schatz-, Bobl- or Buxl-Future.
[3] „(T)here are good reasons to expect that scarcity will materialise first and foremost in those market segments with a higher duration, potentially helping to maximise the economic impact of our operations." Cœuré (2015). See Rho (2019) for a quantification of the effect.
[4] Germany's negative net issuance between 2015 and 2019 reduced the amount of outstanding Bunds.
[5] Duffie (1996) describes in detail the transactions involved in building up short positions using the repo market. Fritsche et al. (2020) derive a relation between repo market functioning and the swap spread.

driven specific collateral repos (SC). Those contracts are entered in order to receive a specific security. SC repos are quoted as implicit interest rates of the collateralised loan. If a specific collateral is in high demand or short supply it is called "special", because investors are willing to accept particularly low interest rates on the lent money to get their hands on the specific bond. In Figure 1, this specialness is represented by the low SC repo rates (grey dots) relative to the Deposit Facility Rate (DFR) which represents the interest rate for a safe overnight deposit at the Eurosystem. We observe increasing average specialness and a larger dispersion of SC repo rates from 2014 to end-2016. In 2017 and 2018, the average specialness and dispersion gradually declined.[6] In our empirical analysis, we relate the changes in repo specialness of Bunds to changes in the Eurosystem's APP (black-solid vertical lines in Figure 1) and in the Eurosystem's securities lending (SecL, red-dashed vertical lines). Details of both programmes are provided below.

Figure 1: Repo Rates for Bund Collateral



Each grey dot represents a SC repo with a specific German bond as collateral. DFR is the Eurosystem's deposit facility rate. C-max is the maximum repo rate for which the Eurosystem accepts cash as collateral in SecL. Vertical lines refer to changes in PSPP parameters (black) and SecL parameters (red dashed) described in section 0 and section 3. Data censored at -2% and 0.5% to improve visibility. Source: Bundesbank and BrokerTec (BT).

The drivers of repo specialness can be structured along the theoretical work of Duffie (1996): specialness changes when supply shocks such as APP purchases and SecL operations affect the available amount of an asset in the market. Regulatory and institutional factors are alternative supply factors in the repo market. Liquidity and the existence of Futures markets may affect the demand for a specific bond on the repo markt and its specialness.

[6] Bundesbank (2022) provides an overview for the repo market with Bund collateral.

This paper contributes to the empirical literature on repo specialness in three dimensions: First, we identify a new "eligibility effect" of PSPP-purchases in the repo market. Second, we are among the first to investigate the flow effect of SecL in the euro area. Third, we show that hedging demand for Bund Futures and regulatory window dressing effects at year-end have a stronger impact on the repo market than the flow effect of unconventional monetary policy.

Our first contribution is a distinction between actual purchases of a bond – the classic flow effect – and bond's eligibility for PSPP purchases. We show that being eligible for purchases has an effect on a bond's specialness even if it is not purchased. In Figure 1, the elevated dispersion of repo rates in 2015 and 2016 is explained by the fact that many Bunds were not eligible for purchases. The relatively small share of Bunds eligible for PSPP purchases in 2015 and 2016 exhibits a high degree of specialness. The deviation from market neutrality in PSPP purchases of Bunds due to the purchase restrictions created frictions in the repo market. Controlling for a bond's PSPP eligibility reduces the flow effect of an actual purchase.

Our second contribution is to use the full granularity of Bundesbank's SecL operations in Bunds and investigate their impact on repo specialness. Since Bundesbank is offering fixed-term repos rather than open repos, the supply shock is exogenous when the collateral is returned to Bundesbank: The asset has to be returned independently of market conditions on the term leg. This technique circumvents two endogeneity problems inherent in other shocks to the bond supply. First, PSPP purchases are concentrated in rather cheap bonds to avoid further market stress and understate the flow effect.[7] Second, SecL by the Eurosystem is designed to address asset shortages and, therefore, specifies a maximum repo rate ("C-max" in Figure 1) and SecL volume is endogenuously concentrated in securities with very low repo rates. Using our exogenous shocks, we do find flow effects of SecL but their magnitude is smaller than for PSPP purchases of the same volume.

Our third contribution is to compare the asset supply shocks from PSPP purchases and SecL to alternative drivers of repo specialness. Most importantly, we introduce a new measure of Futures hedging demand. We proxy the need for Futures hedging using the trading volume in Bund Futures contracts. An increase of the Futures trading volume has a larger impact on repo rates than the supply shocks that originate from unconventional monetary policy. Similar conclusions can be drawn for the year-end effect caused by banking regulation.

[7] See De Santis and Holm-Hadulla (2017) and Arrata et al. (2020).

There exists a limited strand of empirical literature that shows how PSPP affects market functioning.[8] It mainly supports the hypothesis that central bank's asset purchases lead to scarcity effects. Arrata et al. (2020) show the PSPP is depressing repo rates, in particular prior to January 2017. They identify two possible channels: first, by increasing the scarcity of the bonds purchased, and second, by increasing the amount of excess liquidity. Jank and Moench (2018) find evidence that the scarcity effect is larger for bonds where large amounts are held by strategic (inelastic) investors like insurance companies and pension and mutual funds. Brand et al. (2019) provide evidence for three main channels which systematically affected repo specialness premia and which exhibit substantial country-specific differences. These are – according to the authors – bank funding stress, fragmentation in the sovereign bond market, and safe asset scarcity. Jank, Moench and Schneider (2021) show the increasing scarcity caused by the PSPP leads to a faster circulation of the expensive bonds between banks. We confirm the role of purchases from the literature but show their effect is smaller when the eligibility effect is taken into account.

The existing literature on the effect of SecL in the euro area concentrates on changes in the repo market resulting from the introduction of cash collateral as per the ECB Governing Council decision in December 2016 (red "C" in Figure 1) without using SecL transaction data.[9] The findings by Jank and Mönch (2018) and Arrata et al. (2020) indicate that SecL has helped alleviate scarcity. However, the same ECB Governing Council meeting widened the eligible set of securities (black "DFR"), implemented only a few business days after the introduction of SecL against cash collateral. We show that distinguishing between the introduction of cash collateral ("C") and the widening of the eligible Bund set ("DFR") using existing methods is not possible. To the best of our knowledge, the only paper that uses SecL transactions to study mitigation effect of alleviate increased repo specialness in the euro area is Carrera de Souza and Hudepohl (2022). They focus on a shorter time period (2020-2021) in major Euro area bond markets and find that SecL operations reduce repo specialness. In contrast, we exploit the whole granularity of PSPP and the SecL data of Bundesbank for the German Bund market. Also, our supply shocks are the return of the SecL volumes to Bundesbank instead of the SecL

[8] Besides the PSPP, the effect of ECB's SMP on repo markets is studied by Corradin and Madalloni (2017). D'Amico et al. (2018) investigate the impact of the Fed's QE on the US repo market.

[9] From an international perspective, Fleming et al. (2010) study the effectiveness of the Term Securities Lending Facility (TSFL) of the Fed in 2008. They find that the TSFL has precipitated a significant narrowing of repo spreads between US Treasury collateral and less liquid collateral. For Japan, Han and Seneviratne (2018) analze the impact of QE and the SecL facility on asset scarcity, also using actual SecL data. They find the Bank of Japan's SecL reduced the adverse impact of the BoJ's purchases on bond market liquidity.

volumes themselves to circumvent the above mentioned endogeneity problem of SecL that is caused by the minimum pricing rule of SecL.

The important role of Futures hedging demand for repo specialness is reflected in the exsting literature. Carrera de Souza and Hudepohl (2022) or Brand et al. (2019) identify the average specialness premium for the cheapest-to-deliver bond.[10] We identify a time-varying indicator for Future hedging demand. Another demand factor is the market liquidity of a bond. In fact, specialness in the repo market can be seen as a reflection of search frictions and difficulties in identifying lenders of securities. Hence, investors that trade assets purchased under a central bank's asset purchase programme may face higher search costs as shown by Ferdinandusse et al. (2020) or Kandrac (2018). If the free float in a specific bond is reduced, market dealers might lower their participation in the repo market due to the increase of borrowing costs of that bond. In general, traders who are looking for a specific security and have difficulties in finding it are accepting to pay a premium to temporarily acquire that security in the repo market (Duffie et al., 2002). We control for liquidity of the Bund cash market but find no significant effect.

Regulatory factors on the repo market are studied in Munyan (2017) and Garcia et al. (2021). Both show that European banks conduct window dressing around balance sheet reporting days that reduces the supply of repos and increases repo specialness. The low repo rates at year-end in Figure 1 reflect that supply effect. We do not quantify this time-varying effect but control for the calendar effects it in the econometric setting.

Our paper has several important policy implications. First, when designing a large-scale asset purchase programme like the PSPP, market neutrality of purchases over the whole maturity spectrum is crucial for market functioning. Targeting a broad set of eligible securities helps to reduce pressure and avoid shortages in specific eligible market segments. Second, the size of the purchase programme relative to the free float of the targeted assets and other implementation parameters are key to market functioning, thus confirming the observations for other markets (BIS Markets Committee, 2019). Third, there are important drivers of scarcity that are beyond the scope of the central bank like banks' window dressing and Futures hedging demand. Lastly, securities lending helps to alleviate market tension but should not be regarded as a magic bullet when adressing market frictions caused by asset purchase programmes, hedging demand or banking regulation.

[10] Arrata et al. (2020) show the flow effect of PSPP purchases is larger for the cheapest-to-deliver bond. Brand et al. (2019, Appendix A) link the specialness premium to the bonds' age and argue that the deliverability into the Future is the main driver of that effect.

The remainder of this paper is structured as follows. Chapter 2 summarises details of the PSPP programme and discusses the link between the PSPP and repo specialness. Chapter 3 describes the Bundesbank's securities lending facility and its impact on repo specialness. Chapter 4 concludes.

2 Bund purchases and repo specialness

> *"Accordingly, the preservation of market liquidity can be considered as a prerequisite for the proper working of the portfolio rebalancing channel … We will try to avoid, to the extent possible, purchasing specific securities such as current cheapest-to-deliver bonds underlying futures contracts, securities commanding "special" rates in the repo market as a sign of temporary scarcity, and other assets displaying significant liquidity shortages." Cœuré (2015)*

2.1 APP purchases and the effect on Bunds' free float

Our dataset starts in January 2013 well before the implementation of any asset purchases by the Eurosystem. The first purchases under the extended asset purchase programme (APP) took place on 9 March 2015 with net purchases of €60 billion per month. From April 2016 to March 2017, the monthly net purchases increased to €80 billion. From January to September 2018, a net volume of €30 billion per month was purchased. In the last quarter of 2018, monthly net purchases of €15 billion preceded the reinvestment phase that started in January 2019. Our sample ends in March 2019. The changes in net purchases are indicated as vertical black lines in Figure 1.

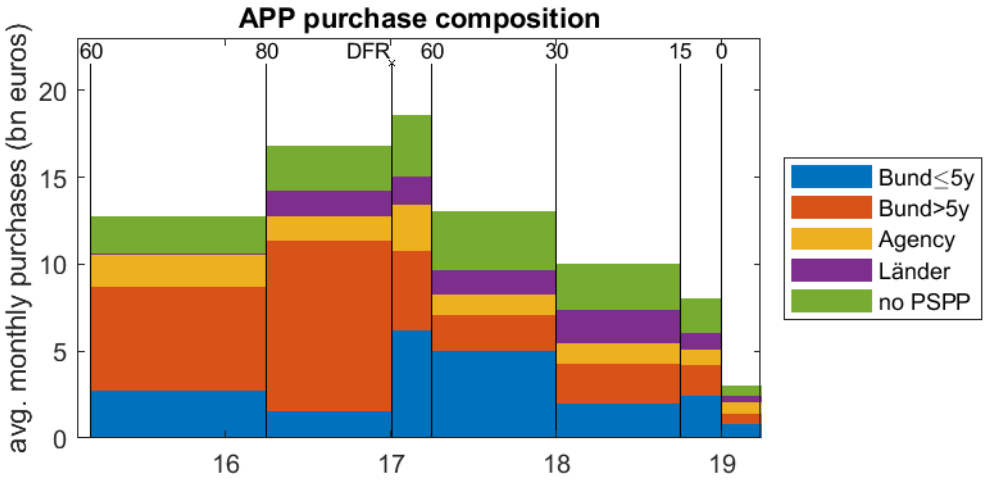
Each grey dot in Figure 1 represents a repo rate for a SC-Bund from BrokerTec, the leading repo trading platform for Bunds.[11] For basically every active Bund there is a BrokerTec quote which is why we observe a dense grey area in Figure 1.[12] The grey repo rates with specific collateral (SC) are below the rate for repos with unspecified general collateral (GC) of high credit quality [the GC rate is the upper border of the grey area]. The difference between the repo rate collateralised by a specific Bund and the rate of a GC repo is the *specialness* premium of that specific collateral. All German Bunds trade at a specialness premium in Figure 1. We observe increasing average specialness and a larger dispersion of SC repo rates from 2014 to end-2016. Low interest rates and low repo

[11] Schaffner et al. (2019), Figure 5.

[12] The data displayed are what is known as the spot-next contract (S-N) which means the collateral is delivered in two business days, similar to delivery in the spot market, and returned one business day later. We concentrate on S-N because no more than one out of three bonds is quoted in the overnight contract (O) with delivery today and return tomorrow. Overnight contracts are more likely to be quoted with very low rates, compared to S-N. Thus, the need to borrow a security at short notice today is related to a special premium.

rates are an intended consequence of expansionary monetary policy in general and of an asset purchase programme in particular. By the end of 2016, however, a consensus had emerged among market participants and monetary policymakers that the large dispersion and low level of special repo rates for Bunds was reflecting an unintended asset shortage rather than desired asset scarcity.[13] In 2017 and 2018, the average specialness and dispersion gradually declined. We relate the changes in repo specialness of Bunds to changes in the Eurosystem's APP (black-solid vertical lines in Figure 1) and in the Eurosystem's securities lending (SecL, red-dashed vertical lines).[14] Details of both programmes are provided below.

Figure 2: APP gross purchases



APP purchase volumes include purchases under the third Covered Bond Purchase Programme (CBPP3, since October 2014), the Asset-Backed Securities Purchase Programme (ABSPP, since November 2014) and the Corporate Sector Purchase Programme (CSPP, since June 2016).[15] Under the Public Sector Purchase Programme (PSPP), German agencies like Kreditanstalt für Wiederaufbau (KfW) and three other public banks have been eligible since the start of the APP in 2015. Since 2016, bonds issued by German Federal states (vertical black line "Länder" in Figure 1) have been eligible and in March 2018, seven additional German public banks became eligible for PSPP purchases (vertical black line "7 Ag." In Figure 1). Overall, German Federal

[13] This view was later corroborated by academic research conduceted by Pelizzon et al. (2020) during that period.

[14] Market contacts indicated the low repo rates led to market entries of strategig Bund investors in the Bund repo market. This is supposed to contribute to the decline in repo specialness but we do not have quantifiable information.

[15] A breakdown of net APP purchases for the Eurosystem as a whole can be found at: https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html#pspp

securities (Bunds) account only for a fraction of gross purchases by the Bundesbank (Figure 2).[16] At the beginning of the APP, about two-thirds of the purchased gross volume was realised by way of Bund purchases. As more securities became eligible, the absolute Bund purchase volume and as a share of PSPP gross purchases declined.

Until the end of 2016, Bund purchases were dominated by long-term bonds (Figure 2). During that time, bonds were only eligible for PSPP purchases if their yield was above the deposit facility rate (DFR) and their remaining term to maturity exceeded two years. The low level of German yields at that time considerably reduced the maturity spectrum of German bonds eligible for purchases before 2017. In mid-2016, only bonds with a residual maturity in excess of nearly eight years were eligible for purchases. This represented not more than one third of the total outstanding German bond volume. The two reductions in the DFR in late 2015 and early 2016 only temporarily expanded the eligible maturity spectrum. Due to the small eligible bond set, Bunds with a maturity beyond five years of around €10 billion were monthly purchased by the Eurosystem at the time when the aggregate net purchase volume totalled €80 billion per month. During that period Bund purchases by the Eurosystem exceeded gross issuance in that maturity spectrum.

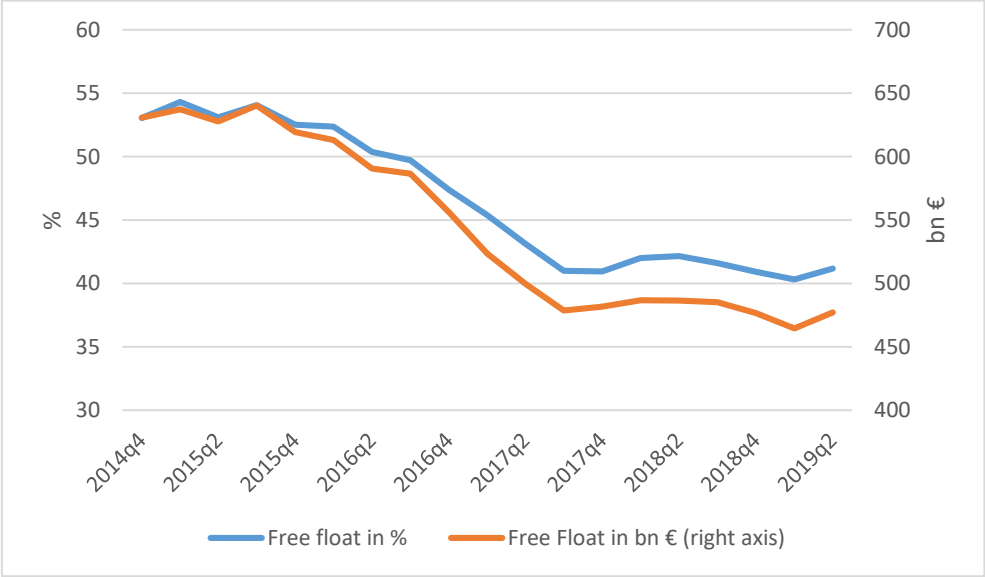
On 2 January 2017, the DFR constraint was abandoned and the minimum maturity reduced to one year (vertical black line "DFR" in Figure 1 and Figure 2). This widened the spectrum of eligible Bunds. Since then, all bonds have been eligible with the exception of Federal money market papers (Bubills) and seasoned bonds that were close to maturity. In early 2017, many purchases were made in short-term Bunds. Since 2018, long-term (maturity above five years) and short-term (maturity below five years) Bunds have been purchased on a similar scale. Also, the total amount of bond purchases declined alongside a reduction in Bund purchases as of 2018. Since then, Bund purchases have accounted for about half of the APP gross purchases (Figure 2).

By the end of the net APP-purchases in 2018, the Eurosystem was the largest holder of German Bunds according to the Eurosystem's Securities Holdings Statistics. Consequently, the free float share of Bunds steadily decreased over the term of the PSPP purchases. The free float is determined from the holdings of price-sensitive investors such as almost all private (financial and non-financial) investors like e.g. banks, mutual funds and private households. These investors contrast with what are known as strategic investors. Apart from central banks and the public sector in general, the insurance and pension funds sector are usually also counted among the strategic investors as their

[16] Gross purchases depicted in Figure 2 contain the net purchases (€60, €80, €60, €30, €15, €0 billion per month) and reinvestments of the principal payments from maturing bonds.

investment behaviour is mainly driven by regulatory guidelines. The decline in the Bund free float (Figure 3) does not simply mirror the increase in aggregate PSPP purchases. In 2015, the free float was quite stable due to large sales of Bunds by the non-euro area public sector (inter alia central banks), which is regarded as strategic investors. Only as from 2016, when private investors sold Bunds to the Eurosystem, did the free float begin to decline substantially.[17]

Figure 3: Free float of Bunds



Source: ESCB (SHSS-database), German Finance Agency, Bundesbank, own calculations. Quarter-end data, based on nominal values. Free float includes total holdings of the private sector without insurance sector and pension funds. We attribute the amount outstanding of which we do not know the holder sector as it is not captured by the SHSS-database equally to the strategic and to the free float investors.

In order to study the effects of the PSPP and the SecL facility on repo specialness, we use data from Brokertec which is the most important repo market platforms for Bunds. Repo activity in Bunds on BrokerTec is concentrated in specific collateral that is PSPP-eligible. Concentration of PSPP purchases on a narrow set of bonds in 2015-16 increased the specialness of those bonds: in Figure 1, for the S-N term, the repo rates for PSPP-eligible collateral (in blue) are the most expensive repos in the market. The gap between eligible (blue) and non-eligible (yellow) collateral was widest in late 2016, reflecting the concentration of the PSPP volume on a small set of bonds with a yield above the DFR. However, the dispersion across repo rates in the eligible set is quite large: There are eligible bonds – mostly seasoned bonds – with repo rates above the average ineligible rate and close to the upper boundary of the grey area. There is some dispersion in the ineligible

[17] See Bundesbank (2018) and Arrata and Nguyen (2017).

set as well, but ineligible bonds with an expensive repo rate in the lower part of the grey area are observed only infrequently.

The purchased bonds (green in Figure 1) have an average repo rate (volume-weighted by PSPP purchase volume) that usually lies between the eligible (blue) and ineligible (yellow) bond set. In other words, relatively scarce papers are bought at lower volumes compared to cheap bonds: This is consistent with the Bundesbank avoiding purchases of securities that are particularly scarce. This constellation illustrates the endogeneity problem for PSPP flows: Less expensive bonds are purchased in greater proportions such that the effect of PSPP-purchases may be underestimated. This argument is also used by Jank and Moench (2018) and Arrata et al. (2020) to justify their results. As endogeneity prevents discovery of a scarcity effect in the repo market, their estimates represent a lower bound.

There are infrequent specific repo trades with KfW bonds on BrokerTec and basically no trades for other agencies and Länder. By contrast, inflation-linked Bunds – the least liquid segment of Bunds – are continuously quoted as specific collateral on BrokerTec.[18] Agencies and Länder bonds seem to serve as general collateral, rather than specific collateral. Without repo rate data for agencies and Länder, we cannot consider these securities in the remainder of this paper. In the regression analysis below, we concentrate on Bunds. Therefore, we investigate the difference in specialness within the Bund market, but not the total specialness of Bunds.[19]

2.2 Repo specialness and the PSPP flow effect

Repo specialness is the difference between the repo rate for German general collateral rate for the S-N term and the special collateral rate for an individual bond from BrokerTec. High spread values indicate a high level of scarcity or shortage. We use the Tomorrow-Next (T-N) term for German GC since there are infrequent trades in the GC sector for the S-N term:

$$Spread_t^i = GC_{t+1}^{T-N} - RepoSC_t^i$$

With this measure of specialness, we investigate specialness relative to the cheapest way to receive an unspecified Bund by a GC repo. Hence, we estimate the effect of the PSPP on specialness within the Bund market using the following regression:

[18] According to market contacts, EUREX Repo might be a more important marketplace for Germans Länder and agencies than BrokerTec, which is the dominant platform for Bunds as specific collateral.
[19] Cross-country comparison is in Brand et al. (2019) and Arrata et al. (2020).

$$Spread_t^i = \sum_{h=0}^{H} \beta_{PSPP}^{h} \cdot PSPP_{t-h}^i + \beta_{Elig} \cdot Elig_t^i + \alpha_i + \alpha_t + \alpha_L \cdot Spread_{t-1}^i + \delta\, Controls_t^i + \varepsilon_t^i$$

This difference-in-difference setup allows us to analyse the impact of the PSPP on bonds that are purchased on day t relative to those that haven't been purchased on that day. The Bundesbank's PSPP purchase volume is measured relative to the bond's free float. Free float is defined as the sectoral holdings of the private sector without the insurance sector and pension funds as the latter are assumed to be long-term investors (Figure 3).[20] The data comes from the Eurosystem's Securities Holdings Statistics. Issuance data and the amount of own bonds held for credit authorisations are from Deutsche Finanzagentur GmbH.

$$PSPP_t^i = \frac{€Purch_t^i}{FreeFloat_{t-1}^i}$$

$PSPP_t^i$ captures the flow effects of the asset purchase programme. Purchases of a single bond range between €2.5 million and €400 million each trading day. The median is €25 million and quite stable over the different aggregate purchase volumes (Table 1). In terms of free float, the median purchase is 0.27 % of the free float. Since cumulative purchases reduce the free float over time, purchases of the same absolute size increase the flow effects ($PSPP_t^i$) more in later stages of the APP than in earlier stages. By including the free float in the flow effect, we introduce a stock aspect to the flow analysis.

A PSPP purchase is a negative local supply shock, i.e. it is supposed to increase scarcity in that asset and lead to lower repo rates and higher specialness compared to other non-purchased bonds. Purchase time *t* refers to the day the contract is made. Delivery of the bonds sold to the Bundesbank is two days later. In that way, the purchase day matches the timing of the spot-next repo specialness. By adding lags of purchase volumes, we can investigate whether the flow effect is most relevant when the purchase is made in *t*, as the reduction in the free float becomes certain, or later, when the asset actually leaves the books of PSPP sellers in *t+2*.

[20] We also exclude all public investors like central banks and governments.

Table 1: PSPP Bund purchases during overall PSPP purchases of ...

Panel A: € million per bond and trading day

	N	mean	sd	skewness	p5	p25	p50	p75	p95
… €15 bn	430	28.35	14.48	0.48	10.0	20.0	25.0	50.0	50.0
… €30 bn	1,297	28.86	13.74	0.70	10.0	20.0	25.0	50.0	50.0
… €60 bn	6,578	22.92	17.75	1.52	5.0	10.0	20.0	25.0	50.0
… €80 bn	4,103	26.01	22.01	4.46	10.0	10.0	25.0	25.0	50.0
Overall	12,408	24.75	18.94	3.02	5.0	10.0	25.0	25.0	50.0

Panel B: as a percentage of free float

	N	mean	sd	skewness	p5	p25	p50	p75	p95
… €15 bn	430	0.54	0.48	2.08	0.10	0.23	0.41	0.70	1.50
… €30 bn	1,297	0.47	0.37	2.84	0.12	0.25	0.39	0.56	1.24
… €60 bn	6,578	0.43	0.69	7.12	0.05	0.12	0.23	0.46	1.22
… €80 bn	4,103	0.40	0.49	5.79	0.08	0.18	0.26	0.43	1.12
Overall	12,408	0.43	0.59	7.04	0.07	0.15	0.27	0.47	1.21

Time-fixed effects α_t capture joint movements in scarcity such as calendar effects due to regulatory-induced window dressing at year-end (see Munyan (2017)). Bond-fixed effects α_i capture high specialness premia we usually observe for Bubills – German money market papers – and low specialness premia we usually observe for inflation-linked Bunds. The lag of the specialness in the regression is designed to capture persistence in the specialness. The bond-specific controls $Controls_t^i$ contain proxies for cash market liquidity, repo volume and futures hedging pressure. These results are covered in detail in section 2.3. Standard errors are clustered by bond and time.[21]

[21] In all our regression analysis, we use both bond and time period clustering. As we assume that the error terms will likely contain shocks common to many bonds (e.g. adjustments to monetary policy measures), in our view it is important to also cluster by time. Moreover, given that our dataset contains both a large number of bonds and time periods, we think that it is important to cluster by both dimensions. If we would cluster e.g. only by bond, we'd allow the error term to be correlated within each bond over time, but correlation across bonds within each time period would be ruled out. That could cause a bias in our standard errors (see Thompson, 2011, and Petersen, 2009). There are several related papers that we have cited in our work which use also both clustering dimensions (e.g. Corradin and Maddaloni, 2017, Rho, 2019, and Jank et al., 2021).

Table 2: Repo specialness and PSPP

Dependent variable: repo spread (basis points)

	Panel A			*Panel B*		*Panel C*		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
PSPP purchases	0.426***		0.295***	0.851***	0.841***	0.198	0.178	0.252**
(% of free float)	(0.000)		(0.006)	(0.001)	(0.001)	(0.422)	(0.466)	(0.017)
IA_80bn X PSPP purch						0.294	0.301	
						(0.374)	(0.364)	
IA_30bn X PSPP purch						-0.185	-0.188	
						(0.525)	(0.519)	
IA_15bn X PSPP purch						-0.405	-0.408	
						(0.417)	(0.413)	
D_PSPP elig		0.561***	0.512***			0.275**	0.277**	0.270**
		(0.000)	(0.000)			(0.018)	(0.017)	(0.017)
IA_80bn X PSPP elig						0.893***	0.893***	0.944***
						(0.004)	(0.004)	(0.002)
IA_30bn X PSPP elig						0.0809	0.0793	0.0768
						(0.644)	(0.650)	(0.655)
IA_15bn X PSPP elig						-0.124	-0.126	-0.146
						(0.544)	(0.539)	(0.467)
IA_D_SLcash X PSPP purch				-0.556*		0.00602		
				(0.054)		(0.984)		
IA_D_DFR X PSPP purch					-0.543*		0.0286	
					(0.059)		(0.922)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bond fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	104,355	104,355	104,355	104,355	104,355	104,355	104,355	104,355
Adjusted R-squared	0.876	0.876	0.876	0.876	0.876	0.876	0.876	0.876

p-values in parentheses
* p<0.10 ** p<0.05 *** p<0.01

*Table 2 reports the results of a panel regression of repo specialness on various explanatory variables related to PSPP purhases. PSPP purchases capture the purchase amounts relative to the free float (in %). IA_...bn X PSPP purch are interaction terms of a dummy variable which is one in the period when the aggregated PSPP volume was 80, 30 and 15 (60 billion is the benchmark case) and the PSPP purchase volume. D_PSPP elig is a dummy variable that takes the value of 1, when a bond is eligible for purchases under the PSPP on day t and 0 otherwise. IA_...bn X PSPP elig are the same interaction terms like above using PSPP eligibility instead of actual purchases. IA_D_SL cash X PSPP purch is an interaction term of a dummy variable accounting for the introduction of cash collateral in SecL and PSPP purchases and IA_D_DFR X PSPP purch accounts for the time when the DFR got abandoned as maturity restriction. We control for different bond-and time-specific variables and include time- and bond- fixed effects. Standard errors clustered by bond and time are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.*

Table 2 contains the results of the regressions of repo specialness on PSPP purchases without lagged purchases (H=0). Panel A addresses the interaction of purchases and PSPP-eligibility. Model (1) replicates a key result from the literature, which is that PSPP purchases increase specialness significantly. For each percent of free float purchased,

specialness increases by 0.43 bp. A median purchase of 0.3 PP of free float (see Table 1) leads to a flow effect of about 0.12 bp. During the late phase of the PSPP – with monthly net purchases of €15 billion – the purchases reduce free float by more than 0.7 PP in 25 % of the cases (see Table 1, Panel B), which implies an increase in specialness of 0.3 bps. This magnitude is broadly in line with the existing studies: Arrata et al. (2020) estimate a flow effect of 0.78 bps for purchasing 1 % of the amount outstanding. Given that the free float of Bunds is between 30 % and 40 % of the amount outstanding, their effect is smaller than ours. However, they consider not only Bunds but also French, Italian and Spanish government bonds in their analysis, which are less stressed. Jank and Mönch (2018) estimate for Bunds a stronger impact of 2 bps for a purchase of 1 PP of the amount outstanding, but their study ends in 2017, before market conditions eased. For Bunds, Brand et al. (2019) find an increase in specialness of between 0.3 bp and 0.4 bp for a 1 PP increase in PSPP-holdings relative to the amount outstanding. For the US Treasury market, D'Amico et al. (2018) document a rather small effect of 0.2 bp for a purchase of 1 PP of the amount outstanding. However, average specialness is lower in the US market compared to the Bund market.

Turning to model (2) of Table 2, a bond that is eligible for PSPP-purchases – but not necessarily purchased – has a specialness premium that is 0.5 bp higher than for bonds that are ineligible for PSPP purchases. The flow effect of actual PSPP purchases when we control for eligibility in model (3) is 30% lower compared to the effect without controlling for eligibility in model (1). For a median purchase of 0.3 PP of free float, the effect is less than 0.1 bp. However, the positive sign illustrates that the potential effects of endogeneity of PSPP purchases – buying cheap assets and avoiding specials – are dominated by flow effects. Otherwise the coefficient for purchases in the presence of eligibility would be negative. The impact of eligibility in model (3) is robust to the inclusion of PSPP-purchases. Thus, the mere fact of being eligible is more important for repo specialness than the actual flow effect from an average purchase.[22]

Panel B addresses the impact of SecL against cash on repo scarcity. Jank and Mönch (2018) and Arrata et al. (2020) use the introduction of cash collateral as a game changer for the repo market (red "C" in Figure 1). Model (4) confirms their results: Bunds that are available for bilateral SecL against cash collateral have a smaller flow effect when they are purchased.[23] PSPP purchases of bonds that are not available for bilateral SecL against

[22] In contrast, Schlepper et al (2020) find no significant impact of eligibility on the cash price change .

[23] Each PSPP-purchase is interacted with a dummy that indicates whether a bond is available for bilateral securities lending against cash from Bundesbank. Before cash collateral was introduced in Dec 16, 2016, the dummy is zero. 30y Bunds were not eligible for SecL before Sep 2017. After these dates, all bonds in Bundesbank's portfolio are available for securities lending and the dummy is equal to one after its first purchase by Bundesbank.

cash see specialness increase by 0.9 bp for each percentage point of free float (when eligibility is not included), while this impact decreases to 0.9-0.6=0.3 bp for bonds that are eligible for SecL. The difference between both effects is significant at the 10% level.

However, cash collateral was introduced at the same ECB Governing Council meeting in December 2016 that abandoned the minimum yield requirement for PSPP purchases ("DFR" in Figure 1).[24] The decision to abandon the minimum yield requirement increased the eligible set of bonds and more previously ineligible short-term bonds were purchased (see Figure 2). Investigating the impact of PSPP purchases on scarcity in Table 2 model (5) before and after the DFR requirement is abandoned yields similar results to the introduction of cash collateral in SecL in model (4). Thus, it is not clear whether the smaller reaction of scarcity to PSPP purchases as of 2017 is due to the changes in PSPP eligibility or to the introduction of SecL against cash.

Table 2 Panel C extends the analysis to include changes in aggregate PSPP-volumes ("60, 80, 60, 30, 15"). The benchmark is provided by PSPP periods in which €60 billion on aggregate was purchased per month (net)- i.e. the coefficient "PSPP purchases" indicates the effect on specialness of purchasing 1 PP of free float at times of aggregate net purchases of €60 billion per month. The interaction coefficients "IA_...bn X PSPP purch" describe the difference in the flow effect during periods of aggregate net APP purchases of €80, €30 or €15 billion. Similar interactions are constructed for the PSPP eligibility. Model (6) in Table 2 shows that changes in the scarcity premium are dominated by eligibility ("D_PSPP elig") but not by changes in actual purchases ("PSPP purchases"). Between April 2016 and March 2017, when €80 billion was bought per month by the whole Eurosystem, the scarcity premia for being eligible was about four times as large as during the reference period with monthly purchases of €60 billion. Unlike to eligibility, there is no time variation in the flow effect "IA_...bn X PSPP purch" and the flow effect of the benchmark "PSPP purchases" turns insignificant. Neither introducing cash collateral nor abandoning the DFR have a significant impact if the other interaction terms are included: changes made at year-end 2016 have a minor impact compared to the changes in the aggregate PSPP purchase volume. Thus, the most relevant period PSPP-eligibility was between April 2016 and March 2017 when the large aggregate purchase volume was elevated at 80 bn and, in 2016, concentrated to few eligible long-term Bunds with a yield above the DFR (see Figure 2). The effect of eligibility therefore may represent unintended side effects of the PSPP. With these results in mind, we use model (8) as our benchmark in the remainder. As interaction terms, it only considers the

[24] From a technical perspective, the similar results should not come as a surprise: Two dummies used for the interaction only differ by a few days at the end of 2016 (DFR in place) and for longer-term bonds ineligible for bilateral SecL against cash between Jan 2017 and Sep 2017.

interaction terms for eligibility but omits interactions of PSPP purchases, the introduction of cash collateral and the abandonment of the DFR.

Figure 4: Persistent effect of PSPP purchases

**,x,+ indicate significance at the 1%, 5% and 10% level. The numbers (1), (3) and (8) refer to the eligibility specification in Table 2.*

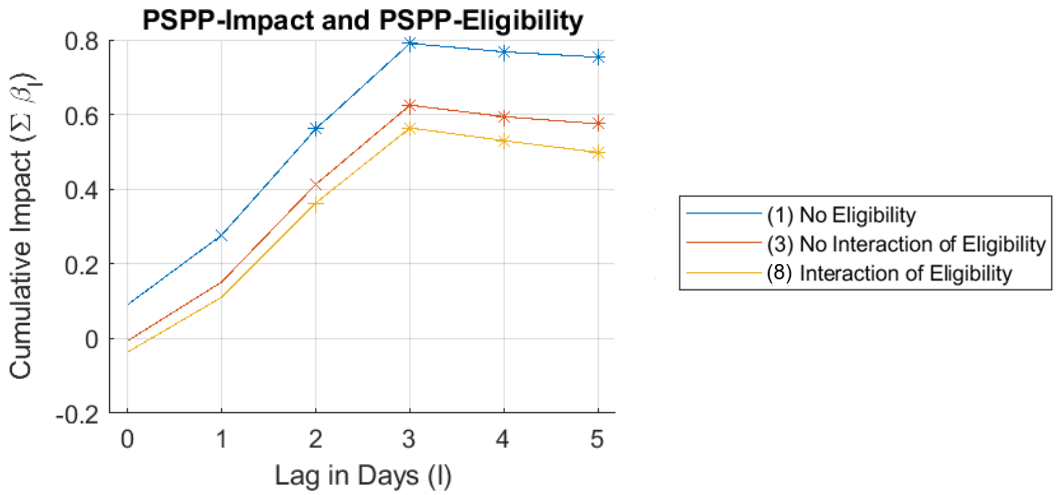


Figure 4 turns to the persistent effect of PSPP-purchases. The models displayed differ in terms of the inclusion of eligibility, and the legend displays the eligibility constellation column from the model in Table 2 (which contains no lags). More specifically, we select regression model (1) which only includes the PSPP purchase effect, model (3) that also accounts for the eligibility dummy and model (8) which includes the interaction terms with eligibility and the purchase volume changes in addition. The three models are augmented by adding five lags of the variables of interest -that is, PSPP purchases relative to free float. Using different lags of the purchase variables in a single regression also controls for the fact that a bond might be purchased multiple times on consecutive days. Compared to the investigation without lags in Table 2, the cumulative effect is twice as large. Independently of the eligibility constellation, the maximum effect is attained after three days. Afterwards, the effect is flat which provides evidence for a permanent purchase effect and against a temporary shortage of assets that is reversed after some days. The purchase effect is significant after one to two days. The flow effect of purchases relates more to actual delivery after two days but not to the day (t=0) when the purchase contract is made. Comparing the three specifications of eligibility confirms our findings from Table 2: the "purchase" effect is strongest for a model that ignores eligibility and is lower for models that take eligibility into account.

On average, the free float of Bunds is about 15 PP lower than prior to the APP (see Figure 3). With a persistent increase in specialness of 0.6 bp per percentage of free float, the total flow effect on repo specialness is approximately 9 bps. This is broadly in line with the

total effect in Brand et al. (2019) for the repo market or the total effect on the cash market in Schlepper et al. (2020). However, the flow effect is lower than the stock (announcement) effects identified in the literature.[25]

2.3 Hedging demand, liquidity and regulatory drivers of specialness

Our analysis includes control variables that might also have an impact on repo specialness in addition to a supply shock from the PSPP. Table 3 shows summary statistics for the repo spread as our independent variable, which we also include as a lagged variable to control for autocorrelation. We further control for the repo volume and for liquidity (bid-ask spread).

Table 3: Summary statistics of control variables

	N	mean	sd	skewness	p5	p25	p50	p75	p95
repo spread *(basis points)*	104,355	8.5	13.8	7.1	-1.5	1.3	4.7	11.4	31.1
repo volume *(€ million)*	104,355	842	775	2	103	321	588	1,102	2,455
bid-ask spread *(basis points)*	104,355	6.1	7.6	3.0	1.0	1.5	3.0	8.0	21.5

In addition to these standard control variables, we also include variables displaying the futures markets, which play an important role for Bunds. A future generates short positions, and the related hedging needs are one of the drivers of repo rates in the theoretical model of Duffie (1996). In the euro area, the three most traded Bund futures (all from EUREX) have a German Bund underlying with a remaining term to maturity of ten, five and two years. Thus, there is special demand for Bunds that are deliverable under futures contracts. In particular, the cheapest deliverable bond under a futures contract upon expiry (cheapest-to-deliver, CTD) is usually more expensive in the repo market than other bonds. EUREX futures usually expire on the tenth day of the last month of each quarter. Trading activity in Bund futures is concentrated in the contract that expires next.

[25] Brand et al. (2019) estimate a repo specialness increase of 0.3 PP for a purchase of one PP of the amount outstanding. Given a purchase volume of about one third of the amount outstanding for Bunds by early 2019, the total effect is close to our proxy of 9 bps. From their price effect or purchases in Euros, Schlepper et al. (2020) derive a proxy for the overall yield effect between 8 bps and 22 bps and a general deterioration of liquidity conditions over time. The stock effect of the PSPP in Arrata and Nguyen (2017), De Santis (2020), Blattner and Joyce (2016) and Altavilla et al. (2015) ranges between 20 bps and 60 bps. In a term structure model, Eser et al. (2019) estimate a stock effect of about 100 bps.

We observe strong trading activity when a contract becomes the next to expire reflecting a build-up of positions. Close to expiry, we see another peak in futures trading activity when open positions are closed prior to delivery. Because this futures trading directly impacts hedging needs and potentially affects scarcity premia in the repo market, we interact the CTD indicator with the trading volume in that specific futures contract. The same is done for the trading volume and an indicator for all bonds deliverable under a specific futures contract. In a second step, the four futures are standardised for time series variation and level, and are summed up to form a single composite variable. Table 4 shows summary statistics for both standardised futures interaction terms, namely IA_ctd_X_vol (cheapest to deliver) and IA_del_X_vol (deliverability).

Table 4: Summary statistics of futures-related variables

	N	mean	sd	skewness	p5	p25	p50	p75	p95
IA ctd X vol	6,243	14.7	7.6	2.1	5.2	9.9	13.5	17.5	28.4
IA del X vol	44,511	5.0	3.1	2.0	1.3	3.0	4.4	6.3	10.4

Before analysing the effect of these control variables in detail, we compare the results for a model including PSPP variables (model (8) of Table 2) with the results for a model (0) without any additional PSPP variables (Table 5). We find that the impact of control variables does not significantly change when we include PSPP variables. Obviously, our universe of control variables seems appropriate as it does not interact with the PSPP variables.

Looking at the effects themselves we find that high futures trading volumes increase Bund specialness. However, the effect is only significant for the cheapest-to-deliver bond. When the standardised trading volume (IA_ctd_X_vol) increases from the median to the 75th percentile (95th percentile), specialness rises by 0.7 bp (2.5 bps). Another driver of a bond's specialness may be its liquidity in the cash market. Particularly liquid bonds may be in high demand and carry a specialness premium. We capture liquidity using bid-ask spreads in the spot bond market from Bloomberg and an indicator for a bond's on-the-run status. Both variables have an insignificant impact on repo specialness in Table 5. From BrokerTec, we include the specific repo volume traded in each bond. The significantly positive coefficient implies that spikes in specialness are usually driven by high demand but not shrinking supply in the private repo market. Repo market entries by strategic Bund investors supplying Bunds on the repo market may have contributed as

Table 5: Control variables

Dependent variable: repospread (basis points)		
	(0)	**(8)**
repo volume *(€ million)*	0.00103*** (0.000)	0.000994*** (0.000)
bid-ask spread *(basis points)*	0.00478 (0.689)	0.000115 (0.992)
D_on the run	0.0217 (0.917)	-0.0262 (0.897)
IA_ctd_X_vol	0.166*** (0.008)	0.166*** (0.009)
D_ctd	-1.519** (0.013)	-1.531** (0.015)
IA_deliv_X_vol	0.0672 (0.177)	0.0669 (0.173)
D_deliv	-0.907** (0.021)	-0.867** (0.023)
lag repospread *(basis points)*	0.821*** (0.000)	0.818*** (0.000)
Constant	0.769*** (0.001)	0.634*** (0.003)
PSPP variables	No	Yes, cf. Table 2
Time fixed effects	Yes	Yes
Bond fixed effects	Yes	Yes
Observations	104,355	104,355
Adjusted R-squared	0.876	0.876

p-values in parentheses
* p<0.10 ** p<0.05 *** p<0.01

*Table 5 summarizes the results of panel regressions of repo specialness on the control variables entering all our etimations. The second column refers to model (8) of Table 2 including also PSPP variables. The variable repo volume captures the transaction volume in a specific ISIN on Brokertec. Bid-ask spread is the difference between the ask and the bid yield given in basis points. D_on the run is a dummy variable that is equl to 1 when a bond is the newest emitted bond of a specific maturity segment and 0 otherwise. D_ctd is a dummy variable that is 1 if a bond is currently the cheapest one that can be delibered into a futures contract and 0 otherwise. IA_ctd_X_vol is an interaction term of the CTD dummy and the futures trading volume in that specific contract. D_deliv is equal to 1 if the bond is deliveralble into the corresponding futures contract and 0 otherwise. IA_deliv_X_vol is an interaction term of that dummy variable and the trading volume in the corresponding futures contracts. We control time- and bond- fixed effects. Standard errors clustered by bond and time are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.*

collateral like the year-end effect of window dressing bank balance sheets. The leverage ratio (introduced in 2015) incentivises banks to reduce their repo business around reporting days to shrink their balance sheet and in particular the liabilities that arise from a repo. The decline in repo rates of 50 bps and more at the turn of the calendar year in Figure 1 illustrates the large magnitude of this effect.

Our findings are in line with the literature. The prominent role played by CTD bonds in the repo specialness premium of Bunds is consistent with Brand et al. (2019), and a stronger flow effect for CTD bonds than for other bonds was also found in Arrata et al. (2020). In the cash market, Ejsing & Shivonen (2009) show that deliverability under futures contracts is more important than the issuance cycle or liquidity proxied by on-the-run status. Overall, the hedging demand represented by futures deliverability is the most important driver of specialness. It has a larger effect on repo specialness than the supply effects from the APP.

3 Securities lending and repo specialness

> *"The problem would be a shortage of collateral and/or an impaired price mechanism. To avoid any shortage of assets that are used as collateral ... securities ... will be made available to the market through securities lending. This will enable securities purchased by the Eurosystem to be used in private transactions and relieve frictions in the functioning of the market, such as failed repo deliveries, which may arise from our purchases." Cœuré (2015)*

The ECB Governing Council decided on 4 March 2015 to make bonds purchased available for lending to support the effectiveness of the PSPP. Like the PSPP purchases themselves, SecL is implemented as a decentralised process by national central banks, which are free to choose their trading platforms.[26] The Bundesbank offers four different SecL channels, two through central clearing counterparties and two bilateral facilities.[27]

3.1 ASL fails lending

The Bundesbank participates in Clearstream's automated securities lending (ASL) to ensure the functioning of the repo market by mitigating breaks in the delivery chain. Since 2 April 2015, bonds from the PSPP portfolio have been made available to Clearstream (red vertical line "ASL" in Figure 1). In case a security borrower fails to deliver the bond,

[26] See the Bundesbank's website for information on SecL: https://www.bundesbank.de/en/tasks/monetary-policy/outright-transactions/outright-transactions-643040?index=1#tar-6

[27] We do not cover trading on EUREX Repo since it only started after the end of our empirical sample.

Clearstream can use the Bundesbank's bonds to deliver the bond and prevent the delivery chain from breaking. The rates charged to the failing counterparty for overnight lending are prohibitive at -140 bps. Therefore, strategic fails play a minor role in ASL. Strong demand for a security in overnight ASL serves as a proxy for times of asset shortage – that is, periods when it is hard to find a specific collateral in due time.[28]

Intraday lending with ASL are free of charge. That allows a CCP member to enter a reverse repo and search for the collateral before the end of the business day. Strong activity in the intraday segment of ASL not necessarily signals stressed repo markets but may also merely be an indication of active trading.

3.2 Strategic securities lending

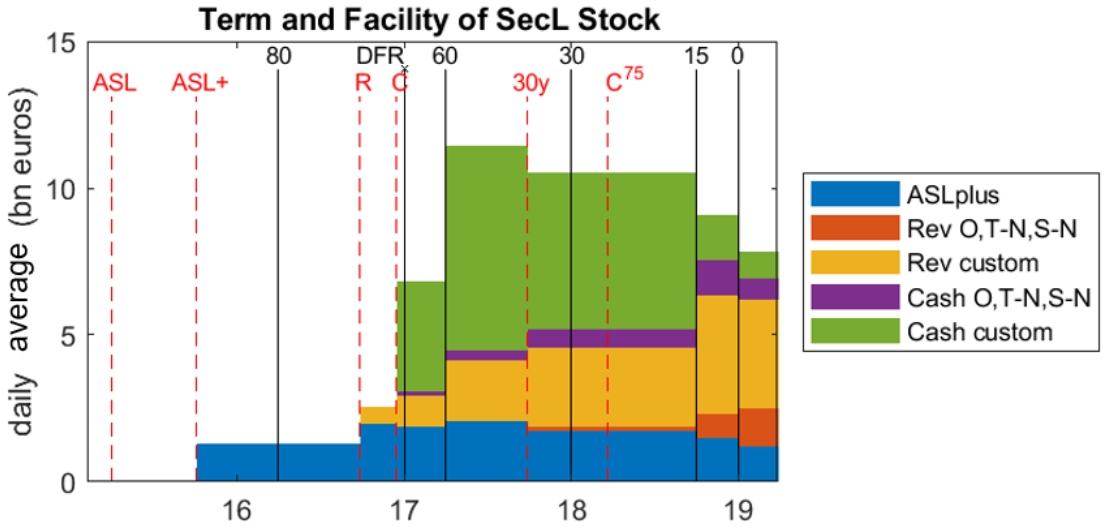
The ASL+ strategic lending facility gives Clearstream the right to lend bonds from the Bundesbank's portfolio at prevailing market conditions in the event of high demand for Bunds (red vertical line "ASL+" for 5 October, 2015 in Figure 5 and others). All financial agents connected to Clearstream automatically have access to the bonds allocated to ASL+. Demand for ASL+ is concentrated in the open repo overnight (O) segment.[29] Via ASL+, around €2 billion was lent out on average per day from 2016 to 2018 (Figure 5). There was less demand in 2018, reflecting the smaller volume and the reduced specialness observed in the private market.

A Bundesbank bilateral repo facility was introduced by combining a repo with a reverse repo on 27 September 2016 (red vertical line "R" in Figure 5 and others). To obtain a specific Bund, the counterparty has to deposit another Federal security as collateral. For example, it is possible to obtain the last-issued 10-year Bund by depositing a German 2-year Schatz. This procedure ensures that the liquidity provided to the private sector – the monetary stance – is unchanged by SecL. A repo against a reverse repo is only possible if the spread between the two contracts is at least 10 basis points (25 bps before December 2016).

[28] The ASL data available to us contains only the bonds of the Bundesbank lent out by Clearstream through ASL, not the whole volume of ASL activity in a specific bond.

[29] Both parties to an ASL+ trade have the right to terminate the open repo contract in order to renegotiate the spread. The lender of the security has the right to deliver the collateral partially. ASL+ is quoted as a spread against general collateral which is approximated by the EUREX GC Pooling ECB Basket. Our data are based on Bundesbank accounting information that only contains the date on which collateral is moved off and onto the Bundesbank's books but not the trade date. While this is not problematic for ASL fails lending, for ASL+ a trade negotiated S-N or T-N will result in a timing mismatch from the spread used. Repos with a fixed duration ("TERM") are of minor importance.

Figure 5: Strategic securities lending



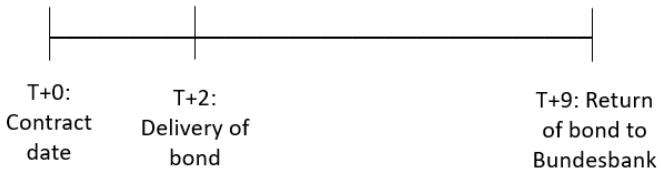
On 8 December 2016, the Governing Council decided to lend assets against cash collateral as of 16 December 2016 (red vertical line "C" in Figure 5 and others). With cash collateral, the monetary stance depends on the volume of SecL but may reduce the potential negative side effects of widespread asset scarcity. Therefore, the Eurosystem imposed a global limit for cash collateral of €75 billion for the whole Eurosystem (€50 billion before 16 March 2018) to mitigate the adverse impact on the monetary stance. The repo rate against cash collateral is the prevailing market rate but not more than 30 basis points below the current DFR (red horizontal line "C-max" in Figure 1).

Bilateral SecL offers the three standard overnight contracts in the repo market (O, T-N and S-N) and flexible contracts with a term of up to seven calendar days. The latter are referred to as "custom (C)" in the remainder of this paper, and they dominate bilateral SecL activity, as shown in Figure 5.[30] The timing of a typical SecL contract offered by Bundesbank is depicted in Figure 6. This is strikingly different from activity on BrokerTec, where spot-next contracts are predominant while the volume for seven-day contracts is negligible. Therefore, it is usually not possible to replicate Bundesbank SecL using BrokerTec data. Figure 5 shows that both types of bilateral SecL contracts and ASL+ are actively used by market participants. Cash collateral used to dominate bilateral SecL in terms of volume in the first years after its implementation in late 2016. Only after market conditions eased in 2018 did reverse repos become more important: there is still

[30] The total amount of securities lent out by the whole Eurosystem can be viewed on the ECB's website: https://www.ecb.europa.eu/mopo/implement/omt/lending/html/index.en.html

sufficient dispersion within the repo market, but most securities trade above the maximum rate of -70 bps required to allow for cash collateral in the S-N term.

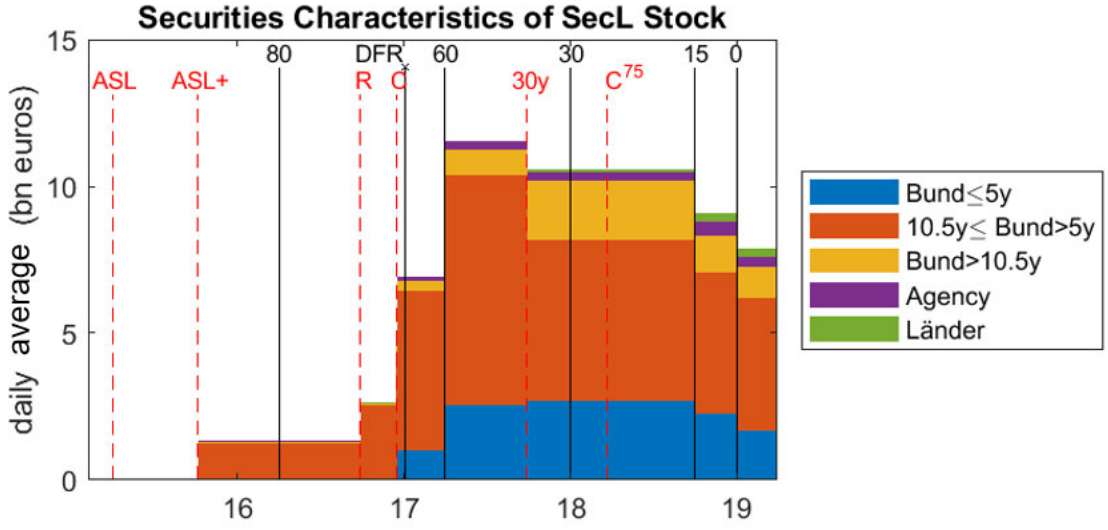
Figure 6: Timing of a stylized SecL contract



3.3 Bond characteristics and pricing of securities lending

The SecL volume is concentrated in Bunds in Germany. While bonds issued by German Länder or agencies are also offered by the Bundesbank in SecL, they play only a minor role in the SecL volume (Figure 7). Although their purchase volume increased over time and their free float declined by more than that of Bunds, these securities do not seem to be scarce. Since the level of free float bonds issued by Länder and Agencies is still considerably higher than for Bunds, it is not only the reduction in free float that affects scarcity, but the level of free float itself matters as well.

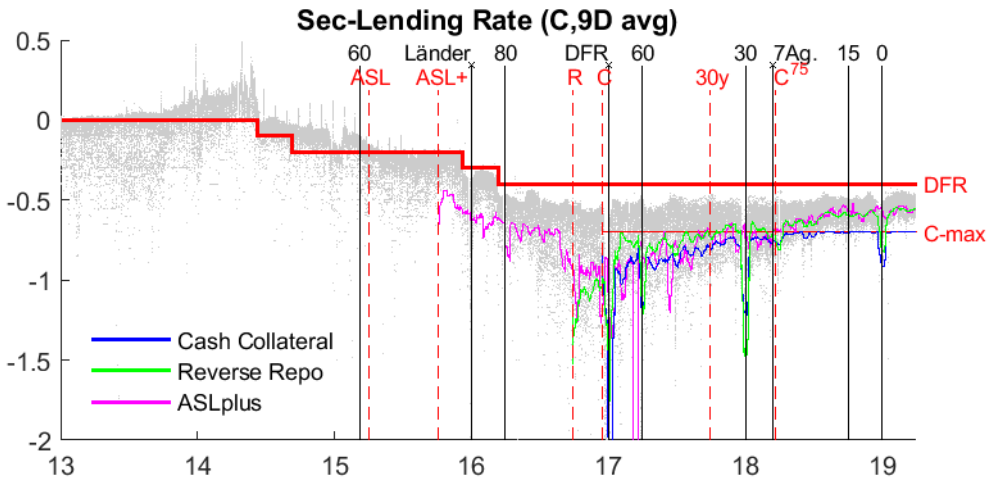
Figure 7: Securities characteristics of securities lending stock



The Bunds used in SecL, as shown in Figure 7 above, have much the same maturity profile as that of the PSPP portfolio. Before 2017, no short-term bonds were lent out. The minimum yield requirement in the PSPP ("DFR" in the figures) created a PSPP portfolio dominated by long-term bonds (Figure 2). Furthermore, the eligibility constraint

generated particular specialness in eligible long-term Bunds, which led to higher volumes of those securities in SecL. The volume of short-term securities increased in 2017 after they became eligible for PSPP purchases, but long-term securities continue to dominate SecL volumes.

Figure 8: Securities lending pricing



ln general, the volume-weighted average rates of SecL operations for reverse repo rates are above the rates for cash collateral (Figure 8). At the end of 2016, the (green) reverse repo transactions were similar to PSPP-eligible bonds' BrokerTec rates in Figure 2. In 2018, when the repo market eased, only a few transactions in SecL were made using cash collateral – usually with a rate of -70 bps. By the end of March 2019, the volume-weighted reverse repo rate was above -70 bps. In January 2017, the reverse repo rates increased quickly while the decline in cash collateral rates was more gradual. However, all the time since the introduction of cash collateral, there were reverse repo transactions with rates below -70 bps, the cash collateral threshold. Thus, it is not only general (safe) asset scarcity in the Bund market, but also scarcity in specific securities that drives SecL volumes. Before long-term bonds became eligible in bilateral lending (28 August 2017, red vertical line "30y" in Figure 7), lending activity in ASL+ was concentrated in rather expensive 30-year Bunds. After that, their total volume increased, and ASL+ -pricing was in line with the bilateral repo facilities.

3.4 Drivers of securities lending volumes

Before we turn to the effect of SecL on specialness, we first investigate the determinants of the volumes in different SecL facilities.

$$SecL_t^i = \sum_{h=1}^{H} \beta_{SecL}^{h} \cdot SecL_{t-h}^i + \beta_{SecLElig} \cdot \mathrm{SecL}Elig_t^i + \sum_{h=0}^{H} \beta_{PSPP}^{h} \cdot PSPP_{t-h}^i + \beta_{Elig} \cdot Elig_t^i + \sum_{j=80,30,15}^{J} \beta_{Elig}^j \cdot Elig_t^i \cdot I^j + \delta\, Controls_t^i + \alpha_i + \alpha_t + \varepsilon_t^i$$

Index i refers to the securities lending facilities summarised in Table 6 specifically, ASL, ASL+ open repos, bilateral SecL against cash and bilateral SecL against reverse repo. For bilateral reverse repo, we also take into account the collateral delivered to the Bundesbank in order to study the characteristics of the (cheap) collateral posted to the Bundesbank in exchange for the special Bund ("Collateral Bilateral"). In line with the PSPP-volume, we measure SecL flow effects relative to the free float of that asset:

$$SecL_t^i = \frac{€SecL_t^i}{FreeFloat_{t-1}^i}$$

The volumes lent out by the Bundesbank in Table 6 per operation are considerably larger than the volumes of PSPP purchases in Table 1. The indicator variable $\mathrm{SecL}Elig_t^i$ highlights whether a bond is eligible for securities lending. It combines the minimum pricing rules, availability in the PSPP portfolio, and programme-specific restrictions: The latter include for ASL and ASL+, the Bundesbank trading desk's selection of the bonds available to Clearstream. For bilateral securities lending, 30-year bonds were not eligible before the autumn of 2017.

Table 7 contains the regression results for the SecL volumes. For bilateral SecL operations against cash and reverse repos, a security that is lent out today is likely to be lent out again tomorrow. Since the maximum term of a bilateral contract is seven calendar days, SecL operations are autocorrelated at lags of five and ten business days, implying that a security that has to be returned to the Bundesbank is likely to be lent out again – a behaviour that we call "chain contracts" in the remainder. In contrast, there is weaker autocorrelation for ASL+ at short lags since it is an open repo. Bond shortage reflected in ASL fails lending is persistent over time. The collateral posted by market participants with the Bundesbank in a bilateral reverse repo is strongly autocorrelated. Relatively cheap bonds remain cheap over time and are continuously used as collateral. Furthermore, the collateral posted with the Bundesbank is also more likely to be ineligible for SecL.

Table 6: Volume of securities lending operations: summary statistics

Panel A: … in € million

	N	mean	sd	skewness	p5	p25	p50	p75	p95
ASL+	1,411	103.0	103.8	2.7	10.0	40.0	75.0	125.0	314.0
Reverse Bilateral	2,324	145.2	132.4	2.1	15.0	50.5	100.0	200.0	400.0
Cash Bilateral	2,909	182.1	171.2	2.1	15.0	65.0	126.0	250.0	512.0
Collateral Bilateral	2,814	134.6	118.7	2.3	21.7	53.8	100.0	170.8	368.7
ASL	4,023	8.8	13.8	2.2	0.04	0.45	2.07	10.00	42.93

Panel B: … as a percentage of free float

	N	mean	sd	skewness	p5	p25	p50	p75	p95
ASL+	1,411	1.64	8.44	35.82	0.14	0.48	0.93	1.85	4.44
Reverse Bilateral	2,324	2.44	2.55	3.21	0.22	0.82	1.70	3.21	7.06
Cash Bilateral	2,909	3.39	14.12	42.67	0.22	1.00	2.04	3.82	8.81
Collateral Bilateral	2,814	3.23	3.65	3.67	0.41	1.11	2.13	3.88	9.88
ASL	4,023	0.14	0.33	12.36	0.00	0.01	0.03	0.16	0.65

The second block of Table 7 covers the PSPP's impact on SecL volumes. The mostly insignificant coefficients suggest that purchases by the Bundesbank do not force market participants to rely on SecL in the following days. Also, the cumulative effect of purchases is insignificant in F-tests for all lags and all lending facilities. Furthermore, PSPP eligibility is unrelated to the securities lent out in bilateral operations by the Bundesbank and to ASL fails lending. Thus, the purchases do not induce asset shortages that force market participants to borrow the (previously sold) bond from the Bundesbank. The collateral delivered to the Bundesbank in a bilateral reverse repo is likely to be ineligible for PSPP purchases as the negative significant coefficient of the PSPP eligibility dummy implies. Furthermore, bonds purchased are likely to be delivered as collateral in bilateral reverse repos. The latter may imply that Bundesbank traders successfully avoid PSPP purchases in bonds that are particularly short in supply. The low specialness makes these bonds natural candidates for collateral in a reverse repo.

A high volume of repo trades on BrokerTec tends to reduce the volume of SecL. Although this relationship is only significant for bilateral reverse repos at the 10% level, a high level of market activity reduces the reliance on SecL. Conversely, SecL acts as a backstop in times of low private market activity. This is of special relevance at year-ends, when

Table 7: Explaining the volume of securities lending operations

Dependent variable (in % of free float)	Reverse Bilateral	Cash Bilateral	Collateral Bil.	ASL	ASL+
h=1	0.0755***	0.119***	0.0777***	0.0243**	0.0227
	(0.0150)	(0.0235)	(0.0163)	(0.00986)	(0.0173)
h=2	0.0153	0.0591***	0.0444***	0.0165	0.0200**
	(0.0142)	(0.0215)	(0.0142)	(0.0128)	(0.00995)
h=3	0.0296	0.0200	0.0492**	0.00316	0.0165
	(0.0287)	(0.0161)	(0.0210)	(0.00613)	(0.0198)
h=4	0.0845***	0.0312	0.0304*	0.0284***	0.0128
	(0.0157)	(0.0192)	(0.0158)	(0.00987)	(0.00800)
h=5	0.106***	0.0462*	0.101***	0.0433*	0.0315
	(0.0247)	(0.0269)	(0.0236)	(0.0253)	(0.0190)
h=6	0.0893***	0.0809***	0.0733***	0.0147***	0.0471***
	(0.0182)	(0.0304)	(0.0259)	(0.00541)	(0.0136)
h=7	0.0650***	0.0332***	0.0652***	0.00361	0.0194
	(0.0194)	(0.0107)	(0.0128)	(0.00529)	(0.0148)
h=8	0.0208	0.0501*	0.0265	0.0138**	0.0171*
	(0.0147)	(0.0256)	(0.0196)	(0.00653)	(0.00883)
h=9	0.0489*	0.0378***	0.0416**	0.0171	0.0403***
	(0.0268)	(0.00957)	(0.0166)	(0.0115)	(0.0109)
h=10	0.0706***	0.0250	0.0231	0.000479	0.0378*
	(0.0245)	(0.0235)	(0.0158)	(0.00796)	(0.0202)
SecLElig	0.135***	0.533***	-0.112***	0.00394***	0.0233***
	(0.0170)	(0.0760)	(0.0186)	(0.000829)	(0.00846)
PSPP purchases	0.0251	-0.0219	0.0702*	-0.00168	-0.00621*
	(0.0256)	(0.0311)	(0.0420)	(0.00541)	(0.00329)
L.PSPP purchases	0.0107	0.0936	-0.0410	0.00385	-0.00775
	(0.0168)	(0.0643)	(0.0296)	(0.00420)	(0.00683)
L2.PSPP purchases	-0.00975	-0.0553	-1.75e-05	-0.00626	0.0138
	(0.0105)	(0.0452)	(0.0401)	(0.00607)	(0.0114)
L3.PSPP purchases	0.0808	0.0746**	-0.116*	0.00726	-0.00438
	(0.0549)	(0.0374)	(0.0609)	(0.00461)	(0.00559)
L4.PSPP purchases	-0.0514*	0.0461	0.0592	0.00416	-0.00101
	(0.0271)	(0.0734)	(0.0699)	(0.00997)	(0.00432)
L5.PSPP purchases	-0.00139	-0.0667	0.0561	-0.00203	0.00541
	(0.0102)	(0.0725)	(0.0396)	(0.00596)	(0.00434)
D_PSPP elig	-0.00191	-0.000879	-0.0328**	7.15e-05	0.00647
	(0.00725)	(0.00935)	(0.0138)	(0.00125)	(0.00414)
IA_80bn X PSPP elig	-0.0154	-0.0246	0.0533**	0.00178	0.0105
	(0.0114)	(0.0150)	(0.0214)	(0.00164)	(0.0115)
IA_30bn X PSPP elig	0.0245	0.0202	-0.0766	0.000929	-0.00533
	(0.0165)	(0.0176)	(0.0492)	(0.00189)	(0.00844)
IA_15bn X PSPP elig	-0.0176	-0.00959	-0.0569	0.00247	-0.0120
	(0.0283)	(0.0166)	(0.0787)	(0.00237)	(0.00915)
repo volume (m euro)	-1.01e-05*	-9.10e-06	-7.26e-06	5.03e-07	-5.06e-06*
	(5.71e-06)	(9.13e-06)	(5.85e-06)	(6.02e-07)	(3.00e-06)
bid-ask spread (bp)	-0.000167	-0.00107	0.00164**	-2.84e-05	8.59e-05
	(0.000451)	(0.000787)	(0.000712)	(4.37e-05)	(0.000186)
IA ctd X vol	0.00664***	0.0203***	-0.00296	0.000406***	0.00355**
	(0.00208)	(0.00522)	(0.00204)	(0.000146)	(0.00174)
D_cheapest to deliver	-0.0655*	-0.187***	0.0273	-0.00145	-0.00853
	(0.0387)	(0.0691)	(0.0374)	(0.00281)	(0.0132)
IA deliv X vol	-0.00181	-0.00223	-0.000155	-0.000150	0.000356
	(0.00198)	(0.00257)	(0.00212)	(0.000119)	(0.00118)
deliverability ALL	0.0289	0.0305	0.0127	4.89e-05	-0.0207
	(0.0193)	(0.0194)	(0.0157)	(0.000928)	(0.0127)
D_on the run	-0.0360***	-0.0400*	0.0593*	0.00279	-0.00941
	(0.0114)	(0.0205)	(0.0302)	(0.00276)	(0.0128)
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Bond fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	104,289	104,289	104,289	104,289	104,289
Adjusted R-squared	0.171	0.269	0.159	0.126	0.042

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

For further explanation see next page.

*Table 7 reports the results of a panel regression of SecL volume on various explanatory variables. The variables h=1 to h=10 capture the first 10 lags of the SecL volume. SecLElig is a dummy variable that is equal to 1 when a bond is eligible for SecL and 0 otherwise. The different lags of PSPP purchases capture the purchase amounts relative to the free float (in %). D_PSPP elig is a dummy variable that takes the value of , when a bond is eligible for purchases under the PSPP on day t and 0 otherwise. IA_...bn X PSPP elig are interaction terms of a dummy variable which is one in the period when the aggregated PSPP volume was 80, 30 and 15 (60 billion is the benchmark case) and the PSPP eligibility dummy. The set of control variables includes the repo volume, the bid-ask spread, a dummy variable that is equl to 1 when a bond has the on-the-run status and 0 otherwise (D_on the run). D_ctd is a dummy variable that is 1 if a bond is currently the cheapest that is deliberable into a futures contract and 0 otherwise. IA_ctd_X_vol is an interaction term of the CTD dummy and the futures trading volume in that specific contract. D_deliv is equal to 1 if the bond is deliverable into the corresponding futures contract and 0 otherwise. IA_deliv_X_vol is an interaction term of that dummy variable and the trading volume in the corresponding futures contracts. We control for time- and bond- fixed effects. Standard errors clustered by bond and time are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.*

SecL steps in to support private market activity.

The liquidity in the cash market proxied by the bid-ask spread has no significant impact on the securities lent out by the Bundesbank. However, the collateral in bilateral SecL has a rather low liquidity, which is consistent with a price discount that makes these bonds natural candidates for collateral to be posted with the Bundesbank. Recently issued on-the-run (OTR) bonds are somewhat less likely to be lent out, either because these bonds are not in the Bundesbank's portfolio in large amounts or because recently issued bonds are easier to source in the private market.[31]

Futures markets are an important driver of SecL volumes. The Bund that is cheapest-to-deliver under one of the four German bond futures on EUREX has a high volume in SecL for all strategic SecL facilities. Furthermore, ASL fails lending increases for the CTD bond with the trading volume in that future.[32] A high trading volume in futures creates hedging demand by investors and the bonds are sourced partially in SecL. This effect is concentrated on the CTD bond. The other bonds that are deliverable under that future are not significantly affected. As expected, the effects are reversed for collateral in bilateral operations, although the impact is not significant.

[31] The Bunds are reopened and the German Finance Agency – the German debt management office (DMO) – retains a certain amount from every auction that is continuously conducted in the secondary market. There might be an impact of debt auction cycle on repo, a point made for instance by D'Amico and Pancost (2022). We control for the debt auction cycle by the on-the-run dummy. However, in line with other research, the debt auction cycle of Bunds is of less relevance compared to the cheapest to deliver on the Bund Future market.

[32] The dummy's negative sign adjusts for the unconditional mean of the futures trading volume.

3.5 Securities lending and repo specialness

In the Eurosystem's SecL, the minimum spread in a reverse repo and the maximum rate in a cash collateral operation create endogenous SecL volumes. The Bundesbank supports market functioning and lends scarce bonds at low repo rates. Hence, within the SecL programme the Bundesbank is supposed to take the role of a backstop facility. We should expect SecL activity only at low rates and cannot use SecL volumes of securities lent out as a local supply shock.

However, the contract specifications of the Bundesbank's bilateral repos allows us to construct an exogenous shock to the bond supply on the term leg of the repo. Most bilateral SecL operations are carried out with a fixed term of seven calendar days (see Figure 5). Regardless of repo specialness on the term lag, the security has to be returned to Bundesbank. Therefore, the operations at the term leg can serve as an exogenous local supply shock.

In our regression analysis, we add SecL variables to the benchmark setting of the PSPP purchases from Section 2.2 with five lags and interaction of the eligibility dummy with the aggregate PSPP purchase volumes of €80 billion, €30 billion and €15 billion:

$$
\begin{aligned}
Spread_t^i = \beta_{ASL}^O \cdot ASL_t^{O,i} + \beta_{ASL}^I \cdot ASL_t^{I,i} + \sum_{h=0}^{5} \beta_{SecL}^{\mathrm{h}} \cdot SecLR_{t-h}^i \\
+ \sum_{h=0}^{5} \beta_{PSPP}^{\mathrm{h}} \cdot PSPP_{t-h}^i + \beta_{Elig} \cdot Elig_t^i + \sum_{j=80,30,15}^{J} \beta_{Elig}^j \cdot I^j \cdot Elig_t^i \\
+ \delta\, Controls_t^i + \alpha_i + \alpha_t + \alpha_L \cdot Spread_{t-1}^i + \varepsilon_t^i
\end{aligned}
$$

The *return* of the asset previously lent out by the Bundesbank $SecLR_t^i$ implies a reduction in free float similar to PSPP purchases and has a positive sign. The return is a percentage of the free float, as with the PSPP purchase and SecL variables above. Furthermore, we include the local supply shock from the return of the collateral that the Bundesbank received in a reverse repo. In that case, the return variable $SecLR_t^i$ has a negative sign, such that the coefficient is positive if the increase in free float upon collateral return leads to lower specialness. In order to stay in line with the timing of PSPP purchases, we treat

$SecLR_t^i$ as occurring not on actual delivery but two days earlier.[33] We restrict our analysis to SecL contracts with "Custom" terms, which are dominated by contracts for seven calendar days. This rather long time period makes the supply shocks more exogenous compared to overnight securities lending.

Figure 9: Persistent flow effect of PSPP and securities lending
(*,x,+ indicate significance at the 1%, 5% and 10% level)

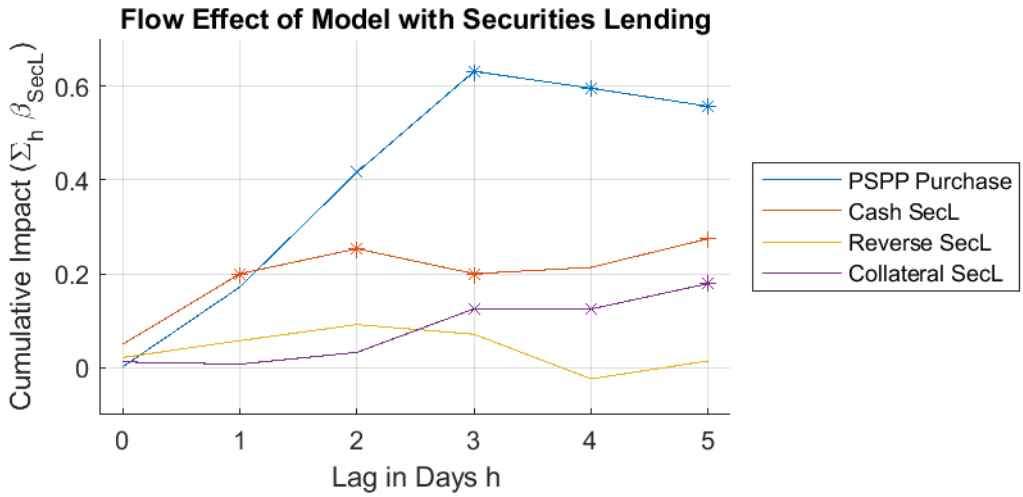


Figure 9 displays the cumulative flow effect when assets are returned at the end of the bilateral SecL contract, and the PSPP purchase effect when SecL is added to the regression. The lines in Figure 9 all refer to the regression in Table 8 in the Annex, Column 4 ("All"). The markers (*, x, +) indicate significance. Similar to the PSPP, the effect is negligible at lag 0 and is only significant after some days. The magnitude of the PSPP flow effect in Figure 9 is similar to the results of model (8) in Figure 4 without SecL. It serves as a quantitative benchmark for the supply shock of SecL.

Securities lent out by the Bundesbank in a reverse repo (yellow) have no effect on repo specialness. SecL against reverse repos alleviates the scarcity of securities *relative* to other securities. Some assets may be structurally more special than other securities. In times of high specialness in a specific security, Section 3.4 provides evidence for a chain of SecL contracts. A new SecL operation offsets the return of an asset, and the expiry of

[33] Thus, lag 0 represents the day on which a lender of a security needs to transact a S-N contract on BrokerTec in order to borrow the asset on the private market he has to return to the Bundesbank in two days. Lag 2 represents the day of actual delivery. For the collateral accepted by the Bundesbank, the equivalent is to terminate a S-N contract transacted on BrokerTec in order to obtain the collateral deposited at the Bundesbank in a reverse repo. We omit ASL+ because the return of the asset in an open repo in the ASL+ overnight segment is endogenous to the repo rate.

a single contract does not necessarily constitute a reduction in the aggregate asset supply. Although the return of the Bund in a reverse repo is a predetermined process and therefore serves as a suitable instrument to identify the impact of SecL on repo specialness, the presence of chain contracts, especially in reverse repo transactions, cannot fully alleviate any existing endogeneity concerns.

The economically largest and statistically most significant effect among the SecL variables concerns the return of securities lent out against cash collateral. Thus, unwinding a temporary increase in the bond supply increases the specialness. SecL against cash collateral addresses specialness of the whole Bund market. Besides window dressing at quarter-end, SecL against cash collateral was only possible in large quantities in 2017 when the repo rates were persistently low. Chain of SecL contracts play a role as well for lending against cash collateral, but to a smaller extend than for the securities lending against reverse repo.[34]

The return of the collateral from the Bundesbank to the SecL counterparty in a reverse repo is not subject to an opposite effect caused by a chains of contracts. The assets were not particularly special when the repo was entered into – otherwise, they would not have been chosen as collateral in the first place. If the collateral becomes special by the end of the SecL-contract, other securities would be chosen to collateralise a chain contract for a scarce Bund. But still, when these initially cheap assets are actually returned from the Bundesbank to the private market after seven days, there is a significant reduction in specialness. Collateral returns are the most exogenous metric for flow effects of all SecL variables.

The coefficients for PSPP flows are larger than the coefficients of all SecL operations. This might be because the unwinding of a temporary expansion of free float though SecL is structurally less important compared to a permanent local supply shock from a permanent PSPP purchase. This implies that SecL cannot unwind all asset shortage effects created by asset purchases. There are two caveats to this comparison of permanent PSPP purchases and the temporary SecL. On the one hand, the volumes of SecL are much higher (Table 6) than the volumes of PSPP purchases (Table 1). Hence, the effect of an average SecL operation on repo specialness would be stronger than that of an average PSPP purchase. On the other hand, the volume of the SecL returns is larger than the free float effect due to the mild chain contracts in lending operations. Therefore, overall it is

[34] In Table 7 the coefficients at lag 5 and 10 – that are most related to the chain contracts – are higher for bilateral SecL against reverse repo than against cash. Cash collateral is autocorrelated at the first and second lag which implies a strong demand on consecutive days before the expiration of the common five trading day contract.

not entirely clear whether SecL has a stronger or weaker effect on repo specialness than the PSPP purchases and what "the" actual flow effect of shocks to the bond supply is.

ASL for intraday contracts ($ASL_t^{I,i}$) has no significant correlation with BrokerTec rates (see Table 8 in the Appendix). Intraday usage provides no evidence for asset shortage. It might just facilitate regular trading and constitute a feature of the trading platform.[35] The volume of assets used by Clearstream in the overnight fails lending facility ($ASL_t^{O,i}$) is a proxy of asset shortage: It has a highly significant positive coefficient, so there are more frequent fails in assets that are particularly special on BrokerTec. This provides evidence for asset shortage in the repo market, and fails occur in assets that are particularly special.

4 Summary and policy conclusions

This paper studies the impact of central bank asset purchases under the Eurosystem's PSPP and the securities lending facility on asset scarcity in the repo market for German government bonds from 2015 to 2019 using transaction-level data.

When analysing the PSPP effect, we distinguish between the impact of actual purchases of a bond (flow effect) on repo specialness and the impact stemming solely from the fact that a bond is eligible for PSPP purchases, even if that asset is not actually purchased. We find that this eligibility premium is larger than the actual flow effect of purchases. The eligibility effect was of particular relevance in 2016/17 when the purchase volume was high and the eligible set was restricted due to the minimum yield requirement. Thus, restricting the eligible set may generate unintended shortage in eligible bonds. Therefore, a broad universe of elgible bonds seems to be an important aspect to circumvent asset shortage.

While previous studies investigate the SecL facility's effects on repo markets simply based on the time when cash collateral was introduced and conclude that it has helped to alleviate scarcity, we use actual SecL operations to identify a possible mitigating effect on asset scarcity. In order to reduce endogeneity problems stemming from SecL transactions, we use the collateral return delivery on the term leg of SecL operations instead of the endogenous lending volume itself. We find that SecL operations have a flow effect but its magnitude is smaller than the flow effect of APP purchases. Our results suggest that SecL indeed has a mitigating effect on asset scarcity but that its influence is limited to counterbalance the unintended side effects emerging from the PSPP of a comparable size.

[35] We controlled for the list of ASL-eligible ISINs that the Bundesbank provides to Clearstream, which is insignificant.

Lastly, we study the impact of alternative drivers of repo specialness - specifically, futures hedging demand, cash market liquidity, and regulatory requirements. We show that the effects of unconventional monetary policy measures are relatively small compared to those that originate in banks' balance sheets window dressing at quarter ends and of hedging pressure on demand for Bund futures. This implies that SecL does indeed help alleviate market tensions to a certain extent but that other factors beyond monetary policy are the predominant drivers of repo specialness.

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Appendix

Table 8: Repo specialness, securities lending and PSPP

Dependent variable: repo spread (basis points)

	Reverse Bilateral	Cash Bilateral	Collateral Bilateral	All
PSPP purchases	-0.0328	-0.0114	-0.0153	0.00214
(% of free float)	(0.120)	(0.122)	(0.120)	(0.122)
L.PSPP purchases	0.149**	0.163**	0.154**	0.170**
	(0.0746)	(0.0761)	(0.0741)	(0.0796)
L2.PSPP purchases	0.256	0.249	0.252	0.244
	(0.157)	(0.167)	(0.163)	(0.170)
L3.PSPP purchases	0.204	0.203	0.209	0.215
	(0.174)	(0.171)	(0.172)	(0.171)
L4.PSPP purchases	-0.0383	-0.0355	-0.0268	-0.0359
	(0.121)	(0.121)	(0.117)	(0.117)
L5.PSPP purchases	-0.0170	-0.0654	0.00686	-0.0385
	(0.143)	(0.143)	(0.139)	(0.141)
D_PSPP elig	0.303**	0.293**	0.289**	0.277**
	(0.116)	(0.114)	(0.115)	(0.114)
IA_80bn X PSPP elig	0.917***	0.954***	0.929***	0.968***
	(0.290)	(0.295)	(0.292)	(0.296)
IA_30bn X PSPP elig	0.0222	0.0223	0.0127	0.0118
	(0.173)	(0.171)	(0.170)	(0.168)
IA_15bn X PSPP elig	-0.198	-0.167	-0.244	-0.209
	(0.204)	(0.199)	(0.202)	(0.195)
ASL Intra	0.0608	-0.653	0.0917	-0.571
(% of free float)	(3.078)	(3.100)	(3.083)	(3.158)
ASL	37.59***	37.35***	37.74***	37.41***
(% of free float)	(10.54)	(10.44)	(10.51)	(10.49)
D_ASL elig	-0.233	-0.214	-0.230	-0.209
	(0.174)	(0.174)	(0.174)	(0.176)
Reverse BilateralR	0.0427			0.0220
(% of free float)	(0.0459)			(0.0426)
L.Reverse BilateralR	0.0548			0.0358
	(0.0453)			(0.0424)
L2.Reverse BilateralR	0.0479			0.0343
	(0.0420)			(0.0438)
L3.Reverse BilateralR	-0.00799			-0.0207
	(0.0303)			(0.0300)
L4.Reverse BilateralR	-0.0864***			-0.0949***
	(0.0309)			(0.0330)
L5.Reverse BilateralR	0.0472*			0.0383
	(0.0272)			(0.0285)
Cash BilateralR		0.0537		0.0502
(% of free float)		(0.0583)		(0.0581)
L.Cash BilateralR		0.153***		0.150***
		(0.0417)		(0.0434)
L2.Cash BilateralR		0.0561		0.0533
		(0.0484)		(0.0484)
L3.Cash BilateralR		-0.0552*		-0.0532*
		(0.0280)		(0.0285)
L4.Cash BilateralR		0.0129		0.0136
		(0.0261)		(0.0258)
L5.Cash BilateralR		0.0613		0.0609
		(0.0390)		(0.0395)
Collateral BilateralR			0.0131	0.0125
(% of free float)			(0.0200)	(0.0198)
L.Collateral BilateralR			-0.00219	-0.00471
			(0.0395)	(0.0396)
L2.Collateral BilateralR			0.0290	0.0251
			(0.0279)	(0.0281)
L3.Collateral BilateralR			0.0942	0.0927
			(0.0689)	(0.0687)
L4.Collateral BilateralR			-5.33e-05	-0.000498
			(0.0214)	(0.0232)
L5.Collateral BilateralR			0.0571***	0.0542**
			(0.0206)	(0.0207)
Controls	yes	yes	yes	yes
Time FE	yes	yes	yes	yes
Bond FE	yes	yes	yes	yes
Observations	104,081	104,081	104,081	104,081
R-squared	0.879	0.879	0.879	0.879

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

*Table 8 summarizes the results of a panel regression of the repo spread on various variables related to PSPP and SecL. The different lags of PSPP purchases capture the purchase amounts relative to the free float (in %). D_PSPP elig is a dummy variable that takes the value of 1 when a bond is eligible for purchases under the PSPP on day t and 0 otherwise. IA_...bn X PSPP elig are interaction terms of a dummy variable which is one in the period when the aggregated PSPP volume was 80, 30 and 15 (60 billion is the benchmark case) and the PSPP eligibility dummy. ASL Intra refers to the volume lent through the ASL intraday facility, ASL is the volume lent through the ASL overnight facility and D_ASL elig is a dummy variable indicating whether a bond is eligible for ASL. The lags of Reverse BilateralR capture the volumes in the reverse repo facility and Cash Bilateral R reflect the volumes of the cash lending facility returned to Bundesbank after maturity. The return of the collateral from the Bundesbank to the SecL counterparty in a reverse repo is denoted by Collateral BilateralR. We control for different bond- and time specific variables as well as for time- and bond- fixed effects. Standard errors clustered by bond and time are given in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.*