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Flexible asset purchases and repo market functioning

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Abstract

Flexibility has progressively become a distinctive feature of the implementation of the Eurosystem's asset purchases. In its many manifestations, flexibility has also been used by asset managers in the daily selection of sovereign bonds to limit the impact of asset purchases on repo market specialness. This study shows that, since the inception of the Public Sector Purchase Programme, flexible purchases of bonds greatly mitigated the Eurosystem's footprint on the repo market.

JEL classification: E50, E52, E58, G10, G18.

Keywords: Asset Purchases, Flexibility, Market Neutrality, Specialness, Repo.

Non-technical summary

Well-functioning repo markets are essential for an adequate transmission of monetary policy. Therefore, it is crucial for central banks to carefully monitor how their policy tools affect these markets.

In simple terms, in a repo transaction, one party sells securities (often government bonds) to another party with an agreement to buy them back at an agreed-upon price. These transactions can involve either a broad pool of securities with similar characteristics or specific sovereign bonds. Asset purchases have resulted in central banks holding significant amounts of government bonds, thereby reducing the availability of these bonds in both the bond market and the repo market.

Data show that since the inception of the ECB's Asset Purchase Programme (APP), overnight repo rates in the euro area have gradually declined. This decline is attributed, in part, to the removal of significant quantities of sovereign bonds from the market, leading to collateral scarcity in the repo market. The reduced availability of government bonds has created a premium on specific securities, known as the "specialness" premium. This scarcity of collateral may cause disruptions in the money market, making it harder for monetary policy to work effectively.

This paper argues that the way purchases are implemented significantly influences the impact of purchase programmes on repo markets. In particular, it highlights the importance of flexible implementation which has prevented "specialness" premiums from significantly widening in the euro area in the past. In this paper, flexible implementation involves a focus on purchasing less scarce bonds whenever possible. The underlying assumption is that central banks' portfolio managers understand that buying large quantities of certain bonds can lead to a higher "specialness" premium for that bond and disrupt the functioning of the repo market. Therefore, on any given day, they exercise some flexibility in their purchases while still meeting their monthly volume targets.

The study provides empirical evidence that a flexible approach to asset purchases has a positive impact on the repo market by increasing repo rates, thus reducing the "specialness" premium. The empirical results show that, over the period 2015-2019, flexibility in asset purchases contributed to attenuating the negative effects generated by large central bank bond holdings, increasing day-to-day repo rates by 0.41 basis points. Additionally, the study highlights that facilities like the Securities Lending Facility (SLF) have also helped alleviate issues in the repo market, confirming earlier results in the literature.

In summary, this paper argues that flexibility in the implementation of asset purchase programmes can mitigate policy-induced asset scarcity and "specialness" premiums in the repo market. This, in turn, helps alleviate the unintended consequences of balance sheet policies. These findings enhance the understanding of the impact of unconventional monetary policies on the repo market and have important implications for the design of balance sheet policies in the future.

1 Introduction

Repo markets are vital components of the financial system and play a significant role in the transmission of monetary policy. As such, developments in these markets are constantly monitored by central banks, not least to evaluate whether the implementation of monetary policy tools results in unintended side effects. Among these tools, asset purchase programmes have gained considerable attention for their footprint on the repo market. The existing literature often underscores the side effects of central banks' asset purchase programmes on the repo market. In this paper, we argue that these side effects can be mitigated through the careful design of purchase programmes.

In a repo transaction, one party sells securities, typically government bonds, to another party and agrees to repurchase them at an agreed-upon date and price. Bonds can either be transacted out of a pool of securities with similar characteristics (general collateral repos or GC repos) or involve specific sovereign bonds under repo agreements (special/specific collateral repos or SC repos). Overnight repo rates in the euro area have gradually declined since the inception of the ECB's Asset Purchase Programme (henceforth, APP). This kind of evidence is not restricted to the euro area, and the academic literature ascribes at least part of this downward pressure on repo rates to the removal of large amounts of sovereign bonds as a consequence of central banks' asset purchase programmes, which create collateral scarcity in the repo market (see e.g. Arrata et al., 2020, Corradin and Maddaloni, 2020 and D'Amico et al., 2018). This effect is especially pronounced for SC repos, where the parties agree to exchange a specific security. Scarcity of collateral gives rise to a premium that market participants must pay to source a special security. This is known as the "specialness" premium. Pronounced specialness exacerbates the dispersion of money market rates due to the scarcity of assets. Such an impairment threatens the transmission of monetary policy when money market conditions markedly diverge from those implied by the intended stance (see e.g., Cœuré, 2018, Schnabel, 2023 and Nguyen et al., 2024). Moreover, expensive collateral raises the cost of accessing liquidity, discourages borrowing, and introduces inefficiencies in the bond market.[1]

[1] Specialness has been associated with suboptimal price discovery in the bond market (D'Amico et al., 2018), mispricing in the cash (and futures) market due to arbitrage limits (Pelizzon et al., forthcoming), liquidity impairments in the model of Huh and Infante (2021), and securities lending (Greppmair and Jank, 2023). Specialness also impacts the term structure (Jappelli et al., 2024) and leads to an increase in fails-to-deliver into short positions, affecting financial stability (Corradin and Maddaloni, 2020). Pronounced dispersion and segmentation of short-term rates also blur pricing signals and have the potential to create a deadweight loss (see e.g., Duffie and Krishnamurthy, 2016, Eisenschmidt et al., 2024). Asset scarcity also provides advantages, in the form of

As mentioned before, the existing literature finds that central banks' asset purchase programmes exacerbate the specialness premium, decreasing rates in the repo market. Many of these studies treat the central bank as an actor that implements purchases regardless of market conditions, mechanically impacting repo rates with each purchase. However, central banks are unlikely to purchase irrespective of market conditions. Instead, asset managers usually strive to implement purchase programmes in a way that minimises the impact on prices and the unintended side effects on market functioning (as explicitly required by the implementation guidelines of the APP, see ECB, 2019). Our paper shows that accounting for the way purchases are implemented is important to assess the effects of purchase programmes on repo markets. In particular, flexible implementation has prevented specialness premia from widening pronouncedly in the euro area. In this paper, flexible implementation essentially means focusing purchases on less special bonds whenever possible. The implicit assumption is that central banks' portfolio managers internalise that buying large quantities of certain bonds may result in a higher specialness premium for that bond and distort the functioning of the repo market. Therefore, on any given day they exercise some discretion over purchases while still fulfilling their volume target over the month. This practice might have contributed to an overall less pronounced repo specialness associated with a given amount of asset purchases over time. We measure the degree to which portfolio managers used this flexibility in the euro area by computing the observed deviation, at bond level, of actual ECB purchases from a counterfactual allocation where, given a daily target, bonds are bought according to their nominal value outstanding relative to the total amount of eligible bonds outstanding on the same day. This counterfactual allocation would leave the bonds' relative distribution unchanged every day. Thus, it would have a neutral impact on relative quantities. We assume that bond prices would then also shift in the aggregate but not relative to each other. In this sense, our counterfactual allocation would be ex-ante neutral also in terms of prices. The idea for this counterfactual purchase strategy comes from ECB's official communication and speeches delivered by Executive Board Members, which support the design of a purchasing strategy that acquires assets proportionally to their market capitalisation.[2]

Econometrically, the idea that purchases should be implemented in a market-neutral manner suggests that the relationship between repo market specialness and the implementation strategies

"specialness revenues", to the incumbent owners of safe assets (Tischer, 2021).

[2] See for example Schnabel (2021).

might suffer from endogeneity concerns. In fact, we observe that our measure of flexibility responds to repo specialness, reinforcing our argument that asset managers account for market conditions when conducting purchases under the asset purchase programme.[3] In this context, our study is the first to introduce an empirical approach that effectively addresses this endogeneity. By doing so, we are able to assess the causal impact of flexibility in the daily implementation of asset purchases on repo markets, marking the principal contribution of our research. To address potential endogeneity, we employ an empirical approach that leverages the exogenous variation arising from the eligibility criteria of the Public Sector Purchase Programme (henceforth, PSPP). These criteria were established prior to the programme's initiation and remain unaffected by developments in the repo market, ensuring their orthogonality to such factors. Based on these predetermined criteria, we identify, on a daily basis, which bonds were *in principle* eligible for purchase under the PSPP. This enables us to compute a counterfactual allocation strategy that considers the entire universe of eligible bonds. Our measure of deviations between actual bond purchases and this counterfactual strategy importantly considers those purchases that could have been executed but were not, owing to Eurosystem asset managers reacting to unfavourable market conditions such as repo specialness. To isolate the deviations specifically attributable to specialness, we control for a variety of other potential sources of deviations in the Eurosystem's purchase strategy. This methodological approach allows us to establish a causal link between implementation strategies and the mitigation of repo market specialness. Our findings suggest that focusing purchases on bonds that are less scarce in the repo market reduces the negative impact of asset purchases on repo rates. Using a newly constructed, confidential bond-level dataset, we find that, between 2015 and 2019, flexibility in purchases under the ECB's APP contributed to increasing repo rates by 0.41 basis points for each EUR 100 million deviation from a market-neutral allocation. This result survives a battery of robustness tests, including bond-level controls, and it remains valid for the period 2020-2022.

To the best of our knowledge, this study is the first to rigorously establish that the implementation of asset purchase programmes plays a crucial role in mitigating their adverse effects on the repo market. Additionally, our dataset enables us to examine the role of the Securities Lending Facility (SLF) – intended to mitigate bond scarcity issues – in alleviating the downward pressure on repo rates stemming from asset purchases. The Eurosystem started to lend securities bought under the APP through the SLF in 2015, initially in exchange for similar securities, and,

[3] As evidenced by the empirical findings of Schlepper et al. (2020) and Baltzer et al. (2022).

from 2016 onwards, also against cash. The academic literature indicates that the introduction of SLF, particularly against cash collateral, eased repo market pressures and reduced episodes of extreme specialness premiums. Our bond-by-bond analysis corroborates this, finding that every EUR 100 million of SLF usage increased repo rates by 0.16-0.20 basis points. By leveraging confidential transaction-level data on the ECB's SLF for the first time, we further validate the effectiveness of such facilities in addressing repo market scarcity. This constitutes the second key contribution of our paper.

In conclusion, our research shows that flexibility in the implementation of asset purchase programmes mitigates policy-induced asset scarcity and reduces specialness premiums in the repo market, thereby alleviating the unintended consequences of balance sheet policies. It also confirms prior findings that facilities like the SLF play a significant role in addressing bond scarcity in money markets. Overall, these results contribute to a deeper understanding of the effects of unconventional monetary policies on the repo market and offer important insights for the design of future balance sheet policies.

Literature review. Our work relates in particular to the latest contributions that focus on the impact of central banks' asset purchases. The connection between repo market specialness and asset purchases can be explained within the theoretical framework of Duffie (1996), which links repo specialness to increased demand for short relative to long positions, frictions that constrain collateral supply, and legal or institutional restrictions on collateral owners or suppliers.[4] Central bank asset purchase programmes reduce the free float of sovereign bonds in the repo market, thereby influencing repo rates. Empirically, Arrata et al. (2020) documents that Eurosystem purchases systematically lower repo rates and increase specialness. They find that central bank purchases of special collateral amounting to 1% of its outstanding (i.e., EUR 150 million in their sample) reduce repo rates by 0.78 basis points, with this estimate rising to -4.6 basis points when using an instrumental variable approach. Similar finding are reported by Corradin and Maddaloni (2020), Brand et al. (2019), Pelizzon et al. (forthcoming), Baltzer et al. (2022) and Ferrari et al. (2021) for the euro area and in D'Amico et al. (2018) for the US. Corradin and Maddaloni (2020) and D'Amico et al. (2018) complement the findings of Arrata et al. (2020) showing that the effect of central bank asset purchases on specialness is persistent. The estimates of Corradin and Maddaloni (2020) are in the range of 15 days, with a peak impact on specialness premium of 4 basis points after 3 days. Brand et al. (2019) further shows that

[4] Early empirical studies are Jordan and Jordan (1997) and Krishnamurthy (2002).

central-bank-induced scarcity does not operates exclusively at the bond level but also at country level, identifying sizeable threshold effects when the central bank's holdings of bonds of a single jurisdiction exceed 10-15%. They also show that scarcity premiums are influenced by bank funding stress and sovereign risk. Focusing on quantitative easing (QE) stocks rather than flows, Pelizzon et al. (forthcoming) finds that asset-purchase-induced scarcity raises funding costs for arbitrageurs in the repo market, contributing to mispricing between treasury bonds and futures in the treasury market. Our paper also builds on the results of Schlepper et al. (2020), who shows that Bundesbank purchase decisions are influenced by repo scarcity and bond liquidity. Building on these findings, our study sheds light on the importance of implementation strategies in mitigating policy-induced repo scarcity. We show that flexibility in the execution of purchases matters and significantly reduces the impact of asset purchases on repo rates. Specifically, targeting purchases towards bonds that are less scarce in the repo market alleviates downward pressure on repo rates, regardless of the overall purchase volume. While our focus is on the repo market, many studies have also highlighted the relationship between asset purchases and the bond market. In an important contribution, De Santis and Holm-Hadulla (2020) stresses how purchasing decisions are affected by the relative value of bonds, estimating the exogenous impact of asset purchases on bond markets. Breckenfelder et al. (2023) also studies the interaction between asset purchases and bond markets, finding that central bank purchase programme designs may interact with the market structure in the euro area sovereign bond markets. To our knowledge, this paper is the first to provide empirical evidence on the benefits of flexibility in the implementation of asset purchases.

Our research also contributes to the broader literature on the effects of collateral policies on asset prices. Seminal works here are Nyborg (2016) and Nyborg (2017). More recently, Baltzer et al. (2022) explores the impact of PSPP purchases on German collateral-backed repos, finding that eligible securities under the PSPP trade at a premium in the repo market. Other relevant studies include Pelizzon et al. (2024) on the eligibility of corporate debt within the Eurosystem and Kandrac (2018) on mortgage-backed securities. Additionally, Hüttl and Kaldorf (2024) recently explored the real effects of the Eurosystem's single list of collateral eligibility. Our contribution to this literature lies in showing how both collateral policies and the execution of asset purchases influence repo market dynamics.

Furthermore, we provide a significantly more granular analysis of the role of the ECB's SLF in mitigating repo specialness induced by asset purchases. Using securities lending data from the ECB, we estimate the bond-level impact of SLF on repo rates. Previous studies, such as Arrata et al. (2020), Ferrari et al. (2021), Jank and Mönch (2018), de Souza and Hudepohl (2024), Baltzer et al. (2022), Greppmair and Jank (2023), Pelizzon et al. (forthcoming) and Brand et al. (2019), highlight the importance of SLF in alleviating the pressure on repo rates in the euro area, using sub-sample analyses and event studies based on Money Market Statistical Reporting (MMSR) data.[5] Notably, Greppmair and Jank (2023) demonstrates how the reduction in Eurosystem lending fees in November 2020 enhanced collateral circulation, alleviating repo market scarcity and improving cash market liquidity. Baltzer et al. (2022) and de Souza and Hudepohl (2024) also illustrate that SLF operations contribute to mitigating scarcity in the repo market for German Bunds and euro area government bonds more in general, although these operations do not fully offset the scarcity effects caused by asset purchases. With respect to this literature, our analysis uses transaction-level SLF data to provide sharper estimates of its impact on specialness in the repo market.

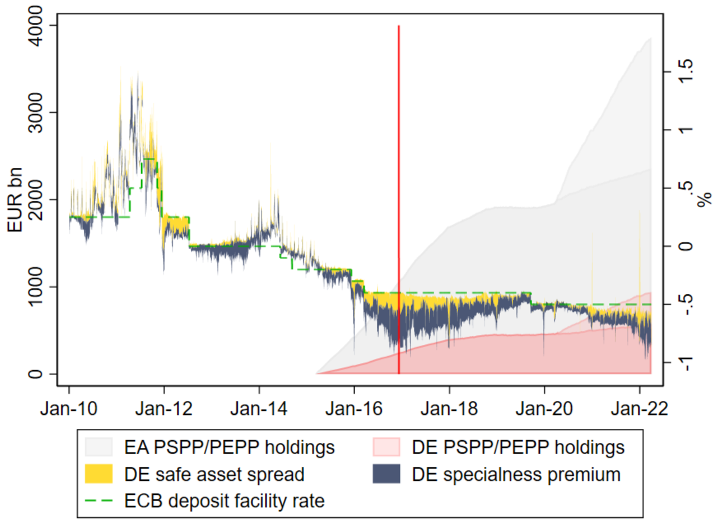
A number of studies emphasise how financial regulations impact intermediation in the repo market, especially when forcing banks and other financial institutions to hold safe assets. Regulations such as Basel III's liquidity coverage ratio (LCR) and leverage ratio (LR) might reduce the supply and re-use of high-quality collateral in repos (Duffie, 2018), thereby influencing market specialness. For instance, recently Ranaldo et al. (2021) finds that both demand and supply effects put downward pressure on interbank rates: Basel III tightens the demand for cash while the European Market Infrastructure Regulation incentivises the supply of cash. Munyan (2017), Horen and Kotidis (2018), Garcia et al. (2021) and Bassi et al. (2023) show that during reporting periods banks reduce the transacted volume in the repo market and offer lower repo rates. Conversely, Bucalossi and Scalia (2016) finds that banks that improved their LR, increased their activity in the repo market. Recent research also emphasises the critical role of repo market structure and central bank policies in the transmission of monetary policy. For instance, Ballensiefen et al. (2023) observes a pronounced segmentation in money markets when repos are more collateral-driven, with repo rates falling below the ECB's deposit facility rate (DFR), affecting the pass-through of monetary policy. Moreover, Eisenschmidt et al. (2024) illustrates that segmentation within the repo market impacts the efficiency and fairness of policy rate transmission, with dealer market power influencing repo rates. While our study is not directly related to this

[5] In the US, Fleming et al. (2010) provides evidence on the Federal Reserve's Term Securities Lending Facility, showing how use of securities lending alleviates pressure on repo rates.

literature, changes in the regulatory landscape and the structure of repo markets are useful to contextualise our results.

2 A concise history of the repo market through the lens of the German collateral

Figure 1: German repo specialness and Eurosystem's asset holdings



Source: Authors' calculations on BrokerTec, Eurex, MTS and ECB
Notes: Rates are determined on the basis of the agreement date of relevant transactions. The Bund Specialness Premium refers to the spread between the general collateral (GC) German repo rate and the special collateral (SC) German repo rate. The Safe Asset Spread is the difference between the GC pooling repo rate and the GC rate on German collateral. The red vertical line refers to December 2016, the month of the introduction of the securities lending facility against cash collateral and the amendment of PSPP guidelines.
Last observation: 31 March 2022

In this section, we outline key developments in the repo market in the euro area since the global financial crisis. To illustrate these developments, we focus on German repo rates. Repo market rate dynamics have changed considerably over the years. As noted earlier, transactions in the repo market can be broadly categorized into two types: GC repos, where bonds are transacted out of a pool of securities with similar characteristics, and SC repos, which involve specific sovereign bonds. Figure 1 presents a decomposition of repo rates for German government bonds into a safe asset spread – the spread between the General Collateral pooling repo rate and the GC repo rate on German collateral – and a specialness premium – the spread between Germany's GC repo rate and its SC repo rate.[6] Broadly, the German safe asset spread represents

[6]The STOXX GC pooling rate is a secured money market rate based on euro-denominated overnight transactions concluded on Eurex, a trading platform. The basket of securities that can be submitted to the platform

the price paid to receive any German bond in a repo transaction and the German specialness premium is the price paid to receive a specific German bond. Before 2015, periods of bond market tensions or macroeconomic crises occasionally caused a widening of the yellow area, reflecting that German government bonds traded at a premium relative to the euro-extended basket of securities due to their safe-haven status. At other times, the blue area widened, indicating that specific German bonds were in high demand. The start of the PSPP in 2015 initiated a period characterized by a pronounced and increasing divergence both between the GC pooling rates and the GC German rates (i.e., the German safe asset spread) and between the GC and SC German rates (i.e., the German specialness premium). Both spreads widened significantly at the outset of the programme, driven by Eurosystem purchases reducing the availability of bonds in the market and increasing the cost of sourcing them in the repo market, particularly through SC repos in jurisdictions like Germany.[7] Spreads started to decline again in the course of 2017 as the Eurosystem introduced two main innovations in its monetary policy implementation framework. First, the option to lend securities purchased under the PSPP against cash collateral via the SLF was introduced in 2016. Before 2016, recourse to SLF was ineffective in alleviating collateral shortages, as only similar securities were accepted as collateral pledged to the facility. Second, in 2016, the ECB amended PSPP implementation guidelines, relaxing the prohibition on purchasing securities below the deposit facility rate and reducing the minimum maturity requirement for PSPP purchases from 2 years to 1 year. The combination of these policies greatly increased the supply of securities purchasable under the PSPP. This helped alleviate downward pressures on repo rates, although specialness spreads remained elevated compared to levels observed before the start of the programme. In what follows, we will illustrate how flexibility in the implementation of purchases is another important feature to mitigate unintended effects of purchase programmes on the repo market and how this flexibility was employed by the Eurosystem in the context of the PSPP.

also includes collateral eligible for Eurosystem's refinancing operations (i.e., ECB Basket). Compared to standard GC transactions, collateral in Eurex's GC pooling platform is not actually transferred.

[7] Notably, the German segment for long term maturities was particularly under pressure as the PSPP eligibility prohibited purchase of bonds with a yield below the deposit facility rate (Cœuré, 2017).

3 Data

We use a novel dataset, constructed from various sources. This unique dataset allows us to quantitatively assess the impact of asset purchases on repo rates and provide evidence on potential mitigating factors. We collect information on repo transactions from BrokerTec, Eurex and MTS. Additionally, we gather securities lending data and eligibility information for bonds under the APP (specifically, the PSPP) from an ECB confidential dataset. Finally, we source bond characteristics and financial market data from ECB internal datasets, Refinitiv Eikon and MTS. The sample includes more than 1,500 International Securities Identification Numbers (ISINs), at daily frequency, spanning from 26 March 2015 to 31 March 2022, covering the seven largest euro area countries (Germany, France, Spain, Italy, Belgium, the Netherlands and Austria).

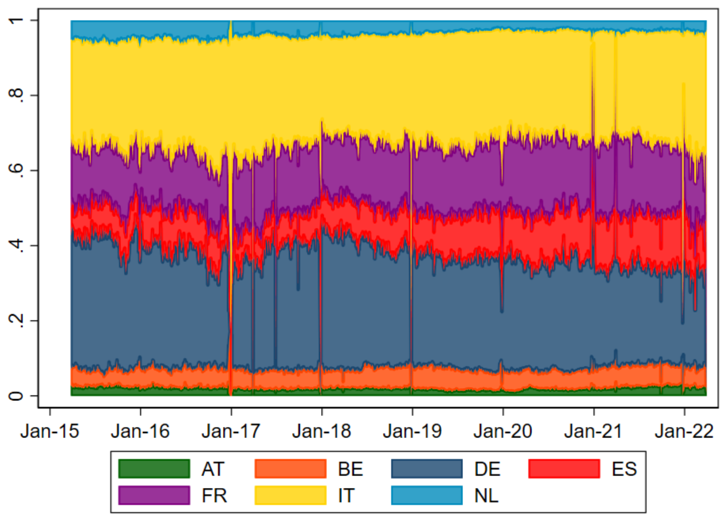
3.1 Repo market data

We use data from the three largest automatic trading systems (ATS) for euro-denominated repos: BrokerTec, MTS repo and Eurex repo. The Chicago Mercantile Exchange's BrokerTec, or simply BrokerTec, is the largest ATS for European government bonds, with a daily average transaction volume of about EUR 370 billion, followed by MTS Repo (approximately EUR 120 billion) and Eurex (approximately EUR 20 billion) - see ECB (2023). For each transaction, the combination of these three datasets provides detailed information, including the ISIN pledged as collateral, the rate paid for the repo agreement, the term (or tenor), the volume, the trade date, the settlement date and the maturity date, resulting in a total of nearly three million transactions. We restrict our focus to SC repo transactions, which account for 82% of the raw dataset and are backed by specific central government bonds issued by the seven jurisdictions in our sample.[8] Breaking down the volumes by jurisdiction, German and Italian collateral-backed repos together comprise around 60% of total volumes, followed by French (17%) and Spanish (11%) collateral-backed repos (see Figure 2). These shares are consistent with recent surveys of the repo market, such as ICMA (2022). Hence, we are confident that our sample offers a representative depiction of the repo market across various jurisdictions, providing valuable insights into the euro repo market.[9]

[8] Our sample excludes bonds issued by supranational institutions - even when issued in one of the seven jurisdictions mentioned above - and stripped bonds.

[9] According to the most recent estimates based on the Money Market Statistical Reporting, around two-thirds of traded volumes in the euro-denominated repo market are centrally cleared, see e.g., ECB (2023) or Eisenschmidt et al. (2024).

Figure 2: Breakdown of repo volumes by jurisdiction



Source: Authors' calculations on BrokerTec, MTS, Eurex
Notes: Volumes refer to spot-next special collateral repos and are calculated on the trade date.
Last observation: 31 March 2022

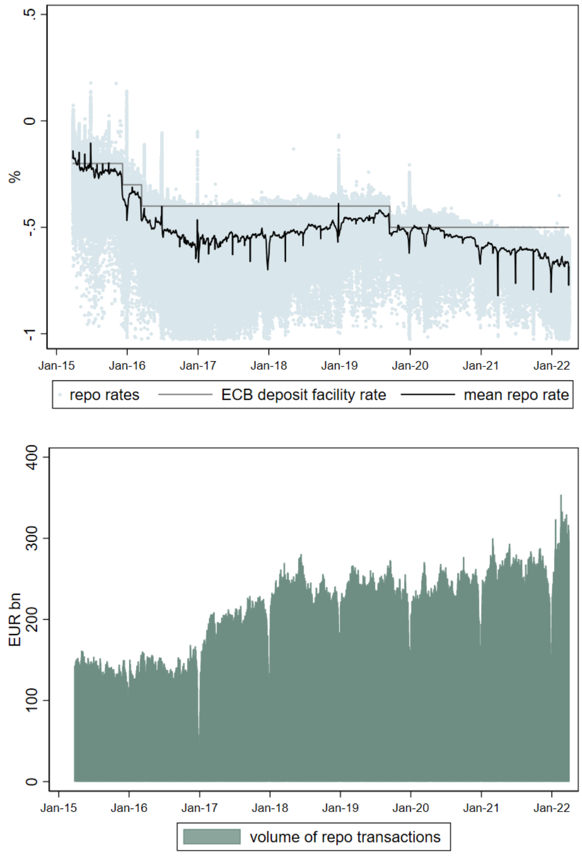
A repo transaction involves two main legs: the first leg, where securities are sold by the borrower to the lender, and the second leg, where the same securities are repurchased by the borrower from the lender. SC repos are typically settled two business days after the agreement is finalized (i.e., two days after the trade date) to align with settlement practices in bond markets (Brand et al., 2019). For this reason, we focus spot-next tenors, where the first leg of the contract is settled at $T + 2$ and the second leg or maturity at $T + 3$.[10] Spot-next tenors are also the most widely traded type of SC repo, accounting for 51% of the total transactions. To ensure robustness, we further trim the data by excluding the 1^{st} and 99^{th} percentiles of repo rates, mitigating the influence of outliers. We report aggregate volumes and rates for our sample in Figure 3 below.

3.2 Securities Lending Facility data

We use a unique ISIN-level dataset on the ECB's Securities Lending Facility. The Eurosystem set up the SLF in 2015 to lend back to markets the bonds it had purchased under the APP. Initially, bonds were lent using an equivalent security as collateral, ensuring the transaction was liquidity-neutral. In December 2016, as the balance sheet expanded, the Eurosystem introduced

[10] Alternative tenors are tomorrow next, where repos are settled one day after the trade date, at $T + 1$, and the bond is repurchased at $T + 2$, or overnight when the agreement and settlement occur on the trade date T and the second leg is settled at $T + 1$. Appendix D presents and discusses the results for these tenors.

Figure 3: Daily SC repo rates (lhs) and volumes (rhs)



Source: Authors' calculations on BrokerTec, MTS, Eurex
Notes: On the left-hand side, each dot refers to the spot-next special collateral rate of a security, computed as the daily volume-weighted average of transactions for the same security. On the right-hand side, values of volumes correspond to aggregate daily figures. The sample includes repos with underlying securities of government bonds from DE, FR, ES, IT, BE, NL, AT.
Last observation: 31 March 2022

the possibility of borrowing securities against cash collateral.[11] The borrowing limit for the Eurosystem was first set at EUR 50 billion, then increased to EUR 75 billion in March 2018 and to EUR 150 billion in November 2021.[12] Figure 4 illustrates the history of the ECB's securities lending balances, categorized by pledged collateral type. From this dataset, we use information on the ISIN, the nominal volume lent and whether the lending was made against cash or securities (i.e., the transaction type).

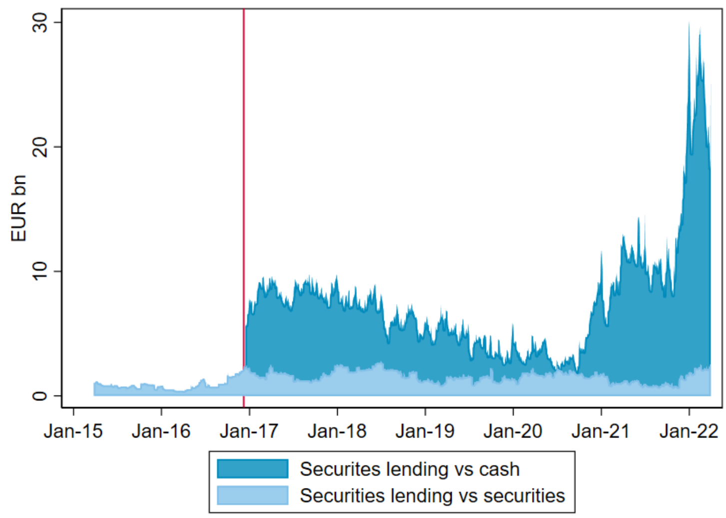
Like purchase programmes, the securities lending of Eurosystem bond holdings is implemented in a decentralised manner, with national central banks using different lending arrangements.[13] Our source, the ECB dataset, includes a broad range of securities, covering ISINs from

[11] See: `https://www.ecb.europa.eu/press/pr/date/2016/html/pr161208_2.en.html`.

[12] See: `https://www.ecb.europa.eu/press/govcdec/otherdec/2021/html/ecb.gc211217~e4ba94a36d.en.html`.

[13] SLF transactions have either an open term or a term period. Open transactions have no fixed maturity and

Figure 4: Daily loans of securities lent by the European Central Bank, breakdown by collateral



Source: ECB
Notes: Values refer to aggregate volumes of daily loans at nominal value. The red line indicates the start of securities lending arrangements against cash.
Last observation: 30 March 2022

all euro area jurisdictions.

3.3 Eurosystem asset purchase programmes and eligibility data

For the purchase programmes, we use ECB proprietary data that includes all PSPP transactions conducted by the Eurosystem at the ISIN-day level. The dataset provides information on the security's ISIN, trade/settlement date, and nominal purchase amount. A bond may be purchased multiple times in a single day by the same or different central banks of the Eurosystem, and our dataset records all such transactions. To aggregate values, we sum the daily volume of all transactions involving the same ISIN. We verify that our dataset is representative by merging it with SC repo transactions data at the ISIN-day level, achieving an 81% match. This suggests our dataset captures the majority of PSPP purchases during this period.

To compute our counterfactual purchase strategy, we need to define the universe of bonds eligible for purchases. The Governing Council established clear rules governing asset eligibility under the PSPP.[14] Among those rules we recall:

1. Debt instruments issued by central, regional or local euro area governments, recognised

are automatically settled every day. They can be terminated on any day within an agreed period of time. Term period transactions have a maturity of up to 14 days. Transactions are settled either on the trade date T, $T+1$, or $T+2$. For both open and term transactions, we use the trade date to merge with the other datasets. Volumes therefore refer to all lending that was agreed on that day regardless of the term of the repo.

[14] For the complete framework of legal and technical rules governing PSPP purchases see ECB (2020).

agencies, international organisations, multilateral development banks located in the euro area are eligible for purchase.

2. Debt instruments must comply with the eligibility criteria (minimum credit rating) for marketable assets for Eurosystem credit operations.[15]

3. Debt instruments must have a minimum residual maturity of 2 years (if purchased before January 2017) and of 1 year (if purchased after January 2017).[16]

4. Debt instruments must have a maximum residual maturity of 30 years.

5. A blackout period applies to debt instruments around the time of their issuance or reissuance and to debt instruments with maturities near to newly issued ones. This ensures compliance with the European treaties of Lisbon and Maastricht, which prohibit monetary financing of euro area governments.[17]

6. Purchases of debt instruments with a negative yield to maturity below (but not equal to) the deposit facility rate can be undertaken to the extent necessary. The requirement was binding at the start of PSPP but was relaxed after January 2017.[18]

7. An issue share limit and an issuer limit, both of 33%, are imposed on holdings (at nominal values) of any security and any euro area government.[19] The issue share limit constrains the maximum amount of a single security that the Eurosystem - after consolidating the holdings of all portfolios from the national central banks - is allowed to purchase. The issuer limit, conversely, constrains the maximum amount of an issuer's total outstanding debt instruments that the Eurosystem - after consolidating the holdings of all portfolios from the national central banks - is allowed to purchase.

Using the requirements listed above, we construct an eligibility indicator in the form of a dummy variable for the PSPP (i.e., 1 if the bond is eligible, 0 otherwise). The data for this variable come from several internal ECB datasets, and, to our knowledge, it represents the most granular eligibility variable used in this literature.

[15] For further details see Article 3 of ECB (2020).
[16] See: https://www.ecb.europa.eu/press/pr/date/2016/html/pr161208_1.en.html.
[17] See https://www.ecb.europa.eu/press/accounts/2015/html/mg150219.en.html.
[18] See: https://www.ecb.europa.eu/press/pr/date/2016/html/pr161208_1.en.html.
[19] The issue share limit was initially set at 25% and was later increased to 33% in September 2015.

3.4 Bond market data and other controls

We complement data on the repo market with daily information on the underlying securities. For each bond, we obtain the nominal value outstanding, issue and maturity date, yield, bid and ask prices, and an indicator for cheapest-to-deliver (CTD) bonds. We also gather data on tapping events, on-the-run bonds, and various issuer characteristics (issuer name, issuer group, sector of issuer, country of the issuer) as well as details about the type of bond and coupon (indicator for stripped and inflation-linked bonds, denomination, coupon rate and frequency). These data are primarily retrieved from an internal ECB Market Operation Dataset (MOPDB) but are supplemented with information from Refinitiv Eikon, Bloomberg, and MTS. Finally, we use information on the nominal amount (before haircut) of collateral pledged in the form of government bonds to the Eurosystem for open market operations.

4 Methodology

We build an empirical model to relate asset purchases to developments in the repo market. We set up a panel regression to explain bond-level variation in SC repo rates across the euro area. The dependent variable is the difference in each ISIN's repo rate over two business days, regardless of whether the days are consecutive. For periods where data from BrokerTec, MTS, and Eurex are provided at the transaction level rather than bond level, we calculate daily bond-level data by computing a volume-weighted average of the repo rates of all the transactions $j = 1, ..., n$ for each ISIN i on trade date t. This step is necessary to align the granularity of the repo market data with all the other data we use, mainly on asset purchases. The dependent variable is then constructed as follows:

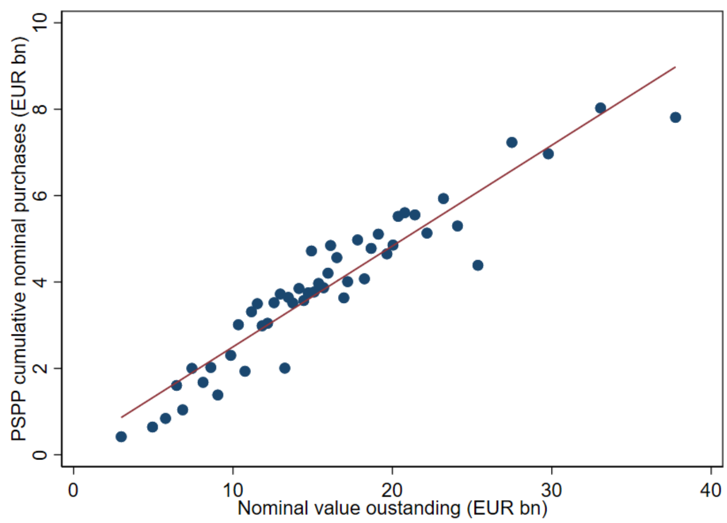
$$RPrate_{i,t} = \frac{\sum_{j=1}^{n} reporate_{i,j,t} \times repovolume_{i,j,t}}{\sum_{j=1}^{n} repovolume_{i,j,t}} \tag{1}$$

We consider the variable in first differences to remove persistent trends from our specification.

4.1 Bond Flexibility

We compute a measure of bond-level flexibility, with the aim to capture the impact on repo rates of particular purchase strategies that the Eurosystem might have implemented under the PSPP. Eurosystem portfolio managers always had some leeway to purchase less-special bonds on any given day, while still meeting their volume target over the month. The extent to which portfolio managers used their discretion is captured by the deviation, at the ISIN level, of the actual purchases from a counterfactual ex-ante market-neutral allocation. The concept of market neutrality was first mentioned by Benoît Cœuré in March 2015 (Cœuré, 2015). Since then, ECB Executive Board Members have referred to market neutrality as a strategy that purchases securities in proportion to their relative (eligible) market capitalisation with the aim of not distorting the relative prices of assets (see e.g., Schnabel, 2021 and Mersch, 2018, ECB, 2019). Indeed, in aggregate figures, the higher the nominal value outstanding of a given security, the higher its representation in the ECB's balance sheet, meaning that Eurosystem's asset managers have allocated their purchases broadly following market capitalisation. This is clearly shown in Figure 5, which illustrates in a bin scatterplot the relationship between cumulative purchases under PSPP as of March 2022 and their nominal value outstanding by ISIN. The correlation coefficient is 0.62. However, the correlation decreases significantly when we consider daily purchases. The coefficient drops to 0.24, suggesting that alternative purchasing strategies might be employed in day-to-day operations, and that these strategies are weakly correlated with the nominal amount outstanding.

Figure 5: Correlation between cumulative PSPP purchases and nominal value oustanding



Source: Authors' calculations on ECB data, Refinitv Eikon and MTS
Notes: Each dot refers to binned cumulative PSPP purchases of a security plotted against its nominal value outstanding. The sample includes purchases of government bonds from DE, FR, ES, IT, BE, NL, AT.
Last observation: 31 March 2022

In principle, there are different approaches to defining a counterfactual ex-ante market-neutral allocation. This could be based on quantities or prices, defined as having no impact on either quantities or prices in a certain market, or linked to particular financial indicators, etc. In sum, there is no single definition of an ex-ante market-neutral allocation. We define our counterfactual ex-ante market-neutral allocation as a purchase strategy where, given a daily target for country c, each day t the central bank buys a bond i as a share of the bond's nominal value outstanding relative to the daily total amount of eligible bonds outstanding for country c in the same day t. Following this kind of strategy in practice would would leave the relative distribution of bonds unchanged by the central bank's purchases. For instance, given a daily country target of EUR 1 billion for a country on a specific day, a bond i with a nominal value outstanding of EUR 10 billion and the country's eligible nominal amount outstanding of EUR 100 billion on the same day, a market neutral purchasing strategy would purchase a proportion of bond i equal to 0.1 of the daily target of EUR 1 billion, namely EUR 100 million. While this strategy focuses on quantities, the final allocation would still affect bond prices if the central bank adopted it. We assume that, as the central bank would leave the relative distribution of bonds unchanged, prices would all shift in the aggregate but not relative to one another. In this sense, our counterfactual ex-ante market-neutral allocation would also be neutral with respect to prices, though it could still account for the purchase-induced drift that is observed in the data and has been already documented in the literature. In particular, our purchase strategy does not account for specialness. In reality, we know Eurosystem's asset managers respond to market conditions, such as repo specialness, as this is explicitly allowed under the PSPP implementation guidelines.[20]

We compare the bond/day allocation derived from our counterfactual strategy with the actual purchases carried out by the ECB. Our main independent variable is then computed as:

$$BondFlex_{i,t} = \underbrace{\frac{NomValOut_{i,t} * PSPPtarget_{c,t}}{eligibleNomValOut_{c,t}}}_{neutral \quad allocation} - \underbrace{PSPPpurchase_{i,t}}_{actual \quad allocation} \tag{2}$$

where $PSPPpurchase_{i,t}$ is the nominal amount of asset purchases of bond i under the PSPP, $PSPPtarget_{c,t}$ is the daily target for PSPP for country c, and $NomValOut_{i,t}$ is the nominal outstanding amount of bond i. Finally, $eligibleNomValOut_{c,t}$ is the sum of the outstanding

[20] The implementation guidelines of the programme repeatedly mention "flexibility" with respect to the adherence to *"the principle of market neutrality via smooth and flexible implementation"* or *"the flexibility is granted to NCBs"* and *"flexibility in the day-to-day selection of securities to be purchased in a jurisdiction is conducive to preserving market liquidity [...] significant efforts are undertaken to avoid buying securities that are scarce"* but also *"flexibility is applied, including to take into account the relative values of bonds and the liquidity of the different maturity segments"*. See `https://www.ecb.europa.eu/mopo/implement/app/html/pspp-qa.en.html`.

amount of all bonds eligible on day t for a country c. This is computed using the PSPP eligibility criteria discussed in Section 3.

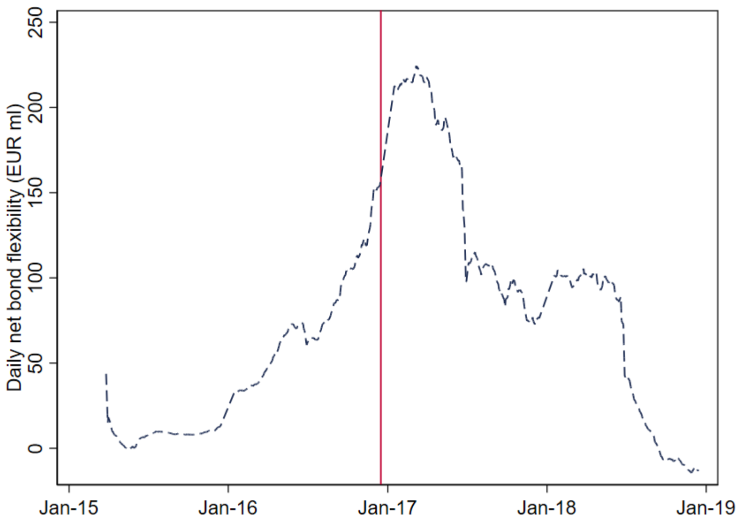
A positive value of our main independent variable – i.e., a positive deviation from the actual allocation - signals that the amount of purchases executed on a given day was fewer than the neutral allocation prescribed, meaning that Eurosystem asset managers purchased less than required to maintain market neutrality under our definition. Figure 6 reports the sum of the daily deviations from our market-neutral allocation. The figure demonstrates that the Eurosystem did indeed deviate from our counterfactual allocation. The evidence suggests that this flexibility was employed to varying degrees over time, increased during the first years of the PSPP, and peaked around the time of the introduction of SLF against cash and the joint expansion of the eligible universe of securities purchasable under the PSPP. In fact, the change in the collateral framework provided asset managers with an opportunity to diversify purchase allocations across a broader range of securities. As explained in Section 3.3, this change enabled them to extend purchases to government bonds with shorter remaining maturities and yields below the DFR. Broadening the range of purchasable securities may have contributed to a reduction in our flexibility measure after 2017.

The measure we propose is first presented in absolute terms (in EUR bn). Later in the analysis, we rescale this measure to EUR 100 ml to facilitate comparisons with prior studies. This approach aligns our results with those in Arrata et al. (2020), the closest paper to ours, which shows that purchases of 1% of a bond's nominal value outstanding have a -0.78 basis points impact on repo rates. In their sample, this corresponds to a theoretical bond purchase of EUR 150 million.[21] However, due to factors such as the programme's design, the central bank has a maximum purchasable limit for each bond. As this amount decreases with higher levels of central bank ownership, an alternative neutral allocation can be computed that considers the effective purchasable space for each bond. Appendix E presents the results using a modified version of our flexibility measure to account for a bond's free float, by which we mean the amount of the bond outstanding minus the portion already held by the central bank. Moreover, using absolute measures can obscure the relative impact of bond purchases across different contexts, for example as these measures do not account for the nominal value outstanding of the bonds being

[21] Regarding the summary statistics for the mean purchase, one can refer to Schlepper et al. (2020), which reports a mean purchase value ranging between EUR 13 ml and EUR 25 ml for PSPP trades on German bonds. This range should roughly match the tick size in other jurisdictions. A theoretical purchase of EUR 150 ml would therefore be an outlier. However, we decided to scale the effect of flexibility on repo rates similarly to Arrata et al. (2020), using EUR 100 ml as a theoretical unit for our variable.

purchased. By employing relative measures, we can more accurately gauge the impact of bond flexibility. To address these limitations and improve the scalability of our findings, Appendix E also presents results using these two alternative definitions of $BondFlex_{i,t}$. These measures provide a broader perspective and help readers interpret the results more comprehensively. Despite these adjustments, the conclusions of our analysis remain consistent with those derived from our baseline regression.

Figure 6: Developments in bond flexibility under the Public Sector Puchase Programme



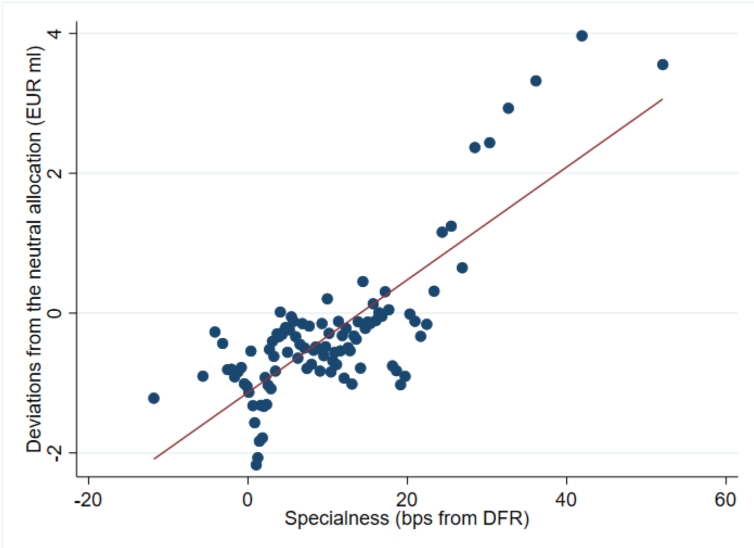
Source: Authors' calculations on ECB data and Refinitv Eikon.
Notes: The figure reports the time series of daily net sum of bond flexibility in response to specialness. The measure is calculated as in Equation (2). We only select repos with rates above the 90^{th} percentile, which in our sample roughly corresponds to a repo rate of 25 basis points below the DFR. We further apply a moving average filter of 6 month and exclude year-ends and periods of heightened volatility. The red line indicates the introduction of SLF against cash collateral and the broadening of the eligibility rules for PSPP. The sample includes observations from DE, FR, ES, IT, BE, NL, AT.
Last observation: 1 January 2019

There appears to be a strong and positive relationship between specialness and flexibility at the bond level in the data. Figure 7 supports the claim that larger deviations from our neutral allocation occur on days when bonds are more expensive in the repo market, or are deemed more special. We will assess this relation more formally in the remainder of the paper.

4.2 The Model and the Endogeneity of Bond Flexibility

In this paper, we aim to shed light on a "flexibility channel" in the design and implementation of asset purchases, which could mitigate policy-induced scarcity in the repo market. Conceptually, the practice of focusing purchases on less-special bonds whenever possible might have contributed to a less pronounced overall repo specialness associated with a given amount of

Figure 7: The relation between specialness and bond flexibility



Source: Authors' calculations on BrokerTec, MTS, Eurex and ECB data
Notes: Variables observations are binned for easier visualization and interpretation. The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. We also exclude outlier observations such as year-ends and period of heightened volatility. A higher value of flexibility means that asset managers purchase less than the neutral allocation prescribes, as in Equation (2).
Last observation: 1 Jan 2019

asset purchases over time. Eurosystem's asset managers acknowledge that buying certain bonds may result in a higher specialness premium for that bond and potentially impact the repo market. Therefore, on any given day they exercise leeway on purchases while still fulfilling their volume target over the month. As previously noted, the implementation guidelines of the PSPP explicitly state that *"significant efforts are undertaken to avoid buying securities that are scarce, as measured by metrics such as [..] pricing in the repo market"*.[22] Therefore, the relationship between specialness in the market and the implementation of purchases might suffer from endogeneity problems. It follows that simply regressing the daily difference of repo rates on our flexibility measure for the instances when a purchase was made would deliver a biased coefficient. Nonetheless, running this regression can still provide useful information.[23] Consider a snapshot of the market as in Figure 8. Each day, a bond can be either eligible/not eligible under the PSPP and either purchased/not purchased. Computing the deviations from the neutral

[22]See `https://www.ecb.europa.eu/mopo/implement/app/html/pspp-qa.en.html`.

[23]The computation of specialness as the first difference of special repo rates follows Arrata et al. (2020). As explained in their paper, the computation of specialness based on GC rates would not be suitable for a panel exercise with high heterogeneity in GC repo rates, for instance, due to sovereign credit risk. In addition, we control for the general level of interest rates through our time fixed effects, and we employ country-by-time fixed effects in most of our specifications which absorb country-specific intercepts. Thus, having SC rates or spread between a GC and SC rates would not yield different results, as GC effects would be captured by the country-time fixed effects.

allocation exclusively for eligible and purchased bonds (green rows in Figure 8) would fail to capture the impact of purchases that could have been executed but were not (the yellow rows in Figure 8) due to, for instance, Eurosystem asset managers avoiding purchases in unfavorable market conditions. For this reason, the coefficient would be downward-biased. The analysis would underestimate the impact of flexibility, but at the same time it would provide a plausible lower bound. Therefore, we find it informative to show the results of the following specification:

$$\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad QEpurchase_{i,t} > 0 \tag{3}$$

Where i is an ISIN and t is a day. As mentioned above, this specification captures the "endogenous" effect, considering only realized deviations from the neutral allocation (i.e., when a purchase is made, $QEpurchase_{i,t} > 0$). This corresponds to estimating the impact using the green rows in Figure 8.

Figure 8: The endogeneity between repo specialness and bond flexibility

ISIN	DATE	REPO RATE	ELIGIBLE	SPECIALNESS	QE PURCHASES	BOND FLEXIBILITY
A	01/01/2022	-0.12	NO	NO	-	-
A	02/01/2022	-0.15	NO	NO	-	-
A	03/01/2022	-0.24	YES	YES	4	+2
A	04/01/2022	-0.13	NO	NO	-	-
A	05/01/2022	-0.25	YES	YES	3	+1
A	06/01/2022	-0.37	YES	YES	0	-2
A	07/01/2022	-0.45	YES	YES	0	+3
A	08/01/2022	-0.13	NO	NO	-	-
A	09/01/2022	-0.11	YES	NO	5	-7
A	10/01/2022	-0.14	NO	NO	-	-
...	...	...	...	...	...	...

Our identification strategy overcomes the endogeneity issue by computing deviations from the market-neutral allocation daily for every bond, subject to the bond's compliance with PSPP's eligibility criteria, as described in Section 3.3. By computing our independent variable for all eligible bonds daily, our strategy accounts for both observed deviations from the neutral allocation (i.e., when a bond is eligible and purchased) and unobserved deviations (i.e. when a bond is eligible but not purchased). The exogeneity of the eligibility criteria of the PSPP - established before the programme's initiation – ensures the orthogonality of our measure to repo market's developments. For successful causal identification of the "flexibility channel", it is crucial to also account for these cases. Therefore, we run the following specification:

$$\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad (4)$$

The estimation accounts for the effect of the green and yellow rows in Figure 8. If endogeneity affects our estimation, we should observe a substantial increase in the coefficient of $BondFlex_{i,t}$.

Finally, we test whether the estimated impact of bond flexibility on repo rates is stronger for highly special bonds. We focus on a sub-sample of our dataset which contains the most special repo trades. To run this test, we use multiple definitions of "specialness". Substantial positive deviations from the neutral allocation in response to specialness would intuitively support the hypothesis that flexibility in purchases is linked to repo market specialness. We test this hypothesis using specification (4) while restricting the sample based on alternative definitions of specialness.[24]

Unless otherwise stated, in our specifications we use bond and time-country fixed effects (α_i and α_t) to capture heterogeneities across securities (e.g., issue date, coupon rate, etc.) and in the macroeconomic and monetary policy environment at the country level (e.g., excess liquidity, repo rates levels, issuer dynamics, etc.). Error terms ($\epsilon_{i,t}$) are clustered by country-maturity bucket to account for correlations in the standard errors among bonds with similar residual maturities.[25]

5 Results

In this section, we first substantiate our claim that deviations of actual purchases from our measure of market-neutral allocation are mainly driven by specialness in the repo market, and subsequently quantify how much flexibility in asset purchases mitigates policy-induced specialness in the repo market. We also confirm previous results that the introduction and use of the SLF reduced specialness in the repo market.

Flexibility in the daily allocation of sovereign bond purchases can be used in response to a

[24] Endogeneity might arise also from the interplay between the bond market structure and asset purchases. in their recent work, Breckenfelder et al. (2023) identify a recurring pattern in German sovereign bond prices at month-end during the PSPP. This finding raises potential concerns about endogeneity in our analysis, as market participants might anticipate and react to the central bank's purchasing behaviour, impacting the extent to which the ECB's asset managers may employ flexibility in purchases. Appendix B replicates the analysis in Breckenfelder et al. (2023) for our flexibility measure to assess whether predictable patterns emerged at the end of each month.

[25] We use five buckets. Bonds are categorized into buckets based on their remaining maturity: below one year, one to two years, two to five years, five to ten years, and above ten years.

variety of factors, for instance, the pricing of bonds, repo specialness and bond liquidity (see e.g., De Santis and Holm-Hadulla, 2020, Schlepper et al., 2020 and Baltzer et al., 2022). In what follows, we aim to gain insights into the factors that influenced the decision-making process of the Eurosystem's asset managers under the PSPP. To do so, we regress our measure of bond flexibility on several explanatory variables as shown in specification (5):

$$BondFlex_{i,t} = \beta_0 + \beta_1 Specialness_{i,t} + \beta_2 Bondyield_{i,t} + \beta_3 BidaskSpread_{i,t} + \\ + \beta_4 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \tag{5}$$

We run our regression on data from 26 March 2015 to 1 January 2019. We end the sample at the beginning of 2019, which coincides with the end of net asset purchases and the start of the period of reinvestments under the PSPP. Table 1 shows that repo specialness ($Specialness_{i,t}$), measured as the spread of a bond's repo rate from the ECB Deposit Facility Rate, seems to be the most important driver of daily deviations of actual purchases from our neutral allocation. A 1-basis-point higher specialness, at day-bond level, is correlated with roughly EUR 100 million more bond flexibility employed by the Eurosystem's asset managers. The coefficient remains significant, and increases in magnitude, if we lag the variable by one day. We also find threshold effects when the Eurosystem's holdings of a bond under the PSPP exceed 20% of the bond's nominal value outstanding. That is, the closer the holdings are to the issuer limit of 33%, the more asset managers positively deviate from the neutral allocation (either they purchase less or do not purchase at all). These results substantiate our claim that our measure of flexibility indeed responds to specialness, supporting the empirical finding that asset managers pay attention to market conditions when buying securities under the asset purchase programmes – in line with Schlepper et al. (2020) and Baltzer et al. (2022). As mentioned in Section 4.2, this result raises endogeneity concerns.

We then proceed by comparing the impact of flexibility in asset purchases on repo rates in the endogenous and exogenous specifications.[26] Results are in Column (1a) and Column (1b) of Table (2) respectively. Both specifications yield a positive coefficient, implying that the use of flexibility at bond level has a positive impact on repo rates. A higher rate in SC repos is to be interpreted as a reduction in the specialness income for a given security and hence, a lower cost of sourcing a special bond. Column (1b) of Table 2 shows that in the period analysed, a EUR 100 million deviation from the neutral allocation for a bond - in other words, purchasing

[26] We report the full results of the endogenous specification in Table 7 of Appendix A.

Table 1: FE panel regressions of bond flexibility on explanatory variables

	(1)	(2)	(3)
Specialness	0.101***	0.090***	
	(3.09)	(2.84)	
Bond yield	-0.583	-1.203	
	(-0.71)	(-1.51)	
Bid-ask spread	0.006	-0.000	
	(0.33)	(-0.02)	
Dummy: PSPP Holdings > 15%		0.895	0.913
		(1.50)	(1.47)
Dummy: PSPP Holdings > 20%		5.033***	4.954***
		(8.29)	(8.03)
Specialness (lagged)			0.118***
			(3.56)
Bond yield (lagged)			-1.174
			(-1.49)
Bid-ask spread (lagged)			0.008
			(0.27)
Constant	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes
Country-Time FE	Yes	Yes	Yes
R-squared	0.17	0.18	0.18
Observations	228,003	228,003	181,298

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of bond flexibility on explanatory variables: $BondFlex_{i,t} = \beta_0 + \beta_1 Specialness_{i,t} + \beta_2 Bondyield_{i,t} + \beta_3 BidaskSpread_{i,t} + \beta_4 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$, see specification (5). $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

less than the neutral allocation prescribes - increases its repo rates by up to 0.43 basis points (0.42 with country-time fixed effect and 0.58 for the lagged variable, see Columns (2) and (3) respectively). We report the results in EUR 100 million to align with the existing literature. For comparison, Arrata et al. (2020) shows that purchases of 1% of a bond's nominal value outstanding have a -0.78 basis points impact on repo rates. This corresponds to a theoretical purchase of a bond of EUR 150 million in their sample. Compared to the results in Column (1a) (0.21), the estimations corroborate the initial hypothesis that the coefficients of specification (3) are downward-biased, because of the endogeneity between bond flexibility and repo rates. Again, the bias originates from the failure to account for the purchases - and the resulting deviations from the neutral allocation - that could have been made, but were not made, due to the Eurosystem's asset managers reacting to unfavourable market conditions. When unobserved deviations are accounted for, the magnitude of the coefficients almost doubles in size across all specifications. In the endogenous regressions shown in Column (1a), a EUR 100 million deviation from the neutral allocation for a bond increases its repo rates by 0.21 basis points. The current benchmark bond-level estimation of the impact of the Eurosystem's asset purchases on repo rates is provided by Arrata et al. (2020), who estimate a downward impact of -0.78 basis points.[27] In a rough estimate, comparing the coefficient from our endogenous regression (0.21) and the endogenous estimation provided by Arrata et al. (2020) (-0.78) suggests that approximately one fourth of the mechanical impact of asset purchases on repos can be mitigated with a flexible implementation of purchases.

Our specification also allows us to shed light on other specialness-mitigating factors and tools. Table 2 shows several interesting results. Column (4) shows our findings when we control for data on the SLF and on the collateral pledged by banks with the Eurosystem in monetary policy operations. The granularity of the data on the ECB's SLF transactions allows us to distinguish between securities lending transactions backed by cash and those backed by securities. While transactions against cash impact the supply of collateral to the market and reduce scarcity, trades against collateral do not and, therefore, we are not surprised to find a non-significant impact for the latter. The significant coefficient of SLF against cash ranges between 0.16 to

[27]In results not shown here we estimate the impact of the Eurosystem's asset purchases on our sample in a similar fashion to Arrata et al. (2020). We find that purchasing 1% of the nominal value outstanding (approximately EUR 145 million on average in our sample) of a bond reduces repo rates by -0.86 basis points. Our estimates on the effect of plain purchases are then in line with the existing literature. Arrata et al. (2020) also uses an instrumental variable regression to deal with the endogeneity between asset purchases and repo rates and estimates a causal impact of 4.6 basis points.

0.20 basis points for a EUR 100 million of collateral released into the market. Using a different measure and sample, the estimates of de Souza and Hudepohl (2024) are broadly in line with ours. In results not shown here, we also test the impact of lagged securities lending flows. The coefficient is more significant, albeit smaller in magnitude, for up to three days of lags.[28] We also find a negative coefficient for the Eurosystem's operations that withdraw collateral from the market, such as Targeted Longer-Term Refinancing Operations (TLTROs). These operations act on repo rates in a similar fashion as asset purchases but have a smaller impact. For EUR 100 million of marketable collateral pledged with the Eurosystem through TLTROs, we find that its repo rate decreases by 0.017 basis points in our sample.

In Column (5a) we further introduce a number of bond controls which are standard in the literature such as tapping events, on-the-run-bonds, cheapest-to-delivery (CTD) bonds and bond market liquidity conditions.[29] In our sample, we classify a bond as on-the-run if it is traded in the repo market in the first three weeks after issuance. The coefficient for on-the-run bonds is significant and negative in sign, as expected. Such bonds are in fact often used for short-selling and the high demand for these bonds pushes their repo rates lower than those of their off-the-run counterparts (i.e., bonds with an earlier issuance date) (Jordan and Jordan, 1997). We also expect - and detect - an opposite effect for a tapped bond - a bond whose nominal value outstanding increases. During the period around re-issuance dates, bonds tend to experience high demand in the repo market and often appear in special repos (D'Amico et al., 2018). Results are qualitatively unchanged if we exclude year-ends and periods of heightened volatility (Column (5b)). Contrary to the existing literature we do not find a significant effect of CTD bonds in the futures market.[30] After controlling for a variety of bond-level controls, we find that a deviation from the neutral allocation of EUR 100 million increases repo rates by between 0.41 and 0.43 basis points depending on the specification. So, despite the lower magnitude, our baseline result still holds.

Finally, we focus on the most special repo trades in our sample. We observe that the top 10% of the most expensive transactions in our dataset have a rate that is approximately 25 basis points below the ECB Deposit Facility Rate. Using this threshold, we create a dummy variable,

[28] Results are available upon request.

[29] On-the-run bonds are newly issued instruments for a particular maturity and country. These bonds are well-known to be the most traded securities because of their high liquidity. The high volume of transactions for on-the-run bonds tends to make these securities' prices higher and their yields lower (Krishnamurthy, 2002).

[30] However, this could be due to our particular sample, as it only includes data on CTD for a subset of countries from the Eurex platform, focusing primarily on Germany and Italian bonds.

Table 2: FE panel regressions of repo rates on bond flexibility and bond-level controls

	Endogenous	Exogenous					
	(1a)	(1b)	(2)	(3)	(4)	(5a)	(5b)
Bond Flexibility	0.213**	0.430***	0.423***		0.412***	0.412***	0.427***
	(2.63)	(4.64)	(4.51)		(4.43)	(4.52)	(4.99)
Bond Flexibility (lagged)				0.581***			
				(7.94)			
SL vs cash					0.164*	0.165*	0.207***
					(1.79)	(1.80)	(2.80)
SL vs securities					0.121	0.114	0.183
					(0.49)	(0.46)	(0.65)
OMO Collateral					-0.017***	-0.017***	-0.022***
					(-2.99)	(-3.02)	(-4.95)
Dummy: Cheapest-to-deliver						-0.038	-0.033
						(-0.90)	(-0.82)
Dummy: On-the-run						-0.293**	-0.300**
						(-2.22)	(-2.30)
Dummy: Tapping						0.219***	0.177*
						(3.11)	(1.87)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	Yes	No	No	No	No	No
Country-Time FE	No	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.58	0.54	0.51	0.53	0.53	0.53	0.51
Observations	48,872	226,944	227,761	180,623	180,818	180,818	169,307

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility. For Column (1a) we use specification (3): $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad QEpurchase_{i,t} > 0$. We report the full results of the endogenous specification in Table 7 of Appendix A. For Column (1b)-(5b) we use specification (4): $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$. $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Column (5b) excludes year-ends and periods of heightened volatility. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

$Specialness_{i,t}$, and run specification (4) using various subsamples. We expect the coefficients of bond flexibility to increase considerably if the Eurosystem's asset managers react to specialness by deviating substantially from the neutral allocation. Results of the fixed effects regressions are reported in Table 3 and show a very strong impact of bond flexibility on the most special repo rates. In the sample considered, a deviation of EUR 100 ml from the neutral allocation now increases repo rates by between 1.37 to 1.48 basis points. We report the full set of coefficients in Table 8 of Appendix C.

Table 3: FE panel regressions of repo rates on bond flexibility and bond-level controls for special rates

	(1)	(2)	(3)	(4)	(5a)	(5b)
Bond Flexibility	1.415***	1.442***		1.474***	1.371***	1.475***
	(2.88)	(3.35)		(3.08)	(2.86)	(3.57)
Bond Flexibility (lagged)			1.521***			
			(7.84)			
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	No	No	No	No	No
Country-Time FE	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	Yes	Yes	Yes
R-squared	0.67	0.62	0.64	0.64	0.64	0.65
Observations	17,300	19,037	15,210	15,103	15,103	13,099

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility: $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad specialness_{i,t} = 1$. We define a rate "special" if the rate is above the 90^{th} percentile, which roughly corresponds a repo rate approximately below 25 basis points the ECB Deposit Facility Rate. The controls used are SLF vs cash, SLF vs securities, OMO collateral, dummy for cheapest-to-deliver, dummy for on-the-run, dummy for tapping. $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Column (5b) excludes year-ends and periods of heightened volatility. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

We also run three additional specifications including the controls and fixed effects as in Table 3, Column (5a), but we change the definition of specialness. We compute the 75^{th}, 80^{th} and 95^{th} percentiles of the repo rates in the sample and define "special" (i.e., set $Specialness_{i,t} = 1$) the rates above the percentile thresholds. We report the panel regressions coefficient of bond flexibility in Figure 10 of Appendix C. For reference, we also report the coefficient of the top 10% of the most expensive repo trades (1.37 in green, see Table 3 Column (5a)), which again, corresponds to the 90^{th} percentile. Overall, despite a visible increase in the coefficients across samples, the baseline results remain qualitatively unaffected.

6 Robustness

In this section we run several robustness analyses, considering different sample periods, focusing on particular countries, and testing the exogeneity of some of our assumptions.

6.1 Sub-sample analysis and the Covid-19 pandemic sample

In this subsection we run specification (4) while restricting our sample to German and Italian observations and compare the results to those for the rest of the countries in the sample. The purpose of this exercise is to make sure our findings are not driven by a subset of countries. We single out Germany and Italy because the evidence suggests that these two countries - Germany in particular - were especially affected by repo specialness in the period considered. Table 4 shows the regressions' results. Columns (1), (3) and (4) report the results for the regressions without bond-level controls, while Columns (2), (4), (6) include them. The coefficients of the regressions for German collateral-backed repos are significantly higher than the baseline estimations. Compared to Table 2 Column (2), the coefficient almost doubles. The coefficients for Italian collateral-backed repos are instead close to the baseline estimations - despite with a lower significance. The same argument applies to the remaining countries. Overall, we conclude that no specific country is driving the panel's results.

Table 4: FE panel regressions of repo rates on bond flexibility and bond-level controls for country's sub-samples

	(1) DE	(2) DE	(3) IT	(4) IT	(5) Other sample	(6) Other sample
Bond Flexibility	0.791**	0.769**	0.293**	0.352**	0.319***	0.286***
	(3.78)	(3.59)	(5.40)	(3.25)	(2.88)	(2.89)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	No	No
Country-Time FE	No	No	No	No	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
R-squared	0.47	0.50	0.59	0.59	0.49	0.51
Observations	37,712	29,896	67,298	53,448	122,751	97,474

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility: $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$ for a sub-sample of countries, see specification (4). The controls used are SLF vs cash, SLF vs securities, OMO collateral, dummy for cheapest-to-deliver, dummy for on-the-run, dummy for tapping. $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Statistical significance is evaluated based on standard errors, clustered at maturity bucket level.

We also test the impact of bond flexibility for the period March 2020 to March 2022. This sample captures the Covid-19 pandemic and the deployment of the Pandemic Emergency Purchase Programme (PEPP) by the ECB. However, we compute our bond flexibility measure based solely on PSPP purchases because the computation of our measure relies on public announced targets (see Equation 2 in Section 4.1) which did not apply to PEPP. Table 5 shows the results for specification (4) with controls (Column (1)) and without controls (Column (2)) and specification (4) constrained by the specialness dummy with controls (Column (3)) and without controls (Column (4)). Estimates on this shorter sample are lower in magnitude than for the previous sample. We think this is due to two important differences between the samples. First, the envelope of PSPP purchases for this period was rather small as the Eurosystem strongly relied on PEPP purchases to inject reserves into financial markets. For comparison, the volume of net purchases under PSPP from March 2020 - 2022 amounted to around EUR 450 billion, vs more than EUR 1700 billion of the PEPP. In addition, this period is characterised by a strong issuance of government bonds which likely reduced the impact of asset purchases on the repo market.[31]

Table 5: FE panel regressions of repo rates on bond flexibility and bond-level controls for the Covid-19 pandemic period

	(1)	(2)	(3)	(4)
Bond Flexibility	0.114***	0.122***	0.191***	0.290***
	(6.42)	(5.22)	(2.80)	(3.72)
Constant	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes
Country-Time FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
R-squared	0.72	0.71	0.88	0.85
Observations	162,208	129,228	5,646	4,172

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility. The regression equation in Column (1) and (2) is $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$, see specification (4). The regression equation in Column (3) and (4) is $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad specialness_{i,t} = 1$. We define a rate "special" ($specialness_{i,t}$) if the rate is above the 90^{th} percentile. The controls used are SLF vs cash, SLF vs securities, OMO collateral, dummy for cheapest-to-deliver, dummy for on-the-run, dummy for tapping. $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 25^{th} of March 2020 to the 31^{st} of March 2022. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

[31] ECB (2021) stresses the contribution of issuance activities by euro area governments in explaining repo rates fluctuations in 2020. The activation of PEPP in the first half of 2020 coincided with a strong issuance of government bonds, which possibly contained the downward pressures of unprecedented Eurosystem asset purchases.

6.2 The endogeneity of the collateral framework

Our identification strategy would run into problems if the central bank had modified some of its collateral framework criteria over time to respond to developments in the repo market. Specifically, we refer to point 1, 2, 6, 7 and the change in the minimum residual maturity since 2017 (point 3) in Section 3.3. While we would argue that most of the changes in the collateral framework for PSPP stemmed from considerations related to the cash market - rather than the repo market - we cannot totally exclude this possibility. In that case, the endogeneity between developments in the repo market and eligibility requirements would invalidate our identification. We therefore perform a robustness test where the denominator of Equation (2) - which eventually constrains the sample on which we run our regressions - only accounts for the criteria that were decided ahead of the start of PSPP in March 2015. We run specification (4) using this more constrained version of our independent variable. Table 6 reports the results and shows that the coefficients do not significantly change from the baseline results presented in Table 2 in Section 5. Hence, the stability of results speaks against a significant role of endogeneity in the collateral framework in our estimation.

Table 6: FE panel regressions of repo rates on bond flexibility and bond-level controls - alternative eligibility variable

	(1)	(2)	(3)	(4)	(5a)	(5b)
Bond Flexibility	0.441***	0.426***		0.419***	0.420***	0.440***
	(4.69)	(4.44)		(4.31)	(4.37)	(4.82)
Bond Flexibility (lagged)			0.598***			
			(7.47)			
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	No	No	No	No	No
Country-Time FE	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	Yes	Yes	Yes
R-squared	0.54	0.50	0.52	0.52	0.52	0.50
Observations	225,906	226,012	179,327	179,503	179,503	168,383

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility: $\Delta RPrate_{i,t} = \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$, see specification (4). $BondFlex_{i,t}$ is calculated as in Equation (2) but with an alternative eligibility variable employing minimum and maximum residual maturity requirements and blackout periods, see point 3,4 and 5 of Section 3.3. The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. The controls used are SLF vs cash, SLF vs securities, OMO collateral, dummy for cheapest-to-deliver, dummy for on-the-run, dummy for tapping and lagged bid-ask spread. Column (5b) excludes year-ends and periods of heightened volatility. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

7 Conclusions

This paper provides evidence on the impact of the use of flexibility in the daily allocation of sovereign bonds asset purchases on specialness in the repo market. We find that the implementation strategy of asset purchases matters greatly for repo market outcomes. Specifically, our results suggest that, in the period 2015-2019, flexibility in asset purchases contributed to increasing special repo rates by 0.41 basis points for each EUR 100 million deviation from our neutral allocation. Our findings support the introduction of flexibility in the collateral framework of the Eurosystem's asset purchases as a tool to mitigate the unwanted side effects of balance sheet policies. Our results suggest that a flexible allocation of purchases across time, asset classes, and jurisdictions can be beneficial for achieving a market-neutral allocation of purchases. Our paper also supports previous findings that underscore how facilities such as the SLF attenuate bond scarcity in money markets. Overall, these results enhance the understanding of how unconventional monetary policies affect the repo market and bear important implications for the design of balance sheet policies in the future.

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A Endogenous Regression - Full Results

Table 7: FE panel regressions of repo rates on bond flexibility - full results

	(1)	(2)	(3)
Bond Flexibility	0.213**	0.270***	
	(2.63)	(2.92)	
Bond Flexibility (lagged)			0.340***
			(4.16)
Constant	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	No	No
Country-Time FE	No	Yes	Yes
R-squared	0.58	0.51	0.53
Observations	48,872	53,162	41,426

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility: $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad QEpurchase_{i,t} > 0$, see specification (3). $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

B Market's reaction to asset purchases

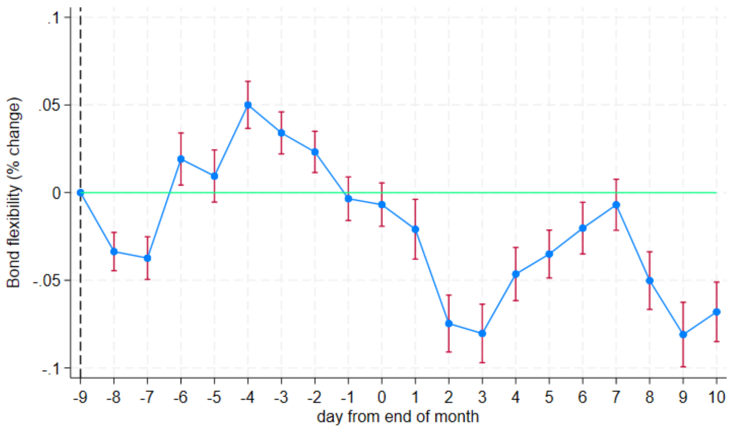
A study by Breckenfelder et al. (2023) identifies a recurring pattern in German sovereign bond prices during the PSPP and may raise concerns about potential endogeneity in our analysis, as market participants might foresee and react to the central bank's purchasing behaviour, impacting the extent to which the ECB's asset managers may employ flexibility in purchases. Motivated by this evidence we replicate their analysis on our sample and in particular on our flexibility measure, to check whether there are predictable patterns at the end of each month.

We then run the following regression specification:

$$log(BondFlex_{i,t}/BondFlex_{i,t-9}) = \sum_{t=-9}^{T=8} \alpha_t \times D_t + \epsilon \quad (6)$$

where D_t is a dummy variable as in Breckenfelder et al. (2023) and $t = 0$ is the last day of the month. Results are shown in Figure 9.

Figure 9: Bond Flexibility (% Change) Over Time



Source: ECB
Notes: The figure shows the percentage change in bond flexibility over a period of days relative to the end of the month, ranging from 9 days before to 10 days after the month-end.
Last observation: 30 March 2022

Bond flexibility indeed exhibits some variability before and after the month-end. The highest positive percentage change is approximately 0.05% before month-end and the lowest is -0.1% after. No significant percentage change appears on day 0. Moreover, positive (negative) percentage changes indicate that the central bank is buying less (more) than the neutral allocation, so if anything this evidence suggests some frontloading of purchases at the beginning of the month and less activity at the end. In the paper, we take the month-end (and quarter-, year-end) effects into consideration by using dummies.

C Extended results

Table 8: FE panel regressions of repo rates on bond flexibility and bond-level controls for special rates

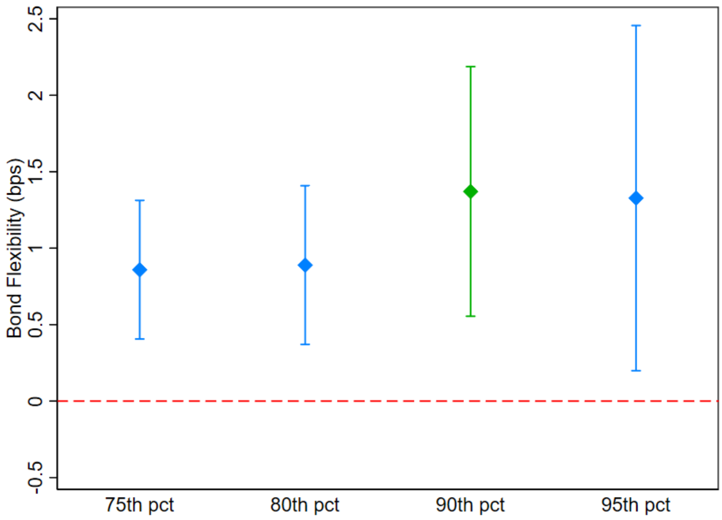
	(1)	(2)	(3)	(4)	(5a)	(5b)
Bond Flexibility	1.415***	1.442***		1.474***	1.371***	1.475***
	(2.88)	(3.35)		(3.08)	(2.86)	(3.57)
Bond Flexibility (lagged)			1.521***			
			(7.84)			
SLF vs cash				0.048	0.045	0.177
				(0.33)	(0.31)	(1.51)
SLF vs securities				2.290	2.259	4.410
				(0.92)	(0.93)	(0.98)
OMO Collateral				-0.081	-0.073	-0.090
				(-1.28)	(-1.19)	(-1.66)
Dummy: Cheapest-to-deliver					-0.188	-0.186
					(-1.26)	(-1.04)
Dummy: On-the-run					-4.430***	-4.679***
					(-4.94)	(-5.01)
Dummy: Tapping					0.062	-0.065
					(0.07)	(-0.07)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	No	No	No	No	No
Country-Time FE	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.67	0.62	0.64	0.64	0.64	0.65
Observations	17,300	19,037	15,210	15,103	15,103	13,099

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility: $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad specialness_{i,t} = 1$. $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26th of March 2015 to the 1st of January 2019. Column (5b) excludes year-ends and periods of hightened volatility. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

Figure 10: FE Panel regression coefficients of repo rates on bond flexibility and bond-level controls by percentile of specialness



Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility: $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \quad if \quad specialness_{i,t} = 1$. The controls used are SLF vs cash, SLF vs securities, OMO collateral, dummy for cheapest-to-deliver, dummy for on-the-run, dummy for tapping. We include bond and country-time fixed effects. The coefficients reported in the figure are of $BondFlex_{i,t}$, which is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

D Empirical Analysis and Tenor Choice

Our analysis focuses on SN tenor. We chose to focus on this tenor because we judged it as the closest to the settlement of cash market outright purchases. The timeline we have in mind is as in Figure 11. This appendix shows the impact of bond flexibility on the repo rates with TN and ON tenor.[32] Table 9 presents the results of the exogenous specification, see Equation 4. Compared to our baseline results, the coefficients are larger for both the TN and ON tenors. We reconcile this evidence by considering how many times a bond can be exchanged in the repo market before it is settled in a QE purchase. Specifically, a SN tenor settles on the same day as the purchase, while the same bond can be repoed multiple times before it is settled in a QE purchase for the TN and ON tenors. Therefore, the potential impact of flexibility might increase given the increased circulation of the collateral. Although the coefficients for the ON and TN tenors have higher magnitude then for the SN tenor, they are less statistically significant.

[32]Thanks to an anonymous referee for this suggestion.

Figure 11: Timeline of the cash market and repo market

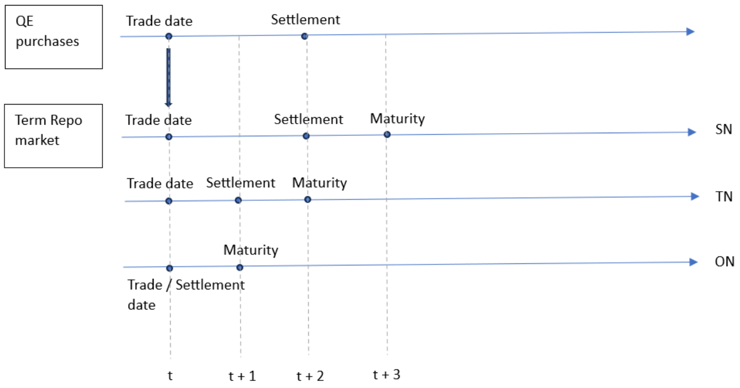


Table 9: FE panel regressions of repo rates on bond flexibility for different repo tenors

	(1) SN	(2) TN	(3) ON
Bond Flexibility	0.430***	0.521**	2.111
	(4.64)	(2.70)	(1.00)
Constant	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	Yes	Yes
Controls	No	No	No
R-squared	0.54	0.26	0.40
Observations	226,944	198,428	11,799

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility for different tenors. We use specification (4): $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$. $BondFlex_{i,t}$ is calculated as in Equation (2). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

E Alternative measures of flexibility

In this Appendix we repeat the regressions for the exogenous specification using two measures of $BondFlex_{i,t}$, a relative measure and a modified absolute measure. First, we rescale $BondFlex_{i,t}$ by the nominal value outstanding of the ISIN as in Equation 7. A relative measure of BondFlex helps the reader to clarify and interpret the results more generally.[33]

$$RelativeBondFlex_{i,t} = \frac{BondFlex_{i,t}}{NomValOut_{i,t}} = \frac{PSPPtarget_{c,t}}{eligibleNomValOut_{c,t}} - \frac{PSPPpurchase_{i,t}}{NomValOut_{i,t}} \quad (7)$$

[33]We thank an anonymous referee for this suggestion.

The results, shown in Table 10 below, are consistent with our previous results. An increase of 1% in the deviation from the neutral allocation of a bond relative to its nominal value outstanding increases repo rates between 0.49 and 0.54 basis points. In our sample, this corresponds to approximately 140 EUR ml. This brings the estimates in the ballpark of our baseline results - expressed in EUR 100 ml - in Table 2. Second, we recompute $BondFlex_{i,t}$ by using the free float of the ISIN and of the country instead of the (eligible) nominal value outstanding, see Equation 8.[34] This way we control for central bank holdings in the computation of the neutral allocation.

$$BondFlex_{i,t} = \frac{Freefloat_{i,t} * PSPPtarget_{c,t}}{Freefloat_{c,t}} - PSPPpurchase_{i,t} \tag{8}$$

The coefficients are comparable to the baseline results in Table 2: a deviation of 100 EUR ml from the neutral allocation increases repo rates by 0.40 and 0.42 basis points, depending on the specification.

[34] By "free float" we mean the amount outstanding less what is held by the central bank.

Table 10: FE panel regressions of repo rates on relative bond flexibility (by bond's nominal value outstanding) and bond-level controls

	(1)	(2)	(3)	(4)	(5a)	(5b)
Relative Bond Flexibility	0.541***	0.532***		0.509***	0.491***	0.504***
	(5.76)	(5.36)		(4.81)	(4.93)	(5.13)
Relative Bond Flexibility (lagged)			0.795***			
			(10.96)			
SL vs cash				0.164*	0.165*	0.207***
				(1.79)	(1.79)	(2.80)
SL vs securities				0.116	0.110	0.178
				(0.47)	(0.44)	(0.62)
OMO Collateral				-0.017***	-0.017***	-0.022***
				(-2.98)	(-3.01)	(-5.01)
Dummy: Cheapest-to-deliver					-0.032	-0.027
					(-0.76)	(-0.66)
Dummy: On-the-run					-0.200	-0.205
					(-1.60)	(-1.65)
Dummy: Tapping					0.216***	0.174*
					(3.09)	(1.85)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	No	No	No	No	No
Country-Time FE	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.54	0.51	0.53	0.53	0.53	0.51
Observations	226,944	227,761	180,623	180,818	180,818	169,307

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility. We use specification (4): $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$. $RelativeBondFlex_{i,t}$ is calculated as in Equation (7). The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Column (5b) excludes year-ends and periods of hightened volatility. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

Table 11: FE panel regressions of repo rates on an alternative (absolute) measure of bond flexibility and bond-level controls

	(1)	(2)	(3)	(4)	(5a)	(5b)
Bond Flexibility	0.427***	0.420***		0.408***	0.408***	0.423***
	(4.65)	(4.51)		(4.42)	(4.51)	(4.98)
Bond Flexibility (lagged)			0.575***			
			(7.95)			
SL vs cash				0.164*	0.165*	0.207***
				(1.79)	(1.79)	(2.80)
SL vs securities				0.121	0.114	0.183
				(0.49)	(0.46)	(0.65)
OMO Collateral				-0.017***	-0.017***	-0.022***
				(-2.99)	(-3.02)	(-4.95)
Dummy: Cheapest-to-deliver					-0.039	-0.034
					(-0.91)	(-0.83)
Dummy: On-the-run					-0.295**	-0.301**
					(-2.23)	(-2.31)
Dummy: Tapping					0.218***	0.176*
					(3.11)	(1.86)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-Bucket-Time FE	Yes	No	No	No	No	No
Country-Time FE	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.54	0.51	0.53	0.53	0.53	0.51
Observations	226,944	227,761	180,623	180,818	180,818	169,307

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table shows coefficients from panel FE regressions of the first difference of daily volume weighted repo rates on bond flexibility. We use specification (4): $\Delta RPrate_{i,t} = \beta_0 + \beta_1 BondFlex_{i,t} + \beta_2 Controls_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t}$. $BondFlex_{i,t}$ is calculated as in Equation (8), which uses the free float. The sample period runs from the 26^{th} of March 2015 to the 1^{st} of January 2019. Column (5b) excludes year-ends and periods of hightened volatility. Statistical significance is evaluated based on standard errors, clustered at maturity bucket-country level.

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