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The effect of asset purchases on repo rates: Evidence from Germany

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Abstract: In recent years, repo rates declined markedly below the European Central Bank (ECB) deposit facility rate, the rate at which banks receive interest for their excess reserves. This coincides with the ECB's Asset Purchase Programs (APPs) launch in October 2014. The thesis analyzes how institutional features of the ECB's monetary policy framework that were designed to support monetary policy and avoid market distortions actually disconnect the repo rates from the key central bank target rates. Specifically, the thesis shows how asset eligibility to the ECB's APPs generates dispersion in repo rates between transactions secured by collateral that is eligible and non-eligible for asset purchases. By purchasing assets in large quantities, the national central banks decreased the available supply of eligible securities in the repo market, rendering them more special and decreasing the repo rates. Using a large micro dataset with daily transaction data in the German repo market, the thesis estimates that repo transactions secured by eligible collateral to the APPs have, on average, a 10 basis points lower rate than transactions with non-eligible collateral.

Keywords: Repo Market, Monetary Policy Transmission, Asset Purchases, Specialness, Central Bank Framework, High-Frequency Data

JEL: E40, E42, E50, E58, G10

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List of Abbreviations

DFR Deposit Facility Rate

APPs Asset Purchase Programs

ECB European Central Bank

PSPP Public Sector Purchase Program

CSPP Corporate Sector Purchase Program

ABSPP Asset-backed Securities Purchase Program

CBPP3 Third Covered Bond Purchase Program

PEPP Pandemic Emergency Purchase Program

CCPs Central Clearing Counterparties

GC General Collateral

SC Specific Collateral

MMSR Money Market Statistical Reporting

CSDB Centralised Security Database

repo repurchase agreements

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1 Introduction

The market for repurchase agreements (repo) is a cornerstone of the money market and constitutes a crucial first step of monetary policy transmission to the economy. The repo market allows financial participants to cover their short-term funding and collateral needs by borrowing and lending cash against collateral. In recent years, repo rates have gained considerable attention since they did not only drop into negative territory but also declined markedly below the European Central Banks Deposit Facility Rate (DFR). The DFR is the target interest rate in the Eurosystem and represents the rate at which banks receive interest for depositing money with the central bank overnight. The decline in repo rates is all the more unexpected since, given repo rates below the DFR, the ECB offers a risk-free, higher rate deposit on banks' excess reserves, theoretically preventing transactions from trading at lower interest rates. An important question is, thus, which frictions hinder the efficient transmission of monetary policy in the repo market. The thesis analyses how security[1] eligibility to the ECB's Asset Purchase Programs (APPs), which were designed to support monetary policy and avoid market distortions, actually drive a wedge between the repo rates of transactions secured by non-eligible and eligible collateral. Unlike most papers in the literature, the thesis does not use security-level data on the daily purchase volume undertaken by the national central banks, but it uses a new set of plausible exogenous events to analyze the effect of security eligibility to the APPs. The novel identification strategy includes: a temporary stop of the asset purchases in 2019 and a change in the eligibility criteria in 2017. The hypothesis is that repo transactions secured by eligible collateral trade below the DFR and at lower rates than transactions collateralized by non-eligible collateral.

The ECB's APPs are a package of unconventional monetary policy measures that were enacted in October 2014 to support the monetary policy transmission mechanism and to counteract growing concerns of prolonged low inflation rates. The objective was to increase inflation to a level below but close to 2%. The programs pumped large amounts of central bank money into the money market. At the peak of the APPs in 2017, the Eurosystem held 1,500 billion euros in government bonds,[2] which constituted around 20% of the entire euro area sovereign bond market (Arrata et al. 2020). By purchasing securities in huge quantities, the Eurosystem has decreased the net available supply of assets in the market and made them, ceteris paribus, scarcer. Especially government bonds, which constitute around 85% of the collateral used in the repo transactions, were the main securities bought under the programs (ECB 2021). Holders of these scarce bonds can demand a below market rate, that is they are only willing to provide the security at a "special" rate (and borrow cash at low negative rates). Security specialness refers to the phenomenon that some repo transactions trade below the prevailing market interest rates. Some repo borrowers might require the securities (e.g., short selling or regulatory reasons) and are accepting to lend money at below market rates. The policy did not only impact the repo market via supply effects but also triggered an increase in demand for eligible assets (Ballensiefen, Ranaldo, and Winterberg 2020). Overall, the decrease in available collateral and increase in demand, increases the specialness premium of eligible securities, disconnecting them from the policy rate and depressing their repo rates.

[1] Throughout the thesis, the words security and asset are used interchangeably. Security in finance refers to a negotiable, fungible financial instrument with some monetary value. A security represents ownership in an entity in the form of a stock or share. There are three primary types of securities: debt, equity, and hybrids. When using the word asset, I refer to a financial asset that describes the economic value of an ownership claim or contractual right. Bonds, stocks, cash, mutual funds, and equities are all examples of assets.

[2] A government bond represents a debt security that is issued by a government to support obligations and spending. Throughout the thesis the word government bond and security are used interchangeably.

The sharp increase in security holdings by the ECB and its national central banks as well as new financial regulations have decreased the availability of high-quality collateral, raising concerns for market participants and policymakers alike. The findings, therefore, have important implications for monetary policy. First, the availability of high-quality securities is widely considered crucial in supporting financial stability and bond pricing (Sunderam 2015). The repo market constitutes an essential link between the shadow banking system and traditional banking, allowing shorting, hedging, and arbitrage trading. By facilitating these transactions, the repo market has become fundamental in ensuring market liquidity and efficiency (D'Amico, Fan, and Kitsul 2018). Liquidity and efficiency in the repo market help to avoid security mispricing in the economy since the repo rate for a specific security indirectly influences the market yields and prices for that particular security (e.g., Duffie 1996, Pelizzon, Subrahmanyam, and Tomio 2018).

Secondly, the repo market plays a crucial role in monetary policy transmission since changes in the policy rates affect the money market first (ECB 2011). At first glance, interest rates below the DFR do not seem to be a worrying issue: With policy rates at the zero lower bound and low inflation rates, negative interest rates should be a positive trend. However, higher rate dispersion in the repo market leads to a lower sensitivity of repo rates to changes in the monetary policy rates (Ballensiefen, Ranaldo, and Winterberg 2020). The lower one-for-one monetary policy transmission has been acknowledged by the ECB. For example, Benoit Coeure, ECB executive board member, has declared: "There is a risk that, under the current framework, some short-term market rates would not respond fully to changes in our key interest rates or, even if they would, that a continued dispersion of short-term rates would adversely impact the transmission of our monetary policy stance", Reuters (2018). Understanding the effects of asset eligibility on the repo market has, thus, important repercussions for the well functioning of the economy, as well as for financial stability.

The thesis uses the German subset of the ECB's Money Market Statistical Reporting (MMSR) dataset that contains high-frequency transaction-level data on repo trades conducted by 115 reporting agents. The dataset is combined with the Centralised Security Database (CSDB), a security-by-security database that has data on issuers, prices, and instruments for debt securities, investment fund shares, and equity instruments issued worldwide. The eligible securities are derived from the list of eligible marketable assets published by the ECB. The analysis covers daily transactions between the German reporting agents and their intra and international counterparties from July 2016 to December 2021.

For the empirical analysis, I run a pooled panel regression where I regress the repo rate on a dummy variable indicating if the security is eligible for purchases under the APPs. The results support the explanation that transactions collateralized by eligible securities trade at significantly lower rates than transactions with non-eligible collateral: The estimated rate difference is 10 basis points.

In the next part, I take advantage of two exogenous changes in the monetary policy framework that allow me to refine my estimation strategy. First, I use the temporary stop of the APPs between January and November 2019 to compare the rate of non-eligible and eligible securities before and after the termination of the purchases. Using the stop of the asset purchases as a difference-in-difference setting, repo rates secured by eligible securities increase during the halt of the APPs, with the difference between non-eligible and eligible securities dropping to 3.69 from 10.7 basis points. When the asset purchases pick up again at the end of 2019, repo rates of eligible securities start to decrease. Over the whole period, the rates of non-eligible assets stay on the same level as the DFR, experiencing almost no reaction to the APPs.

Second, I exploit a change in the monetary policy framework in January 2017 that relaxed some of the eligibility criteria and classified assets as eligible that were previously non-eligible. While in the previous two specifications, the data is grouped by collateral issuer country and sector due to the large size of the dataset, the last specification allows for the analysis to be performed on the security level. I use the modification in the eligibility framework as an event study by comparing repo transactions secured by the same securities that are non-eligible before the policy change and become eligible thereafter. Securities that are non-eligible and become eligible due to some exogenous policy change not only experience a significant drop in the repo rates but are also traded much more frequently. However, the increase in trading volume for eligible securities only explains a small fraction of the decline in repo rates for eligible securities (less than one basis point).

Overall, the results indicate that security eligibility to the ECB's asset purchase programs have a significant negative effect on the repo rates, with eligible securities trading below the rates of non-eligible securities. The results align with findings in the literature that indicate that a 1% increase in asset purchases of a particular security decreases the repo rate of that security by 1 to 3 basis points (see, for instance, Arrata et al. 2020; Corradin and Maddaloni 2020; D'Amico, Fan, and Kitsul 2018). The thesis contributes to the empirical literature on the interlinkage between asset purchases and the repo market in two dimensions: First, the paper is among the first to identify the effect of eligibility on the repo rates instead of using the de facto purchases at the security-day level. Second, I employ a novel set of plausible exogenous changes in the monetary policy framework and analyze a more recent time period.

The thesis has two important implications for monetary policy. First, when conceiving large-scale asset purchase programs, market neutrality over the entire spectrum of eligible securities is crucial for the well functioning of money markets. Increasing the set of targeted securities can help to reduce pressure and avoid scarcity and shortages of specific securities in the market. Second, securities lending, such as the ECB's securities lending facility, can alleviate market pressure. In theory, security specialness only persists because some agents are unwilling to lend the securities they hold. Increasing the scope and pricing options of the lending facilities can help to mitigate pressure. However, the security lending program should not be considered as a magic solution that can solve security scarcity in one go. Some drivers of scarcity, such as window dressing or hedging demand, are beyond the powers of the central bank.

The remainder of the thesis is organized as follows: Section 2 provides an overview of the repo market and the current state of research. The following part, section 3, elaborates on the functioning of the repo market. Thereafter, section 4 describes the data and empirical strategy. In section 5 the thesis then outlines the results and in section 6 tests their robustness. Section 7 gives some limitations and avenues for further research, and section 8 concludes.

2 An introduction to the repo market and the current state of research

2.1 What is a repo?

The first step of monetary policy transmission relies on the money market since changes in the monetary policy affect the money market first. The key instrument in the money markets is the repo transaction, which is now a dominant source of funding liquidity and, therefore, crucial for the central bank's monetary policy pass-through (Ballensiefen, Ranaldo, and Winterberg 2020). After the 2007/08 financial crisis, the repo market has become a predominant source of short-term financing since the European money market experienced a profound shift away from unsecured interbank lending as a source of funding to the secured market (e.g., Mancini, Ranaldo, and Wrampelmeyer 2016). Daily turnover in the secured segment doubled from around 290 billion in 2007 to around 645 billion in 2021, while daily turnover in the unsecured segment has decreased from approximately 170 billion to 20 billion (ECB 2021).

A repo is a trade in which one party (the seller) sells a security, most commonly government bonds, to another party (the buyer) at one price with an agreement to repurchase the security from the buyer at a future date or in case of an open repo on demand (ICMA 2019). The principal use of a repo is the secured lending and borrowing of cash. The repo structure ensures low liquidity and credit risk for the buyer compared to an unsecured transaction. If the seller defaults during the transaction, the buyer can sell the security to a third party to offset the loss. The security, therefore, acts as an insurance and mitigates credit risk. The security of the underlying collateral typically implies that repo rates are below the unsecured market rates and that the deviation from the unsecured rates depends on the value of the collateral (Corradin, Hoerova, and Schepens 2021; Baklanova, Dalton, and Tompaidis 2017). The rate difference between the price paid by the repo buyer at the beginning of the transaction and the price he earns at the end is his profit on the cash that he is lending to the seller. The return is quoted as a percentage and is called the repo rate. For the financial participant selling the security and agreeing to repurchase at a future date, it is a repo. For the participant buying the security and agreeing to sell it in the future, it is a reverse repo (See figure 13).

Some repo transactions are backed by securities from a basket or pool of collateral. These transactions are called General Collateral (GC) repos and trade in the repo market at very similar rates. The buyer of the GC repo (lending cash and borrowing security) is indifferent to the collateral used as long as it offers sufficient credit quality. The collateral used in the transaction can be a single security or a pool of collateral. The primary motivation to enter a GC repo is a priori to lend/borrow cash and is, therefore, often considered as the measure of the cost of borrowing cash (Mancini, Ranaldo, and Wrampelmeyer 2016; CGFS 2017). Other repo trades contain a specific or special security as collateral. A Specific Collateral (SC) repo transaction has a specific collateral (which is in ISIN code) that has to be delivered against cash. In an SC repo, the buyer and seller agree on a specific security for the exchange, while in a GC repo, one security or a security pool is used. SC repo transactions are driven by collateral needs where the seller's primary motivation is to borrow cheap cash and enhance the yield of the portfolio, and the buyer's main motivation is to obtain a specific collateral, e.g., to cover short positions (Schaffner, Ranaldo, and Tsatsaronis 2019). In recent years, a shift in the euro market from more cash-driven to security-driven transactions has been observed. GC trades represent around 10% of total secured transactions while the remaining 90% are special collateral (ECB 2021). An explanation for the different development of the GC and SC transaction volume is excess liquidity induced by the ECB's asset purchases. On average, GC transactions that are primarily used for cash management decline as excess liquidity reduces the banking sector's funding needs (Schaffner, Ranaldo, and Tsatsaronis 2019). SC repo transactions, often used for collateral management, increased over the last years, indicating a shift to a more collateral-driven repo market (ECB 2021).

One can distinguish between three types of repo trades in Europe. First, automatic transactions that are characterized by bilateral collateral management and cleared by Central Clearing Counterparties (CCPs). Those transactions are the principal business model in Europe. Second, automatic transactions that are characterized by tri-party collateral management and cleared by CCPs.[3] This business model is commonly used in the context of GC repo trades (Hu, Pan, and Wang 2021). Third, direct transactions that are characterized by bilateral collateral management and cleared bilaterally. In the last ten years, trading, clearing, and collateral management has been increasingly conducted through automatic trading systems (ATS) that bring together collateral management agents, clearing houses, and the provider of the ATS platforms. In Europe, market trading, especially for government securities, has become increasingly concentrated in the three leading automatic trading platforms: BrokerTec, Eurex Repo, and MTS Repo (Brand, Ferrante, and Hubert 2019). In central clearing, CCPs take on the credit risk of trades by becoming buyers to all sellers and sellers to all buyers (Baklanova, Dalton, and Tompaidis 2017). CCPs eliminate counterparty risk by inserting themselves between the seller and buyer of a previously agreed trade (Boissel et al. 2017).

Government bonds are the dominant type of collateral in the European repo market, accounting for 85% of transactions (ECB 2021). The zero risk and high liquidity of government bonds can explain the reliance on sovereign bond holdings (compared with other securities). Bonds issued by Germany, France, Italy, Spain, the Netherlands, and Belgium account for 92% of total public collateral used in secured transactions. A smaller share of transactions uses collateral issued by the private sector.

2.2 Literature review

The literature can be divided into three branches that analyze monetary policy transmission in the repo market. This section provides the literature overview and names the most influential authors; the following section (3) describes the mechanisms in more detail. Figure 14 in the appendix provides a graphical overview of the literature and where the thesis is positioned in the current state of research.

The first branch of the literature on the repo market analyses monetary policy transmission in the context of market segmentation. For instance, Duffie and Krishnamurthy (2016) examine the pass-through of monetary policy in the United States, focusing on market frictions associated with regulation, infrastructure, institutional segmentation, and imperfect competition within money markets. They develop a new measure of monetary policy dispersion that significantly rises after interest rate hikes. Using the MMSR dataset, Eisenschmidt, Ma, and Zhang (2020) show that dealer market power generates substantial frictions for the monetary policy pass-through in the European repo market. They find that a secured funding facility like the Fed's Reverse Repurchase Facility (RRP) can mitigate dealer market

[3] In a triparty repo, a third entity (apart from the repo buyer and seller) acts as an intermediary between the two parties to facilitate collateral selection, management, and payment.

power and enhance monetary policy transmission. Vari (2020) studies how monetary policy transmission is impacted by market fragmentation, which results from the fact that banks, depending on their country of location, have different probabilities of default. He shows that once fragmentation is introduced in the model, excess liquidity arises endogenously, disconnecting short-term rates from the monetary policy rate. Some authors analyze the impact of stricter capital and liquidity requirements like the Basel regulations that have increased the resilience and ability of banks to provide credit to the economy even in times of stress (Hernandez de Cos 2021), but have also created market frictions. Most of the research focuses on the Basel III leverage ratio (LC), finding that the LC decreases bank's repo borrowing backed by high-quality collateral (see, for instance, Allahrakha, Cetina, and Munyan 2018; Noss and Patel 2019; Ranaldo, Schaffner, and Vasios 2021; Bicu-Lieb, Chen, and Elliott 2020). In Europe, regulatory constraints often bind at specific dates, mainly quarter and year-ends. This leads to significant window dressing around the reporting dates because banks must report their balance sheets at these dates. (e.g., Klee, Senyuz, and Yoldas 2016; Duffie and Krishnamurthy 2016; Munyan 2017).

The second branch of the literature analyses the linkage between security specialness and the effect of asset purchases on the repo market. Security specialness refers to the phenomenon that some repo transactions trade below the prevailing market interest rates. The difference between the market and special interest rate describes the premium of procuring a specific asset since repo buyers are willing to accept below-market interest rates to acquire the security (Duffie 1996). Ballensiefen, Ranaldo, and Winterberg (2020) analyze the effect of collateral eligibility to the APPs and deposit facility access by banks on the continuous transmission of monetary policy. They show that banks with access to the central bank deposit facility and security eligibility to the ECB APPs lead to a repo rates being more misaligned from the monetary policy rate. Corradin and Maddaloni (2020) study how the Italian government bond scarcity premium in the repo market was affected by the ECB's purchases during the euro area sovereign debt crisis. They show that ECB purchases increase the specialness and short-selling of targeted securities. Using propriety data from the ECB's Public Sector Purchase Program (PSPP), Arrata et al. (2020) empirically examine the scarcity channel of the PSPP and its effect on the level of the repo rates. They find that purchasing 1% of securities outstanding decreases the repo rate by 0.78 basis points. Focusing on repo specialness premium, Brand, Ferrante, and Hubert (2019) demonstrate how bank funding stress, structural features of the bond market, and safe asset scarcity have affected repo rates. Ferrari, Guagliano, and Mazzacurati (2017) introduce a new measure of collateral reuse and study the collateral scarcity premium, i.e., the cost of obtaining high-quality collateral that is proxied by the security specialness rate. They find that the cost of high-quality collateral increases with demand pressure through short-selling activities. D'Amico, Fan, and Kitsul (2018) estimate the scarcity value of US treasury collateral by quantifying the effect of security-specific supply and demand factors on collateral repo rates of all outstanding US treasury securities. They find a significant and positive scarcity premium for off- and on-the-run treasuries that prevails for around three months, with a larger magnitude for short-term securities. A more theoretical side of the literature on specialness includes the seminal work of Duffie (1996), who derives causes and symptoms of special repo rates in a competitive repurchase market. Other more recent theoretical contributions include, for instance, Infante (2017) or Nyborg (2019).

A third branch of the literature focuses on the interlinkage between the repo market and other money markets. The literature suggests that central bank purchases have an unintended side effect beyond the repo market: They can affect security yields through the repo market and lead to significant security mispricing. From a theoretical perspective, B. D. Jordan and S. D. Jordan (1997) demonstrate that a higher specialness premium and a lower repo rate for a particular security implies that the security is worth more on the cash market. From an empirical perspective, De Santis and Holm-Hadulla (2017) estimate that the PSPP has, on average, led to a temporary seven basis point decrease in government bond yields on the day of the purchase. The interlinkage between repo rates and asset yields also affects monetary policy rates for other instruments. For example, Pelizzon, Subrahmanyam, and Tomio (2018) demonstrate how the specialness premium also impacts the price of other instruments, such as future contracts, and lead to large security mispricing. Avdjiev, Everett, and Shin (2019) show that the ECB's APPs have left a considerable imprint on international asset portfolios and euro-denominated deposits, indicating a potential cross-border channel of monetary policy. Further, quantitative easing policies also affect bond market liquidity (e.g., Schlepper et al. 2017; Christensen and Gillan 2017).

Contribution: The main contribution of the thesis is to improve the understanding of monetary policy transmission in the German repo market by using a novel identification strategy. The branch of the literature that is the closest is the second one that analyses the linkage between security specialness and the transmission of monetary policy. The contribution to the literature is twofold:

First, I contribute to the research by looking at eligibility instead of de facto purchases. Most authors use proprietary transaction data of daily purchases at the security-day level to assess the impact of an increase in purchases of a particular asset on the repo rate of that security: Arrata et al. (2020) have data on the Public Sector Purchase Program; Corradin and Maddaloni (2020) use data from the Securities Market Program in Italy; Schlepper et al. (2017) employ data for the purchases of German government bonds; D'Amico, Fan, and Kitsul (2018) use data from large-scale asset purchases in the US. In the literature, the supply effect via a decrease in available securities is, thus, well documented. My thesis is one of the only papers that does not look at how much has been purchased at the security level but at the effect of the pure possibility for a security to be bought by the ECB. I am dividing the underlying collateral in a repo transaction into securities that are non-eligible and eligible for APPs. Eligibility does not imply that a security is bought but rather can be bought under the APPs. The thesis provides a first step to better understand security-specific expectation effects about the ECB purchases. As the eligibility criteria are known by market participants and the daily security volume of purchases is not publicly available, I capture the supply effects of a decrease in available eligible securities due to the asset purchases and spillover or expectation effects to eligible securities that are not bought. I leave for further research to disentangle both effects. To my knowledge, only Ballensiefen, Ranaldo, and Winterberg (2020) have used the eligibility distinctions instead of using security-level data of the daily purchase volume. My thesis differs from their paper in that I use the eligibility criteria to analyze the effect of asset purchases on repo rates instead of using the eligibility criteria to explain the reaction of repo rates to changes in the monetary policy target rates.

Second, the thesis contributes to the literature by extending the previous employed time period and using a more comprehensive set of exogenous changes. Most of the papers in the literature have data until 2019 (e.g. D'Amico, Fan, and Kitsul 2018; Ballensiefen, Ranaldo, and Winterberg 2020). In the thesis, I have access to daily transaction level data in the repo market from 2016 to 2021, which, thus, allows me to extend the research to a period of time that has not been analyzed yet. Additionally, the thesis exploits two plausible exogenous changes in the monetary policy framework that have not been used in the current state of research. The events allow me to analyse whether the "new" exogenous changes yield different results to previously employed identification strategies. The main exogenous changes that have been employed so far are the blackout period (De Santis and Holm-Hadulla 2017) in which no securities are allowed to be bought, the eligibility criteria as an instrument for asset purchases (Arrata et al. 2020), and the start of the asset purchases in 2015 for a difference-in-difference analysis (Ballensiefen, Ranaldo, and Winterberg 2020).

3 The repo market in the wake of unconventional monetary policies

3.1 Interlinkage between the cash and the repo market, short and long positions

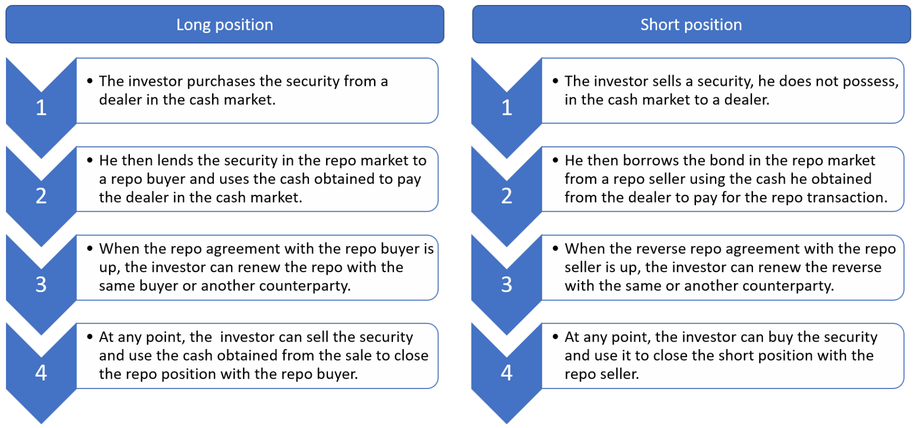
An essential notion in the literature about specialness is the interlinkage between the cash and the repo market. The cash market (or spot market) is a marketplace in which securities or commodities are paid for and received at the settlement date, usually around two to three days after the agreement. For instance, a stock exchange is a cash market because investors receive shares in exchange for cash at the settlement date. In contrast, in the repo market securities are not bought/sold but borrowed/lend for a short period of time.

Suppose an investor purchases a 5-year German government bond from a dealer in the cash market today with payment due tomorrow.[4] On the next business day, the investor has to deliver the funds to pay for the government bonds. To finance the purchase, the investor can sell the asset he acquired in the repo market to a repo buyer and use the cash received to settle the trade with the dealer in the cash market. When the term of the repo agreement is up, the investor can renew the repo with the repo borrower or another counterparty, rolling over the contract and thereby providing continuous financing for his position. At any time, the investor can sell the securities and close the repo position by delivering the cash from the sale in exchange for the assets. He thereby pays off the loan and delivers the securities to complete the sale. In this case, the effect of the repo agreement is that the investor has financed the purchase of the government bond by borrowing money using the securities purchased as collateral. This is also called going long.

An investor going short a position faces the opposite direction. Suppose the investor sells a particular security (a security he does not possess) in the cash market to a dealer today, with delivery due tomorrow. The investor has two options to deliver the security on the next business day in the cash market. Either he buys the security in the cash market from another seller, speculating on a lower price or he engages in a reverse repo transaction; that is, he obtains the asset in the repo market from a repo seller against cash (He lends money and borrows the security). The investor delivers the security to the dealer in the cash market and then uses the money obtained to pay the counterparty in the reverse repo market. The short position can be upheld by renewing the reverse as the term of the repo comes due. The investor can close the position by buying the asset and delivering it the following day in exchange for cash to close the reverse repo. Effectively the investor sold a security to a dealer in the cash market that he did not posse but borrowed in the repo market from a repo seller and bought at a later point, speculating on

[4]Note that the date of the delivery and payment depends on the contract the counterparties decide on, but in the cash market it is most commonly around one to three days.

a lower price. This concept is used in the next section to explain why some financial entities are willing to accept a low repo rate to avoid falling short on their delivery. The following figure (1) depicts the mechanism in more detail.



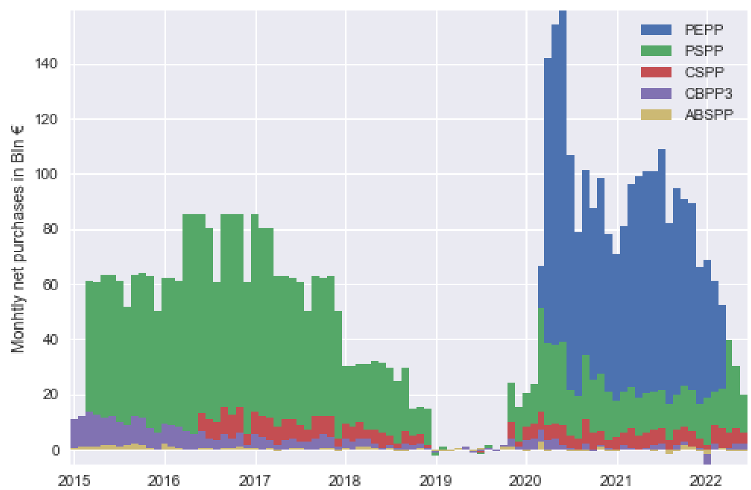
The figure explains the mechanism for short and long positions in the repo and cash market.

Figure 1: Short and long positions

3.2 The repo market and asset purchases: an interplay of different mechanisms

The ECB's APPs are a package of unconventional monetary policy measures that include targeted longer-term refinancing operations. The program was enacted in October 2014 to support the monetary policy transmission mechanism and to counteract growing concerns of prolonged low inflation rates. The objective was to increase inflation to a level below but close to 2%. The program pumped large amounts of central bank money into the money market: Initially, the size of the asset purchases was 60 billion euros per month from March 2015 to March 2016, but subsequently, the ECB expanded the duration and scope of the purchases. At the end of October 2022, the stock of the purchased securities stood at 3,434 billion euros (ECB 2022). The APPs consists of the Corporate Sector Purchase Program (CSPP), the Public Sector Purchase Program (PSPP), the Asset-backed Securities Purchase Program (ABSPP), and the Third Covered Bond Purchase Program (CBPP3). In March 2020, the ECB launched the temporary Pandemic Emergency Purchase Program (PEPP), totalling 1,850 billion Euros in June 2022.[5] Figure 2 depicts the monthly net purchases. To keep market distortions at a minimum, the ECB specifies conditions under which the national central banks are allowed to purchase euro-denominated marketable debt securities (ECB/2020/9). I use the conditions to group the collateral in the repo transaction into non-eligible and eligible for purchases by the national central banks.

[5]Although the PEPP is not counted to be part of the APPs (It is a temporary purchase program), the thesis refers to the APPs as the four programs (CSPP, PSPP, CBPP3 and ABSPP) plus PEPP.



The figure depicts the monthly asset purchases by program. The APPs consist of the Corporate Sector Purchase Program (CSPP), the Public Sector Purchase Program (PSPP), the Asset-backed Securities Purchase Program (ABSPP), the Third Covered Bond Purchase Program (CBPP3), as well as the temporary Pandemic Emergency Purchase Program (PEPP). In 2019, the ECB temporary stopped the asset purchases. Source: ECB

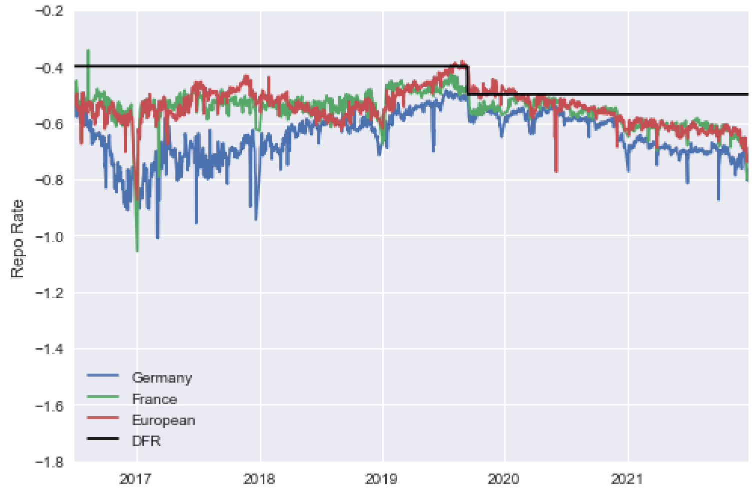
Figure 2: Monthly asset purchases by program

Following the large-scale APPs conducted by the ECB, repo rates did not only drop into negative territory but also declined markedly below the ECB's main policy rates. In the wake of excess liquidity[6], created as a byproduct of asset purchases, a decrease in the money rates does not sound very mysterious: An increase in the supply of available money in the financial system exerts downward pressure on money market rates. Since financial actors do not necessarily require extra liquidity, they are not willing to pay a high interest rate to borrow cash, pushing the repo rates down to the deposit facility rate (e.g., Bech and Monnet 2016; Åberg et al. 2021). The theory predicts that in the wake of excess liquidity, short-term rates decrease until they reach the deposit facility rate and then remain less responsive to further increases in excess liquidity. In principle, repo rates cannot fall below the DFR, because rational agents should not be willing to engage in repo transactions below the DFR. At rates below, financial agents can park their excess reserves at the central bank overnight, receive a more favorable rate and have a lower risk exposure.[7] However, as figure 3 shows, almost all repo transactions trade below the DFR with some repo rates trading at significantly lower rates. The literature stipulates two main factors that can explain the puzzling development of the rates since the start of the asset purchases in 2015.[8]

[6] In the paper, I refer to "liquidity" as the amount of central bank liquidity available to banks. It should not be confounded with market liquidity of the securities used in a repo trade.

[7] At negative repo rates, repo buyers are paying extra money to lend their cash and at repo rates below the DFR, they are paying an even higher amount of money to lend cash.

[8] Unfortunately, the data available is only from July 2016 onwards. Arrata et al. (2020) show that before 2015 repo rates were above the DFR, and with the start of the APPs started to decline and drop below the policy rate.



The graph represents the daily volume-weighted repo rates of transactions that are secured by collateral issued by different countries. The black line depicts the deposit facility rate which is the is target interest rate in the Eurosystem. The DFR is the rate at which banks receive interest for depositing money with the central bank overnight. Source: MMSR

Figure 3: Repo rates by collateral issuer country

First, unequal access to the deposit facility and centralized trading platforms create significant frictions in the repo rates. Repo contracts are traded either over-the-counter or through centralized electronic trading platforms. Participation in one of these e-trading platforms is primarily limited to dealer banks[9] (ICMA 2019). The vast majority of financial market participants have to rely on intermediation by dealer banks to gain access to the repo market. Eisenschmidt, Ma, and Zhang (2020) show how this market friction leads to dealer market power and rate dispersion in the repo market. Financial participants that do not have access to the e-trading platforms do not have an outside option (if they want to participate in the repo market) and are therefore willing to accept rates below the prevailing market rate. For dealer banks, when they engage in a repo, that is, they sell a security and borrow cash, it is beneficial to use their bargaining power and demand a rate as low as possible. Similarly, unequal access to the ECB deposit facility creates bargaining power for access institutions that can price discriminate between customers with a different willingness to pay. In particular, foreign or non-banks cannot access the Eurosystem deposit facility. Access banks can use their bargaining power to remunerate non-access banks at lower rates. Non-access institutions are unable to arbitrage the difference between depositing their liquidity at the central bank or lending it in the repo market, explaining why some repo transaction trade below the prevailing market rates and why the difference between repo rates and the DFR persists (e.g., Arrata et al. 2020; Eisenschmidt, Ma, and Zhang 2020; Koijen et al. 2021).

The second explanation and the bulk of the thesis focuses on security specialness induced by the APPs to explain the low repo rates. As an unintended byproduct of monetary policy, the ECB's asset purchases alter the supply and demand of (high-quality) collateral.[10] At the peak of the APPs in 2017, the Eurosystem held 1,500 billion euros in government bonds, which constituted around 20% of the entire euro area sovereign bond market (Arrata et al. 2020). By purchasing assets in huge quantities, the

[9]A dealer bank is a bank that is authorized to buy and sell debt securities from governments to the investing public.
[10]Note that the ECB via the national central banks did not buy the securities in the repo market, since the repo market is a short term borrowing/selling market, but in other money markets such as the cash market.

Eurosystem has decreased the net available supply of securities in the market and made, all things equal, these securities scarcer. Following Duffie (1996), the holders of scarce assets might demand a specialness premium to lend their securities; that is, they are only willing to provide the security at a repo rate below the prevailing market rate. Consequently, holders of scarce assets obtain extra profits when lending the securities at below-market rates (borrow cash at low negative rates). Some repo buyers (those who lend cash and borrow a security) might need the securities for different purposes, mainly to deliver them after a short sale or for regulatory purposes. As their main motivation to enter a repo transaction is to borrow a specific asset against cash (and since, in some cases, they might require that security), they are willing to lend their money at a lower rate.

- Some financial actors use the repo market to establish short positions; that is, they sell a security they do not possess when prices are high, borrow the security in the repo market to deliver on their contract, and finally buy the security when prices are low. The spread between the price the financial actor pays when initially selling the security and when actually buying it, is the profit on the investment.[11] To deliver the asset and avoid failing on their contract, the short-seller is willing to accept a very low rate in the repo market. Thus, for a given number of short positions, the demand is inelastic to the repo rate of the security. Higher and "price-inelastic" demand leads to lower repo rates for specific securities.

- Regulatory constraints force financial participants to hold certain securities and prevent them from lending those securities in the repo market. For instance, the leverage ratio (LR) disproportionately penalizes low-risk and low-margin activities such as repo intermediation secured by government bonds because it requires banks to hold capital irrespective of the riskiness of the underlying collateral (Gerba and Katsoulis 2021). Consequently, banks cannot as easily intermediate trades between institutions that are short of assets to clients willing to provide those securities. The lack of arbitrage opportunity allows for larger specialness premium to persist. At quarter ends, the effect is stronger because European banks have to comply with those regulations that incentivize them to hold high-quality liquid securities on their balance sheet. (Klee, Senyuz, and Yoldas 2016; CGFS 2017). Financial institutions that hold these assets avoid lending them in the repo market, effectively reducing the supply of specific collateral around reporting dates. Market participants that do not own the securities are willing to accept very low rates to obtain those securities to comply with reporting regulations (e.g., Gerba and Katsoulis 2021; Noss and Patel 2019). According to Duffie 1996, specialness precisely arises because some entities are unwilling to lend their securities. This is consistent with significant rate drops around quarter and year-ends in the dataset (see figure 10 in the appendix).

Following, Arrata et al. (2020), asset purchases did not only decrease the supply of eligible securities but also increased the demand. As holders of eligible securities can demand a specialness premium (a below market rate), investors are incentivized to buy those securities in the cash market and lend them in the repo market at a lower rate, earning a profit (or borrow them in the repo market and then lend them at a lower rate). This also exerts further pressure on the repo rates for eligible securities. In summary, the combination of excess liquidity, the negative deposit facility rate that discourages banks from placing cash at the central bank, a decrease in available high-quality collateral, prudential regulations that encourage

[11] For a more detailed understanding of the interlinkage between the repo market and the cash market, see section 3.1.

banks to hold certain collateral, and inelastic and high demand from short sellers has led to large amounts of cash chasing few securities (Ferrari, Guagliano, and Mazzacurati 2017).

Building on these theoretical foundations, the thesis analyses the impact of eligibility to the APPs on the repo market. By purchasing eligible securities, the Eurosystem decreases their supply, increasing their scarcity and specialness. On the other hand, because eligible (high-quality) assets are increasingly demanded (because of short selling and regulations), their repo rates become largely driven by collateral demand, disconnecting them from the monetary policy rate. The wedge between non-eligible and eligible securities constitutes an unintended side effect of the quantitative easing programs that can increase rate dispersion and limit central bank control over monetary policy pass-through. Figure 12 in the appendix explains this mechanism further. Following the theoretical predictions, I test the following two hypotheses:

H1: Repo transactions collateralized by eligible collateral trade below the deposit facility rate and significantly below the rates of non-eligible securities.

H2: Repo transactions collateralized by non-eligible collateral do not experience a significant reaction to the stop of the asset purchase programs while the rate of eligible securities increases during a period of no asset purchases.

4 Data and Methodology

4.1 Data

The primary dataset used is the German subset of the Money Market Statistical Reporting (MMSR) dataset that contains daily transaction-level data for 115 reporting agents.[12] The data collection is based on the ECB regulation (ECB/2014/48) that requires the biggest financial institutes in the Eurozone to report money market transactions to their respective National Central Banks (NCB). Reporting agents are obliged to report all money market transactions conducted with general governments, financial corporations (except central banks), or non-financial corporations classified as "wholesale" according to the Basel III LCR framework. The dataset contains information on the secured and unsecured money market, the foreign exchange swaps market, and the euro overnight index swaps market. I focus on the secured money market segment, which includes fixed-term and open-basis repo agreements, securities lending against cash, and buy- and sell-back transactions. I further restrict the data to repo transactions. For each transaction, reported information contains the following: information about the reporting agents and counterparty, trading, settlement, maturity dates, interest rates, collateral, haircut, as well as volume and terms of the transaction. The dataset contains around 17 million observations with 10,500 transactions per day.[13] Additional information on the collateral of the repo transaction is taken from the Centralized Security Database (CSDB) at the Bundesbank.[14] The CSDB is a security-by-security database that contains data on issuers, prices, and instruments for debt securities, investment fund shares, and equity instruments issued worldwide. For instance, in the reporting month of June 2021, the CSDB includes more than 13 million securities. The monthly CSDB data is merged with the daily MMSR dataset with the ISIN code and date (monthly/daily adjustment) as matching variables. To distinguish between non-eligible and eligible collateral, I use the ECB's list of eligible marketable assets. The list is updated weekly

[12] The main reporting agents are banks.
[13] For more information on the dataset see Hirsch and Yalcin-Roder (2022).
[14] For more details on the dataset see Bundesbank (2021).

and includes ISIN numbers of eligible securities to the ECB APPs. The data does not only include a list of eligible ISIN numbers, but it contains a list of securities that are eligible on that day. Thus, it allows to measure the effect of changes in the eligibility framework. Because of the sheer size of the three datasets, I use the Hadoop Ecosystem[15] for the data aggregation and cleaning work. This section describes some of the data selections made.

I focus on short-term repo transactions in the Overnight (ON), Tomorrow-Next (TN), and Spot-Next (SN) term segments with the repurchase taking place on the next business day. I keep short-term repos for two reasons: First, these term types make up 97% of the entire trading volume in the dataset, and second, repo trades with longer maturities are riskier and exhibit higher rate dispersion (Ballensiefen, Ranaldo, and Winterberg 2020). I keep bilateral transactions and exclude triparty repos.[16] I further exclude floating rate repos since they are more volatile and only make up a small percentage of the entire trading volume (around 5%). In the literature, it is common to focus on centrally cleared transactions since central clearing removes frictions such as counterparty credit risk (e.g., Brand, Ferrante, and Hubert 2019). However, for output and confidentiality[17] reasons, I further include non-centrally cleared repos collateralized by securities issued by Governments[18], European, and International Institutions. These repo transactions have, on average, lower repo rates than centrally cleared transactions, but they are not as low and volatile as non-centrally-cleared transactions collateralized by private sector securities. Repos with non-eligible assets have a higher share of non-centrally cleared trades than transactions secured by eligible collateral: 71.8% of repo transactions collateralized with eligible securities are centrally cleared, while 30.1% secured with non-eligible collateral are centrally cleared. Throughout the regression analysis, I control for the central clearing status of the transaction. Since eligibility only applies to single securities, I keep transactions with one security pledged as underlying collateral and drop transactions with a collateral pool. In the dataset, single collateral makes up 93.8% of the collateral used in the trades.

The data used covers the period from July 2016 to December 2021. After data preparation and cleaning, the subset includes, on average, 9,000 transactions per day secured by 4,865 different securities (by ISIN number). 99.3% of the sample involves repo transactions collateralized by eligible and 0.7% by non-eligible securities.[19] The German subset of the MMSR data does not include many transactions secured by non-eligible collateral. However, it needs to be kept in mind that after data cleaning, the dataset still comprises more than 14 million transactions. Thus, although 0.7% is a relatively low number, I still have around 90,000 observations for transactions with non-eligible collateral. Table 10 in the appendix gives an overview of the variables and data sources used. Figure 4 shows the average repo volume per transaction in a given week.

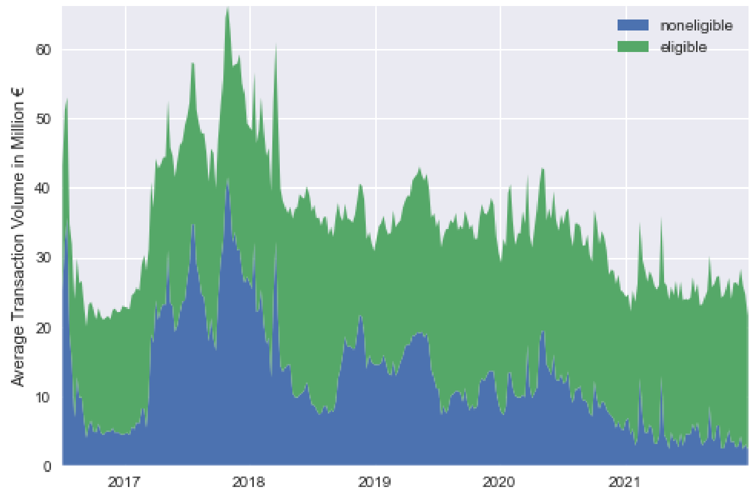
[15] Hadoop is an open-source platform that provides services to interact with Big Data.

[16] Triparty transactions make up around 6.5% of the entire trading volume in the data.

[17] The Deutsche Bundesbank has put in place requirements for researchers and employees working with microdata to ensure data confidentiality. For the non-eligible subset for some trading days, my graphs violated the p% dominance rule that requires at least five different entities where the two largest entities must not exceed 85% of the total value.

[18] For the non-centrally cleared repos, I drop all African, Asian, South American, and Eastern Non-European issuer countries.

[19] Each transaction is weighted by its nominal trading volume.



The graph represents the average nominal amount per repo transaction in a given week for securities that are eligible and non-eligible to the ECB's asset purchases. Source: MMSR

Figure 4: Average transaction volume

The following table provides summary statistics of the main variables used. In line with the expectations, eligible securities trade, on average, over the entire time period at -0.598%, while non-eligible securities have a significantly higher rate of -0.413%. Non-eligible securities used in repo transactions have a much higher share of general collateral (gc_collateral) than eligible securities (52.2% versus 19.5%). This aligns with the hypothesis that eligible collateral is specifically demanded in a repo trade, while non-eligible collateral is less demanded and more used in GC transactions for cash management purposes. On-the-run securities are the most recently issued securities of a particular issuer and maturity. Off-the-run securities are the opposite of on-the-run securities. Off-the-run assets have been issued before an issuer's most recent issue and are still outstanding. The share of on-the-run securities for eligible collateral is 73.6% , while the share of on-the-run securities for non-eligible collateral is lower at 62.2%. Since on-the-run assets most commonly trade at lower repo rates, it is crucial to control for the on-the-run status of the security to avoid any omitted variable bias. The residual maturity[20] of the collateral is slightly lower for eligible securities. (10.6 years versus 8.2 years). Eligible collateral has, on average, a significantly lower yield to maturity of 0.166%.[21] From the perspective of the German banking system, the share of repo transactions (borrow cash and sell a security) is higher for trades secured by non-eligible securities (65.1% versus 59.2%). This implies that German institutions, on average, engage in more repo transactions than reverse repos. The difference in percentage for non-eligible and eligible collateral aligns with the expectations: Short sellers mainly engage in reverse repo transactions to deliver on their engagements, and I expect eligible collateral to have a higher share of short selling. The average nominal amount in euros per transaction is higher for eligible than for non-eligible securities. In the eligible segment, government securities are predominant with a share of 92.3%. In the non-eligible segment, the share of government securities is at 85.2%. This underlines the findings in other studies that indicate

[20]Residual maturity is defined as the difference between the maturity date of the collateral and the date when the repo transaction takes place.

[21]Yield to maturity describes the anticipated return of a security if it is held until it matures. It is expressed as an annual rate.

a share of government collateral of around 85% (ECB 2021). While European collateral issuers make up 96.7% of eligible collateral, they constitute 83.2% of the non-eligible collateral. This is consistent with the eligibility definition: To be eligible for the Eurosystem's credit operations, the collateral has to be denominated in euros. The German banking system has a higher share of non-European counterparties when trading non-eligible collateral than when trading eligible securities.

	non-eligible				eligible			
	mean	SD	p(25)[1]	p(75)[1]	mean	SD	p(25)[1]	p(75)[1]
Repo Rate	-0.413	0.359	-0.798	-0.231	-0.598	0.242	-0.899	-0.417
Centrally cleared	0.301		0	1	0.718		0	1
GC collateral	0.522		0	1	0.195		0	1
On-the-run	0.622		0	1	0.736		0	1
Remain. maturity coll.	3891.988	3490.068	694	5770.600	3026.479	3070.534	573.320	4634.255
Collateral yield	1.336	1.982	0.376	1.890	0.166	0.799	-0.422	0.593
Transaction type	0.651		0	1	0.592		0	1
Transaction amount	1.5e+07	7.9e+07	3.1e+06	6.6e+07	3.1e+07	4.1e+07	8.3e+05	8.2e+07
Share gov securities	0.852		0	1	0.923		0	1
Share EU issuer	0.832		0	1	0.967		0	1
Share EU counterparty	0.877		0	1	0.918		0	1
Observations	93943				13372585			

[1] For the dummy variables, no percentiles and standard deviations are shown.

The table presents summary statistics for the main variables used across the analysis. The central clearing variable is 1 when the transaction is centrally cleared and 0 otherwise. The general collateral dummy takes the value 1 when the asset is GC and 0 for SC. The on-the-run dummy takes the value 1 when the security is on-the-run and 0 otherwise. The transaction type dummy takes the value 1 for a repo trade and 0 for a reverse repo. The three share variables take the value 1 when the counterparty (or collateral issuer) is European (or a supranational bond) and 0 otherwise.

Table 1: Summary Statistics

4.2 Empirical strategy

The thesis analyses how security eligibility criteria, set by the ECB to avoid market distortions, drive a wedge between the repo rates of transactions secured by non-eligible and eligible collateral. Following other major central banks, the ECB announced in 2014 its intention to conduct large-scale asset purchases. The eligibility criteria that specifies conditions under which the ECB via national central banks is allowed to purchase euro-denominated marketable debt securities has been put in place to keep market distortions at a minimum (ECB/2020/9). The key provisions include: (1) a maturity constraint that determines the minimum and maximum remaining maturity of a security; (2) no purchases on the primary market; (3) a blackout period during which securities cannot be bought.[22]; and (4) the purchase of only euro-denominated marketable debt securities.[23] I use the ECB marketable asset database to group collateral in a repo trade into non-eligible and eligible based on the provisions that were binding at the point in time. I argue that the restrictions the Eurosystem imposes on the eligible securities are exogenous to the

[22] This rule implies that securities cannot be bought around their issuance or re-issuance dates.
[23] A list of marketable assets can be found at: `https://www.ecb.europa.eu/paym/coll/assets/html/index.en.html`

repo market. The eligibility criteria were put in place before the start of the asset purchases and before specialness became prevalent in the repo market (Arrata et al. 2020). The technical and legal regulations apply to any security, independently of its repo rate or the repo rate of its neighboring securities. The ECB conducts the purchases in a gradual manner, aiming to achieve market neutrality and avoid interfering with the formation of market prices (ECB 2018). Thus, the eligibility criteria provide a suitable source of exogenous variation.

In the first part, I estimate the effect of eligibility on repo rates by regressing the eligibility dummy on the volume-weighted repo rate. In the second part, I take advantage of exogenous changes in the monetary policy framework that allow me to refine my coefficient estimates for non-eligible and eligible securities. I consider two exogenous changes: A temporary stop in the APPs from January to November 2019 and a change in the eligibility framework in 2017 that relaxed some of the eligibility conditions.

4.2.1 Repo rates by eligibility

This specification tests the effect of eligibility on repo rates (hypothesis 1). The baseline regression reads as follows:

$$RepoRate_{it} = \alpha + \beta_1 D_i^{eligible} + \beta_n Controls_i + FE_{country,sector} + FE_{day} + \epsilon_{it} \tag{1}$$

where $RepoRate_{it}$ represents the volume-weighted repo rate on day t for transaction i; $D_i^{eligible}$ is a dummy variable taking the value 1 if the security is eligible to the APPs. The data is aggregated by trading day, eligibility, collateral issuer sector, country, general collateral, whether the security is on-the-run, and by the central clearing status of the transaction. For the other continuous variables such as the repo rate, the remaining maturity, or the yield of the collateral, a weighted average by the transaction volume of the trade is taken.[24] Ideally, one would not aggregate the data and exploit the full variation of the dataset at security level, but the data, even after data cleaning, is too large to perform a regression analysis.[25] From the data aggregation it follows that t represents the day and i the aggregated transactions per day, eligibility, for a given collateral issuer country and sector, centrally clearing status, as well as an on-the-run/off-the-run and general/specific collateral transaction. Each day has an non-eligible and eligible observation per aggregated group variable, which by construction does not vary over time.[26] All regressions include collateral issuer country and sector fixed effects ($FE_{country,sector}$), which capture heterogeneity in security types (e.g., differences in corporate or government securities) and country specific factors (e.g., risk profile, country credit rating, political uncertainty). Controlling for country fixed effects is particularly important, since, for instance, German securities experience a higher specialness premium (trade below the prevailing market rates) than other European issued securities (Arrata et al. 2020). I further control for daily time fixed effects (FE_{day}) that capture time variant variables such as inflation or excess liquidity as well as joint movements in the repo rates such as year or quarter-end effects induced by window dressing. Since standard errors are most likely correlated within clusters of the same collateral

[24] Two factors determine the trading volume: the cash volume used in the transaction and the daily transaction count (how many times a security is traded per day).

[25] The original data contains information at the transaction level, that is the trade conducted between two counterparties, the security used, the repo rate, and some more information.

[26] A security can become eligible/non-eligible over time, but at the level of data aggregation, I cannot distinguish whether one security issued by, for instance, BMW becomes non-eligible. This security issued by BMW will change from the bucket of eligible German corporate securities to the non-eligible bucket for German corporate securities on the next day. This change is unobserved since on the next day, the German government non-eligible and eligible bucket remains.

issuer countries and sectors, I cluster standard errors at the issuer sector-country level. In the robustness section, I illustrate that the results are also statistically significant across a variety of cluster and fixed effect specifications.

I follow Corradin and Maddaloni (2020) and Arrata et al. (2020) and employ a general collateral dummy that indicates whether the collateral used in the repo transaction is general collateral (GC) or specific collateral (SC). General collateral is mainly used for cash management purposes and is considered the market repo rate on a specific day. Specific collateral mostly trades at repo rates below the general collateral rate due to asset specialness and short selling. I also divide securities into on-the-run (the most recently issued securities of a particular maturity and issuer) and off-the-run securities.[27] On-the-run securities demand a cash premium because they are more liquid than their off-the-run counterparts and are valued by short-sellers (e.g., D'Amico, Fan, and Kitsul 2018). Short-sellers prefer on-the-run securities because they can easily be acquired in the market when needed to close short positions (Graveline and McBrady 2011). Comparable off-the-run securities that have been issued earlier tend to have lower liquidity partly because they are more likely to be held by "buy-and-hold" investors and are therefore not always as easily available in the market (Corradin and Maddaloni 2020). Consequently, I expect lower repo rates for on-the-run securities. I further control for some other transaction-specific effects, including the remaining maturity of the underlying collateral, its yield, or if the repo transaction is centrally cleared. These controls ($Controls_i$) vary over time and across securities, but similarly to the eligible dummy, I lose the time variation by aggregating the data. Table 2 shows a mean comparison test for the main control variables, indicating that they are significantly different across the non-eligible and eligible groups.

	non-eligible	eligible	mean comparison	
	mean	mean	t-value	p-value
Repo Rate	-0.413	-0.598	23.168	0.000
Centrally cleared	0.301	0.718	-297.953	0.000
GC collateral	0.522	0.195	178.102	0.000
On-the-run	0.622	0.736	22.803	0.000
Remaining maturity collateral (days)	3891.988	3026.479	59.844	0.000
Collateral yield to maturity	1.336	0.166	372.462	0.000
Observations	93943	13372585		

The table presents a t-test for the repo rate and main control variables.

Table 2: Comparison in means across eligibility groups

4.2.2 Temporary stop in the asset purchases

I use the fact that the Eurosystem stopped net purchases between January and November 2019 to test hypothesis 2. The end and restart of the APPs provides an 11-month period where no securities have been bought, and only security lending took place. The stop of the purchases and the availability of assets through the ECB's security lending facility should increase the supply of available repo collateral, leading to a convergence in the rates. Since April 2015, the ECB has made a fraction of securities

[27] I did not construct the dummy variables myself but used the data from Michael Schmidt at the Bundesbank.

purchased under the PSPP[28] available for security lending. It is estimated that the program has helped to attenuate the effect, but scarcity premium due to the APPs remain (e.g., Brand, Ferrante, and Hubert 2019; Arrata et al. 2020).

The APPs aim to "provide the amount of policy accommodation needed to ensure price stability" and to "ensure the continued sustained convergence of inflation to levels that are below, but close to 2% over the medium term" (ECB 2018). The temporary stop of the APPs is, thus, unrelated to the repo market and provides a source of exogenous variation. I perform a set of panel analyses where I weigh the pooled regression by the nominal transaction volume of the repo trade. The estimation strategy is a difference-in-difference setting. The treatment variable is the eligibility dummy, the transactions secured by non-eligible collateral constitute the control group, and the stop of the APPs acts as the event variable. The analysis takes data from twelve months before and nine months after the stop of the purchases and excludes the restart.[29] The baseline regression equation can be written as:

$$RepoRate_{it} = \alpha + \beta_1 D_i^{eligible} + \beta_2 D_t^{No\_APP} + \beta_3 D_i^{eligible} \times D_t^{No\_APP} + \beta_n Controls_i + FE_{sector,country} + FE_{day} + \epsilon_{it} \quad (2)$$

$D_t^{No\_APP}$ is a dummy variable taking the value 1 during the stop of the asset purchases. $D_i^{eligible}$ is a dummy variable taking the value 1 if the security is eligible to the APPs. As in regression 1, the data is aggregated by trading day, eligibility, collateral issuer sector, country, general collateral, whether the security is on-the-run, and by the central clearing status of the transactions. For the other continuous variables such as the repo rate, the remaining maturity, or the yield of the collateral, a weighted average by the transaction volume of the trade is taken. By construction, this leads to the time invariance of the eligible variable. Standard errors are clustered at the issuer country-sector level, and issuer country-sector and time-fixed effects ($FE_{sector,country}$) are included. As in the other two specifications, the same security specific controls ($Controls_i$) are added. While regression 1 measures the continuous effect of eligibility on repo rates, this specification compares the rate of (hypothetically) non-eligible and eligible securities before and after the stop of the asset purchases. The regression measures, thus, the effect of the stop of asset purchases on repo rates for non-eligible and eligible securities.

I follow Granger (1969) and Autor (2003) and include leads and lags in the model. The Granger idea is to see if causes happen before consequences and not vice versa. Conditioned on security fixed effects, I test whether the policy change has no anticipatory effects on the repo rates. I estimate the following equation:

$$RepoRate_{it} = \sum_{m=0} \beta_{-m} D_{t-m}^{No\_APP} + \sum_{k=1} \beta_k D_{t+k}^{No\_APP} + \beta_n Controls_i + FE_{sector,country} + \epsilon_{it} \quad (3)$$

where the sums on the right-hand side allow for m lags or post treatment effects and k leads or anticipatory effects. I include 1, 7, 14, and 21 days in leads and lags in the model.

4.2.3 Policy change 2017: Purchases below the DFR

I exploit a change in the APPs framework in January 2017 that increased the pool of securities available for purchases. As of January 2017, the ECB allowed the purchase of securities with a yield to maturity below the deposit facility for all APPs. For the PSPP, the most extensive program, the ECB also decreased

[28] Since 2016, securities bought under the covered bond purchase programs are also available for security lending.
[29] An explanation for this choice of time is provided in section 5.2.1.

the minimum remaining maturity of the security from two to one year. These two exogenous changes relaxed the eligibility criteria and classified some securities as eligible that were previously non-eligible. I keep all repo transactions with collateral that is non-eligible in 2016 and becomes eligible in 2017 due to the policy change. In the dataset, 163 traded securities are affected. The modification in the eligibility framework is unrelated to the repo market since the ECB changed the criteria to continue with "the smooth implementation of the Eurosystem's asset purchases" and adapt to market realities (ECB 2016). The yield criteria were relaxed based on the fact that some assets had a yield to maturity below the DFR and not on the repo rates of the securities or neighboring securities. A similar argument applies to the maturity relaxation: The decision to decrease the minimum requirement from two to one year was not based on the repo market but to increase the available securities for purchases. This specification refines the estimated results from the naive regression and tests hypothesis 1.

The regression setup is an event study where I compare the rate of securities when they are non-eligible and become eligible due to the event. I restrict the period to 6 months before and after the policy change. The data is aggregated at the security-time level[30], standard errors are clustered at the security level, and security-fixed effects ($FE_{security}$) are included in the regression. The security fixed effects, ensure that all security specific characteristics are accounted for, given that they are time invariant. Since the event varies over time and not across entities, the eligible dummy ($D_t^{eligible}$) takes the value 0 in 2016 and 1 in 2017 for all securities, I do not include daily time-fixed effects. I replace the time fixed effects with some macro control variables ($Controls_t$). I follow Corradin and Maddaloni (2020) and Arrata et al. (2020) by controlling for excess liquidity in the economy and expectations about market volatility with the Vstoxx index, an index of perceived economic uncertainty. Excess liquidity describes the volume of extra money in the banking system that has been increasing over the last years because of the ECB's asset purchases and its quasi-unlimited lending of money to banks in the euro area. I calculate excess liquidity based on the Eurosystem's balance sheet as $ExcessLiquidity = CurrentAccount + DepositFacilityRecourse - MinimumReservesRequirement$. I also control for the monthly amount of asset purchases and the GC pooling rate, that is the rate at which the Eurex GC pooling basket is traded. The GC pooling rate is a common benchmark for the short-term secured funding market (Arrata et al. 2020). As in the regression above the same security specific controls ($Controls_{it}$) are included. In this specification, since I aggregate at security level, the control variables vary across entities and time. The regression reads as follows:

$$RepoRate_{it} = \alpha + \beta_1 D_t^{eligible} + \beta_n Controls_{it} + \beta_k Macro\_Controls_t + FE_{security} + \epsilon_{it} \quad (4)$$

where the subscript t stands for day and i for the security traded.

As in the previous specification, I employ a Granger causality test. Conditioned on security fixed effects, I test whether the APPs have no anticipatory effects on the repo rates. I estimate the following equation:

$$RepoRate_{it} = \sum_{m=0} \beta_{-m} D_{t-m}^{Policy} + \sum_{k=1} \beta_k D_{t+k}^{Policy} + \beta_n Controls_{it} + \beta_k Macro\_Controls_t + FE_{security} + \epsilon_{it} \quad (5)$$

where the sums on the right hand side allow for m lags or post treatment effects and k leads or anticipatory effects. I include 1, 7, 14, and 21 days in leads and lags in the model.

[30]Most securities are traded several times a day. I take the volume-weighted average per security and day.

5 Results

5.1 Repo rates by eligibility

The figure presents the repo rates for securities that are eligible and non-eligible to the asset purchases. The average volume-weighed rates for eligible and non-eligible securities in a given week are shown on the right y-axis. The red line depicts the deposit facility rate, which is the target interest rate in the Eurosystem. On the left y-axis, the light blue bars indicate the monthly asset purchases by the central banks. Source: MMSR and ECB

Figure 5: Repo rates by security eligibility

Figure 5 provides a graphical intuition of hypothesis 1, that repo rates secured by securities eligible for the APPs have lower repo rates than non-eligible securities. The figure plots the average weekly repo rate for non-eligible and eligible securities on the right y-axis, as well as the monthly volume of asset purchases on the left y-axis. The graph clearly shows the persistence of a significant difference between the rates. The repo rate for eligible securities is disconnected from the DFR, the monetary policy rate, while the rate for non-eligible securities (ignoring the higher volatility) closely tracks the DFR. One problem of the analysis is the higher rate volatility for repo trades secured by non-eligible collateral. The volatile rates can be explained by the fact that I have fewer observations for non-eligible collateral. Outliers, therefore, have a more significant impact, leading to higher rate dispersion. From 2016 to 2019, the rate difference between transactions with non-eligible and eligible collateral decreases. The gap becomes smaller because the rate of the eligible repo transactions increases while the rate of the non-eligible transactions stays at the same level. During the time of no asset purchases from January to November 2019, the increase in the repo rates for transactions collateralized by eligible securities becomes stronger. At the restart of the purchases, lagged by around four months, the rate of trades with eligible collateral decreases while the rate of repo transactions secured by non-eligible collateral stays close to the level of the DFR. This is in line with the theoretical predictions and hypothesis 2: A decrease (increase) in asset purchases, as shown by the light-blue bars, increases (decreases) the available supply of collateral, which all else equal renders eligible securities less (more) scarce and increases (decreases) the repo rates of trades secured by eligible collateral. Surprisingly, repo rates with non-eligible collateral do not react to the 10-basis point policy rate cut in September 2019, while repo rates secured by eligible collateral decrease after the rate change. This finding is puzzling since I would have expected rates of transactions secured by eligible securities to react less to the rate cut than the non-eligible assets. Ballensiefen, Ranaldo, and Winterberg (2020) show in a continuous pass-through analysis that repo rates with eligible securities have a 50% lower sensitivity to changes in the monetary policy rate than repo transactions with non-eligible securities. The contrary findings can most likely be explained by higher rate volatility and a higher share of non-European collateral among the non-eligible securities.

	(1)	(2)	(3)
	Repo Rate	Repo Rate	Repo Rate
eligible	-0.0902**	-0.0926**	-0.0882**
	(0.0431)	(0.0435)	(0.0438)
eligible×run	-0.00458**		
	(0.000474)		
on_the_run	-0.00854		-0.00481
	(0.00543)		(0.00477)
eligible×gc		0.00308**	
		(0.00188)	
gc_collateral		0.0466***	0.0654***
		(0.00932)	(0.0358)
_cons	-0.668***	-0.687***	-0.702***
	(0.0458)	(0.0311)	(0.0358)
N	126608	134200	126608
adj. R^2	0.426	0.474	0.456
Entity_FE	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes

Standard errors in parentheses clustered at the issuer country-sector level.

* $p < .10$, ** $p < .05$, *** $p < .01$

The table analyzes the effect of eligibility on the repo rates. Regression (1) through (3) employ different variable specifications to account for heterogeneity across collateral types. All regressions include issuer sector-country fixed effects, day fixed effects, and control variables. The eligible dummy takes the value 1 when the asset is eligible and 0 otherwise. The on-the-run dummy takes the value 1 when the security is on-the-run. The general collateral dummy takes the value 1 when the security is GC and 0 when SC. The data is aggregated by trading day, eligibility, collateral issuer sector, country, general collateral, whether the security is on-the-run, and by the central clearing status of the transactions.

Table 3: Naïve Regression

Table 3 displays the naïve regression results, showing the effect of eligibility on the repo rates. As expected, the coefficient on the eligible dummy is negative and highly significant, indicating a substantial rate difference for repo transactions secured by eligible and non-eligible collateral. The effect of asset purchases is likely heterogeneous across different security characteristics. Therefore, regression (1) employs an on-the-run dummy, regression (2) uses a general collateral control variable, and regression (3) includes both. In regression (1), repo trades secured by eligible securities that are off-the-run trade at 9.02 basis points below the repo trades collateralized by non-eligible, off-the-run securities.[31] For on-the-run securities the rate difference becomes stronger and increases further by 0.46 basis points. The insignificance of the on-run dummy indicates that the on-the-run variable does not have an effect on the repo rates per se, but given the significant interaction term, decreases the repo rates for eligible securities. Eligible securities that are specifically demanded (SC) have, on average, a 9.26 basis points lower rate than specific non-eligible collateral (Regression 2). For general collateral, the rate difference between non-eligible and eligible securities is smaller, at 8.95 basis points. The positive coefficient on the general collateral dummy is in line with the expectation, indicating that specific collateral trades at lower repo rates. For eligible securities general collateral trades at 4.97 basis points more and for non-eligible securities it trades at 4.66 basis points more. Regression (3) shows that the effect on eligible securities does not change significantly when not controlling for differences in control variables across the eligible groups. Overall the results validate hypothesis 1 of a negative effect of eligibility on repo rates. In the robustness section, I demonstrate that the estimates hold for different subsets (e.g., government, corporate, European securities) and across different control variable specifications.

5.2 Exploiting exogenous changes in the monetary policy framework

5.2.1 A temporary stop in the asset purchases

The regression set-up is a difference-in-difference setting with repo transactions secured by non-eligible collateral as the control group. From figure 5, it becomes evident that the data violates the parallel trend assumption. The repo rate of transactions with eligible collateral is not parallel to the rate for transactions with non-eligible securities prior to the stop of the APPs purchases. Since, in this period, the volume of the asset purchases also decreased, an increase in the repo rate is not an unexpected trend and in line with the theoretical predictions.[32] However, to compare the repo rates for non-eligible and eligible securities before and after the asset purchases stop, I restrict the sample of eligible securities. I keep transactions pledged by collateral issued by Portuguese, Spanish, Italian, Finish, French, Slovak, Slovenian, Lithuanian, Luxemburgish, or Cypriot entities. Repo trades collateralized by securities issued by these countries experience almost no trend prior to the stop of the purchases (figure 6); that is, they do not react significantly to small decreases in the volume of purchases but only to the stop of the purchases. Figure 3 shows that repo trades secured by collateral issued by different countries trade at distinct rates, with some country rates experiencing an increase in the period before the halt of the purchases and other countries showing almost no trend. The allocation of purchases across jurisdictions following the capital key might explain why repo rates by some countries experience a strong increase to a decline in purchases, and other countries' repo rates almost no trend.[33] The ECB has put in place a capital key, which reflects the country's respective share in GDP and population as a percentage of the whole EU.[34] It follows that securities by some countries (e.g., German government bonds) experience

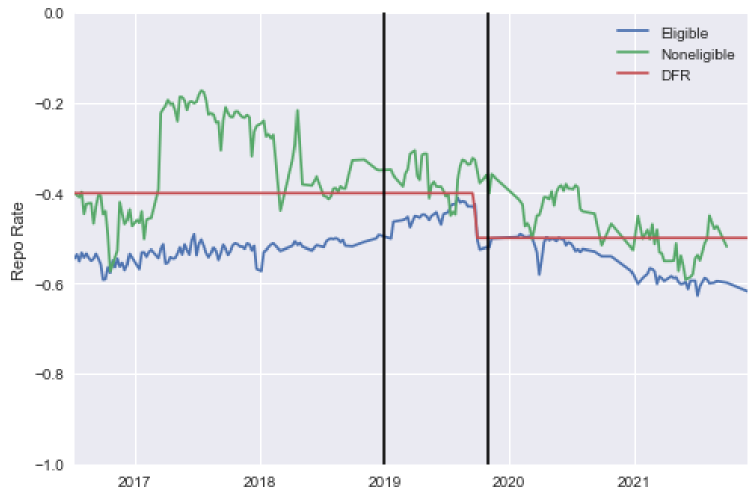
[31] The fixed effects imply that I analyze the effect of a security becoming eligible within one day and within a given country-sector bucket. From the data aggregation, it follows that security technically stands for the volume-weighted average of securities on a day, in a given country, sector, and other group variables. But for notational ease, I refer to the difference in non-eligible and eligible securities for the rest of this interpretation.

[32] Most of the trend prior to the halt of the APP is driven by traded German securities that experience a stronger rate growth.

[33] Repo rates secured by collateral issued by all countries significantly react to the stop in the purchases but experience different strong responses to smaller margin changes in the purchases.

[34] Each country's share can be found on the ECB website: `https://www.ecb.europa.eu/ecb/orga/capital/html/index.en.html`

a higher share of purchases than securities by other countries. Shortly before the ECB announced the restart of the APPs, they also decreased the policy rate by 10 basis points to -0.5%. To avoid picking up rate turmoil around the decrease in the policy rates, I do not include repo trades after September 2019. I further exclude the period before 2018 to eliminate the higher rates of non-eligible securities in 2017. This leaves a sample period from January 2018 to September 2019, with the APPs stopping on January 2019 as event.



The figure shows the average weekly repo rates for non-eligible and eligible securities before and after the stop of the asset purchases from January to November 2019. The red line depicts the deposit facility rate which is the target interest rate in the Eurosystem. To take out a pre-trend in the rate of eligible securities before the asset purchases, transactions with collateral issued by Portuguese, Spanish, Italian, Finish, French, Slovak, Slovenian, Lithuanian, Luxemburgish, or Cypriot entities is included. The black vertical lines indicate the stop and restart of the asset purchases. Source: MMSR

Figure 6: Repo rates by eligibility

Table 4 considers the impact of market segmentation along the lines of security eligibility in a difference-in-difference setting.[35] Regression (1) uses the full dataset with fixed effects, regression (2) includes entity-fixed effects, but no time-fixed effects, and regression (3) takes the subset of government securities. In line with hypothesis 2, the interaction term between the APP and eligible dummy is significant and positive, indicating a decrease in the rate difference between non-eligible and eligible securities during the stop of the purchases. The halt of the APPs increases the available supply of eligible collateral, rendering them less scarce and increasing the repo rates. When daily fixed effects are included, the time-varying APP dummy is excluded. Regression (1) indicates that during asset purchases eligible securities trade on average at 10.7 basis points below the rates of the non-eligible securities. During the halt of the program, the rate difference decreases to 3.69 basis points. Regression (2) shows a similar decrease in the rate difference between non-eligible and eligible securities from 8.98 during the APPs to 5.57 basis points at the stop. In line with the expectations, the rate gap between non-eligible and eligible securities becomes smaller during the stop of the asset purchases. The coefficient on the APP dummy in regression (2) estimates that asset purchases also have a negative effect on the repo rates for non-eligible securities, decreasing them by 2.67 basis points. Although asset purchases have a stronger negative effect on the

[35] As in specification 5.1, I analyze the effect of eligibility within a sector-country and day, but for notational ease, I write the difference between non-eligible and eligible securities.

repo rates for eligible securities, a decrease of 6.08 basis points, I would have expected no significant effect of asset purchases for non-eligible securities. The small, unexpected effect of asset purchases of the rates for non-eligible securities can most likely be explained with the positive outliers for non-eligible securities at the stop of the asset purchases (see graph 6). Overall, the coefficient estimates are similar to the ones in the other regressions. The coefficient for the on-the-run dummy is insignificant across all the specifications, but the general collateral dummy is significant and positive with a similar magnitude to the naïve regression. The interaction terms between the eligible variable and the general or on-the-run dummy are not included since they do not significantly affect the results for the eligible dummy and have similar coefficient estimates as in the naïve regression. The subset of government securities in regression (3) has very similar coefficient estimates to the ones in regression (1). Changing the time window from twelve to six and three months before and after the stop of the asset purchases does not change the results significantly.

	(1)	(2)	(3)
	Repo Rate	Repo Rate	Repo Rate
eligible	-0.107**	-0.0898*	-0.114***
	(0.0533)	(0.0592)	(0.0214)
No_APP		0.0267***	
		(0.00658)	
No_APP×eligible	0.0701***	0.0341**	0.0597***
	(0.0262)	(0.0092)	(0.0207)
on_the_run	0.000585	-0.000522	-0.00407
	(0.00522)	(0.00534)	(0.00414)
gc_collateral	0.0535***	0.0498***	0.0508**
	(0.0118)	(0.0103)	(0.0202)
_cons	-0.756***	-0.723***	-0.708***
	(0.0230)	(0.0246)	(0.0212)
N	31573	31573	24724
adj. R^2	0.597	0.489	0.571
Subset	Full	Full	Government
Entity_FE	Yes	Yes	Yes
Time_FE	Yes	No	Yes
Controls	Yes	Yes	Yes
Macro_Controls	No	Yes	No

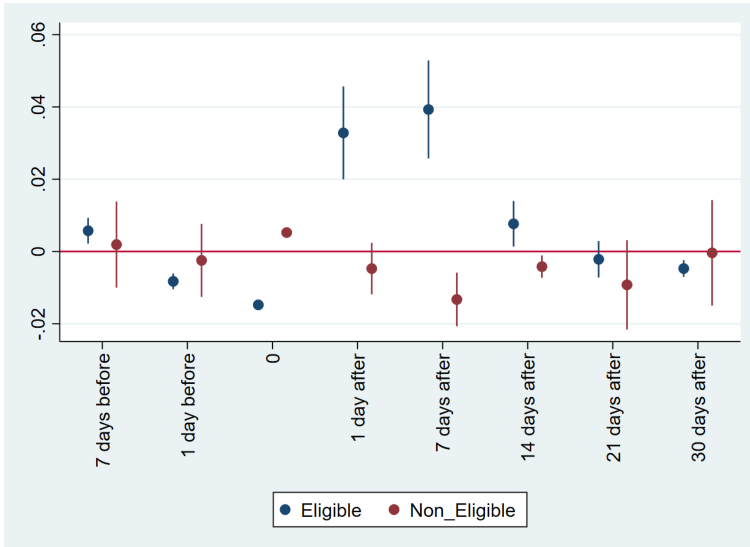
Standard errors in parentheses clustered at the issuer country-sector level.

* $p < .10$, ** $p < .05$, *** $p < .01$

The table reports regression results examining repo rates before and after the stop of the asset purchases. The data is aggregated by trading day, eligibility, collateral issuer sector, country, general collateral, whether the security is on-the-run, and by the central clearing status of the transactions. Regression (1) through (3) employ different variable specifications to account for heterogeneity across transaction types. The regressions include issuer sector-country fixed effects, daily fixed effects, and control variables. The eligible dummy takes the value 1 when the security is eligible and 0 otherwise. The on-the-run dummy takes the value 1 when the security is on-the-run. The general collateral dummy takes the value 1 when the security is GC and 0 when SC. The No_APP dummy takes the value 1 during the stop of the purchases and 0 otherwise.

Table 4: Temporary Stop in the APP

Figure 7 plots the coefficient estimates of regression equation 3. At time zero, the asset purchases stop. The APPs adoption leads are close to zero for eligible and non-eligible securities, showing little evidence of an anticipatory response prior to the event. The rates of the eligible securities react to the stop in the APPs. After one day the rates for trades secured by eligible collateral become positive. The effect lasts for approximately two weeks and then fades away. The rates of non-eligible securities do not experience any significant reaction to the stop of the APPs. This is in line with the expectations of a positive effect on repo rates for eligible securities after the stop of the purchases. It also provides evidence of the parallel trend assumption in that non-eligible securities do not have a significant reaction to the stop of the APP programs, and eligible securities do react after the program stop. Changing the leads and lags does not affect the results.



The graph plots the coefficient estimates of the Granger causality test for eligible and non-eligible securities. It shows the estimated impact of the stop of the asset purchases on the volume-weighted repo rate for weeks before, during, and after the stop. At time 0 the asset purchases stop. The vertical lines represent the ±1.96 times the standard error of each point estimate. Coefficient estimates close to the red horizontal line are not statistically significant. Source: MMSR

Figure 7: Time passage relative to the stop of the asset purchases

The difference-in-difference analysis is performed on the assumption that securities stay eligible or non-eligible over their lifetime. This is not necessarily true since, for instance, securities that fall below the minimum remaining maturity requirement become non-eligible. From the data aggregation at the issuer sector-country level, it follows that each day has an eligible observation per collateral country and issuer sector, which by construction does not vary over time.[36]. Although I expect most securities to remain eligible or non-eligible in the sample, a potential bias might arise from several securities becoming eligible/non-eligible at the same time. However, since no change in the eligibility criteria, besides the one in 2017, has taken place, it is unlikely that many securities will become eligible/non-eligible simultaneously and affect the results significantly. An improvement of the model is to perform the analysis on security level and keep securities that do not change their eligibility group.[37]

5.2.2 Policy change 2017 - Purchases below the DFR

Figure 8 (the left one) depicts the weekly average repo rate and standard deviation for transactions secured by collateral that is non-eligible in December 2016 and that turns eligible in 2017 due to the policy change. If eligibility does not affect the repo rates, you would expect no change in the repo rates collateralized by the same securities after the policy change. However, the figure shows a clear rate difference for non-eligible and eligible collateral: Repo transactions secured by the same securities trade at lower rates when the securities become eligible to the APPs in 2017. Figure 8 (the right one) depicts

[36] See section 4.2.1 for an explanation.

[37] The thesis does not incorporate the improvement of the model due to the large dataset and computer processing power constraints.

the sum of transactions in a given week. As soon as the securities become eligible, a clear increase in their trading volume can be observed.[38] The same securities, when they become eligible, do not only trade at lower rates but are used much more frequently in repo transactions than when they are non-eligible. This indicates that the APPs do not only affect the rates of eligible securities by reducing their supply but also by increasing the demand for eligible assets. Arrata et al. (2020) argue that asset purchases increase the demand for eligible securities, but they (as most other authors) focus on the supply effects of an increase in the APPs and do not measure the demand effects.

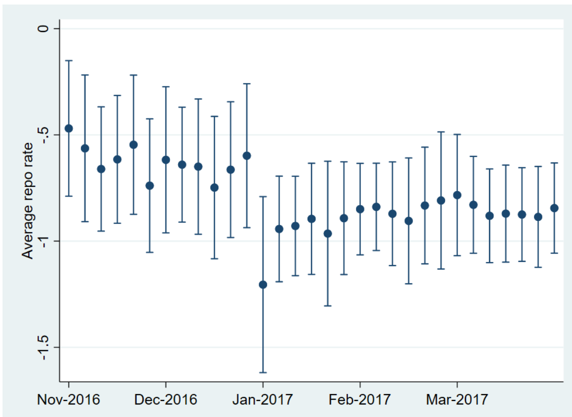


Figure 1: Average repo rates

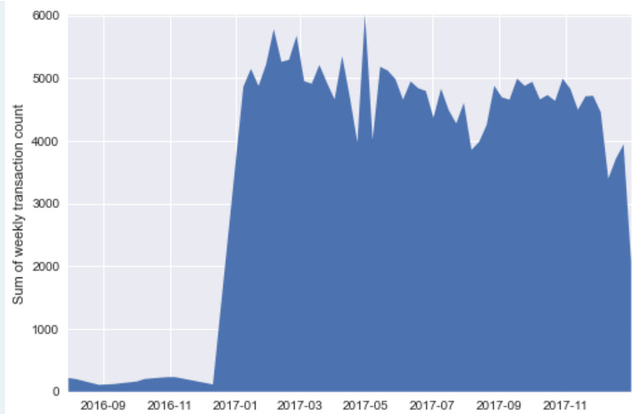


Figure 2: Sum of transaction count

The figure to the left illustrates the volume-weighted-average repo rate and standard deviation in a given week. The graph to the right represents the sum of transactions in a given week. Securities that are non-eligible in 2016 and become eligible in 2017 due to the exogenous policy change are shown. Source: MMSR

Figure 8: Repo rates and volume before and after the 2017 policy change

Table 5 provides statistical support for hypothesis 1 that repo rates secured by eligible collateral trade at lower rates. All regression span the time period from July 2016 to July 2017. The coefficient estimate on the general collateral dummy is statistically insignificant across most of the regression specifications and is, therefore, excluded from the rest of this interpretation. The on-the-run dummy variable specification is not included in this analysis because only two securities over the chosen time become off-the-run. Regression (1) indicates that transactions secured by the same collateral have, on average, a 14.2 basis points lower rate when becoming eligible after the policy change. In regression (2) and (3), I keep the subset of securities that become eligible due to the maturity and yield constraint. Both regressions estimate a significantly negative effect of eligibility on the repo rates. Regression (4) considers the subset of government bonds. The effect of eligibility on repo rates for government bonds is stronger, with a 26.6 basis points difference between non-eligible and eligible securities. Supranational securities constitute the bulk of collateral used in repo transactions because they are preferred by market participants for their "zero-risk" and high liquidity (ECB 2021). As government bonds are already preferred by financial actors and also trade at lower rates[39], the effect of them becoming eligible might be stronger. Additionally, the PSPP, which buys supranational securities, has the highest purchase volume among the APPs. The large purchase volume and the importance of government collateral in the repo market[40] can explain the

[38] Figure 11 in the appendix shows that the full set of securities does not experience an increase in the transaction count.
[39] Government bonds in the sample over the entire period trade on average at -0.6% while corporate securities at -0.48%.
[40] Government securities constitutes around 85% of the collateral in the repo market.

higher estimation results. The difference in repo rates between non-eligible and eligible corporate SC securities is much smaller, at 11.2 basis points (Regression 5). Overall, the results are of the same order of magnitude as the estimates in the above regressions, thus validating the previous results. Changing the time window from six to three or nine months before and after the event does not significantly impact the results.

	(1)	(2)	(3)	(4)	(5)	(6)
	Repo Rate	Repo Rate	Repo Rate	Repo Rate	Repo Rate	Repo Rate
eligible	-0.142***	-0.154***	-0.117**	-0.266***	-0.112**	-0.139**
	(0.0477)	(0.0555)	(0.0572)	(0.0464)	(0.0466)	(0.0537)
gc_collateral	0.0687	0.0875	0.124**	-0.0132	0.113***	0.0873
	(0.0423)	(0.0543)	(0.0634)	(0.0106)	(0.0239)	(0.0543)
eligible×gc	-0.0468	-0.0746	0.0968	0.0183	0.0904**	-0.0747
	(0.0431)	(0.0551)	(0.099)	(0.0149)	(0.0366)	(0.0551)
short_selling						-0.000271*
						(0.000102)
eligible×short						-0.00191**
						(0.000782)
_cons	-0.776*	-0.619*	-0.983	-0.899***	-1.044***	-0.338
	(0.370)	(0.306)	(0.872)	(0.158)	(0.130)	(0.228)
N	109304	23758	89974	83956	16960	108633
adj. R^2	0.311	0.365	0.423	0.495	0.605	0.369
Subset	Full	Maturity	Yield	Government	Corporate	Full
Entity_FE	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	No	No	No	No	No	No
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Macro_Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses clustered at the security level.

* $p < .10$, ** $p < .05$, *** $p < .01$

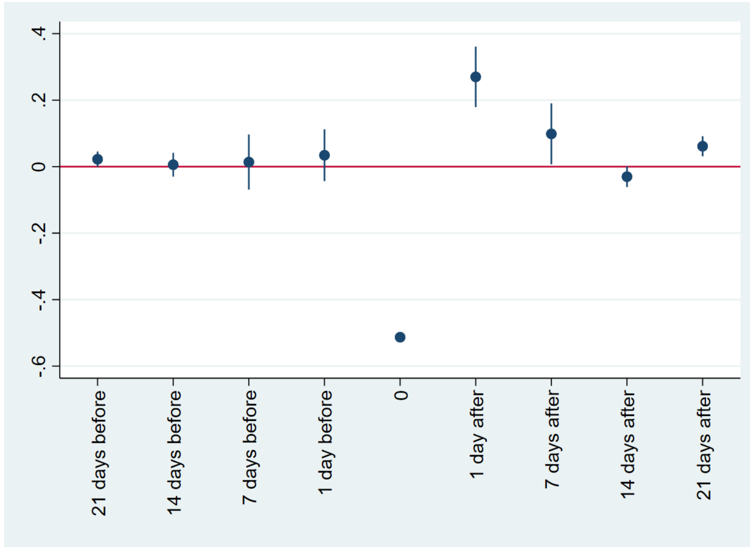
The table depicts the estimation results for securities that are non-eligible in 2016 and become eligible due to the exogenous policy change in 2017. Data from July 2016 to July 2017 is employed. I aggregate the data by trade day and security used in the transaction. Regressions (1) through (6) use different subsets to account for heterogeneity across security categories. All regressions include security fixed effects and control variables. Daily fixed effects are replaced with macro control variables due to fact that the eligible variable in this specification varies across time and not entities. The eligible dummy takes the value 1 when the asset is eligible and 0 otherwise. The change variable takes the value 1 after the policy change in 2017. The general collateral dummy takes the value 1 when the security is GC and 0 when SC.

Table 5: Policy Change 2017

Since I am analyzing the subset of transactions that are collateralized by the same collateral that is non-eligible in 2016 and becomes eligible in 2017, all concerns related to security-specific sorting into the groups can be excluded. Further, no other event related to the repo market coincided with the modification of the eligibility criteria, which can explain why 163 securities trade at significantly lower rates one day after they become eligible. It can therefore be concluded that the eligibility criteria have a negative effect on repo rates. The findings further suggest the importance of demand effects in driving down repo rates. It is improbable that the central banks bought those newly eligible securities within a few days and significantly decreased the supply. It is more likely that investors' expectations about future rates decrease the repo rates for these securities. Holders of the newly eligible assets can demand a lower rate, and repo buyers are willing to accept those lower rates because they expect these securities to become scarcer in the future.

Regressions (6) in table 5 provide a first indicative step in measuring the increase in demand for eligible securities. One of the essential demand factors in the repo market is the demand for short positions. Duffie (1996) or Vayanos and Weill (2008) postulate that short-sellers often use reverse repo contracts to deliver the securities. I follow D'Amico, Fan, and Kitsul (2018) and control for the estimated daily volume of short positions in the repo market. For a given security on a given day, I compute the total transactions initiated as reverse repos and subtract the total amount of transactions as repos. A positive (negative) value indicates a higher (smaller) share of reverse repos and, thus, short selling of a security on a day. The imbalance captures the assets' excess demand on that day and should indicate price pressure in the market. Price pressure can exert downward pressure on the repo rates for these securities. The coefficient on short selling in Regression (5) is negative, as expected, but of a very small magnitude. An increase in short selling by 1 point (a 1-point difference in the demand for reverse repos and repos for a given security) leads to a decline in the repo rates by 0.027 basis points when the securities are non-eligible and to a decline of 0.22 basis points for when the securities become eligible in 2017. Given that the short selling mean in 2016 for non-eligible securities is at 0.10, that is, on average there is almost no excess demand for non-eligible securities on a given day. The effect of excess demand proxied by the repo volume spread for non-eligible securities is, thus, negligible. When the securities become eligible in 2017, the average on the short selling dummy for all eligible securities in 2017 is at 2.33. This indicates that, on average, short selling of eligible securities leads to a decline in the repo rates of 0.51 basis points. One possible explanation for the small coefficient estimates is that the repo volume spread is a crude proxy for short positions: Not every reverse repo transaction is a short position. The estimation results align with the ones from D'Amico, Fan, and Kitsul (2018), who also find mixed results for their short-selling dummy. In some of their specifications, the dummy is insignificant; in others, it is significant but of a minimal magnitude.

Figure 9 shows the coefficient estimates of regression equation 5. The policy adoption leads are close to zero, showing little evidence of an anticipatory response prior to the event. At time zero, the policy change takes place. As expected, the impact on the event is significantly negative. The lags after the policy change also show little change to the policy event. This provides evidence of an instant drop in the repo rates as soon as the securities become eligible. Changing the leads and lags does not affect the results.



The graph plots the coefficient estimates of the Granger causality test for securities that are non-eligible in 2016 and become eligible in 2017 due to the policy change. It shows the estimated impact of the policy change before, during, and after the event takes place. At time 0 the policy change takes place. The vertical lines represent the ± 1.96 times the standard error of each point estimate. Coefficient estimates close to the red horizontal line are not statistically significant. Source: MMSR

Figure 9: Time passage relative to the week of the policy change

The model can be extended by not performing an event study analysis but by running a difference-in-difference analysis. To perform the analysis on security level (and not aggregate the data to reduce the size of the dataset), I decided to keep the subset of securities that are affected by the policy change. However, one could also include securities that are not affected by the event and use them as a control group. This extra security dimension would allow for an additional robustness check.

5.3 Putting the results into context

Comparing the results to findings in other studies proves difficult since my methodology differs from other papers in the literature. For instance, Arrata et al. (2020) find that a 1% increase in public sector purchases of outstanding bonds decreases repo rates by approximately 0.78 basis points. Corradin, Hoerova, and Schepens (2021) find a negative effect of 5 basis points of the Securities Market Program in Italy on repo rates for a 1% purchase in outstanding bonds. The thesis estimates that asset eligibility leads to a 10 basis points lower repo rate for eligible securities (compared to non-eligible securities). Analyzing joint effects between access to the deposit facility and eligibility to asset purchases, Ballensiefen, Ranaldo, and Winterberg (2020) find that eligible securities have a one basis point lower rate, on average than non-eligible securities. It must be noted, that the coefficient is insignificant in most of their regression specifications since they only control for the rate difference in their appendix section among a bunch of other control variables. My thesis also differs from their paper in the aspect that I do not analyze the reaction of repo rates secured by non-eligible and eligible collateral to changes in the monetary policy rate but compare the difference in rates, therefore the results are also not directly comparable. In general, I expect to find higher estimation results since I do not only measure the effect of asset purchases on repo rates but also expectation effects. Further research is required to see where my results stand in the literature.

The estimates for the on-the-run dummy are of a smaller magnitude than the coefficients in Arrata et al. (2020) or Corradin, Hoerova, and Schepens (2021). However, they interact the dummy with the daily amount of APPs purchases at the security level and, therefore, the coefficient estimates might be different.

6 Robustness tests

Robustness tests are conducted along different subsets, fixed effects, and control variable specifications. Some of the key regressions in the sections above already employ different subgroups to analyze whether the results hold across other security categories or issuer countries.

In table 6, I run the regressions for different variable specifications and subsets. Regression (1) employs the baseline on-the-run-dummy specification and regression (2) uses a less strict on-the-run-week dummy variable. Since there is not always a clear division between on-and off-the-run securities, I test for the robustness of the on-the-run coefficients by introducing an on-the-run-week dummy. Securities are classified as off-the-run when a new security of the same maturity and issuer becomes available in the market on the day. The on-the-run-week variable does not consider daily new issues but whether a security has been issued in the same week. Both variables have coefficient estimates of a similar magnitude. Regression (3) and (4) run the analysis on the subset of government and corporate securities. The difference in eligibility is slightly stronger for government securities. The estimates are in line with the fact that government securities are more heavily purchased under the APPs and, therefore, experience a higher scarcity premium. Regressions (5) to (7) include securities of different issuer countries. The rate difference for non-eligible and eligible securities is smaller when analyzing securities issued by German institutions and stronger for Spanish securities (6.25 versus 10.2 basis points for off-the-run SC collateral). A reason for the smaller rate difference between non-eligible and eligible securities might be a higher specialness premium for German securities compared to other European assets (Arrata et al. 2020). Because German securities on average are more special (trade below the prevailing market rate), the difference between non-eligible and eligible securities is smaller since also non-eligible German securities are in higher demand. Across the O/N and T/N market segments, the coefficient estimates are statistically significant and of a similar magnitude.

Table 7 in the appendix reports different regressions with variations in the fixed effects and control variables. Regression (1) represents the baseline regression. Excluding entity fixed effect as in regression (2) leads to a higher coefficient estimate for the eligible variable. Eligible off-the-run securities that are specifically demanded for trade at 14 basis points below non-eligible off-the-run securities that are SC collateral. Regression (3) reports the estimation results when time fixed are dropped but macro control variables (as described in specification 4) are included. The results indicate a smaller negative effect for eligibility. The year_ends variable takes the value 1 around year ends. In line with the expectations, the coefficient estimate on the year-end dummy variable is highly significant and negative, reflecting the strong negative effect of window dressing. Figure 10 in the appendix visually represents the substantial repo rates drop at year-ends. Regression (4) does include no fixed effects. Excluding entity and year fixed effects does change the results slightly, however, the main predictions of a negative effect of eligibility on the repo rates remain.

The coefficient estimates on the Vstoxx variable have a very similar magnitude and significance to the estimation results in Arrata et al. (2020). The results for the asset purchase volume are insignificant and too small to be in line with the estimation results in the literature. The reason for the insignificant results is that I employ the available public data with the monthly volume of total purchases, whereas the authors in the "mainstream" literature use high-quality proprietary data on daily security-level purchases. Excess liquidity is also commonly controlled for in the literature. For instance, Arrata et al. (2020) find that excess liquidity has decreased repo rates by 28.6 basis points. I estimate the effect of excess liquidity to be of a minimal magnitude. The reason for the significant but negligible results is that I calculate excess liquidity based on not very granular, monthly public data. The other control variables have a small effect on the repo rates and excluding them as in regression (5) does not change the results significantly.

From table 2, one could be concerned that including the control variables in the regression is not enough since they affect the non-eligible and eligible groups differently. Therefore, I also interact each of the transaction specific control variables (yield, remaining maturity, and central clearing status of the transaction) with the eligible variable respectively. The findings lead to insignificant results across all three control variables, indicating that the difference in the eligible groups does not translate to a difference in the repo rates.

One concern with the data aggregation is that the results are biased because of some within country-sector trend that I do not capture by aggregating the data. To exclude this kind of bias, table 8 aggregates the data differently by additionally including the maturity bucket of the transaction (e.g. whether the transaction is O/N, T/N, or S/N) and the collateral type of the security in the data aggregation.[41] Regression (1) represents the baseline equation with issuer sector-country and day fixed effects, as well as standard errors clustered at the issuer sector-country level. Regression (2) builds on the baseline regression and further clusters at the issuer sector-country-day level. This approach rules out that error terms are correlated within a given sector-country over time. For instance, Corradin, Hoerova, and Schepens (2021) use the time and bond clustering dimension in their paper. Regressions (3) and (4) include fixed effects and clusters at the security category level. Regression (3) clusters at the asset category-country level and regression (4) at the asset category-country-time level. The results are of a similar magnitude to the baseline regression, with regression (4) having slightly higher significance in the coefficient estimates. Similarly, regressions (5) and (6) include fixed effects and clusters at the maturity-bucket-country level. Overall, these findings indicate that a bias due to different within country-sector trends should not be a major concern.

The estimates are statistically significant and hold across the different specifications. This reinforces the main conclusion of the thesis that transactions collateralized by eligible securities have lower repo rates than transactions secured by non-eligible securities.

[41] The primary asset classification indicates whether the instrument is a debt, equity or fund with some further details.

7 Limitations and future work

7.1 Limitations

Although the main results of the thesis are robust to different specifications, some limitations must be kept in mind. The thesis first and most important limitation relates to the small number of transactions with non-eligible securities. Most transactions in the dataset involve repo trades collateralized by eligible securities. In the German subset of the MMSR, only 0.7% of the trades are collateralized by non-eligible securities. Since the dataset includes more than 14 million transactions after data cleaning, I still have around 90,000 transactions secured by non-eligible collateral, which is just enough to perform a statistically significant regression analysis. However, the rate of non-eligible securities is more volatile because outliers strongly affect the average volume-weighted repo rate.

The second drawback relates to data confidentiality. The Deutsche Bundesbank has put in place requirements for researchers and employees working with confidential microdata that require each output to have at least five different protecting entities where the two largest entities must not exceed 85% of the total value. Each confidential micro dataset at the Bundesbank has its entities that must be protected. In the case of the CSDB and MMSR datasets, I have to protect the name of the reporting entity, counterparty, collateral issuer, and triparty agent. Since most of the repo transactions are centrally cleared by four to five European clearing agencies, I had to include selected non-centrally cleared transactions to fulfill data confidentiality rules. Including non-centrally cleared transactions has some drawbacks related to counterparty risk, higher rate volatility, and lower rates. Although I only included non-centrally cleared transactions secured by collateral issued by American and European governments as well as by the EU body and International Organisations, those rates are lower than centrally cleared transactions. Further, on average, repo trades collateralized by eligible securities contain a higher share of non-centrally cleared transactions. Therefore, in the regression analysis, I include a centrally cleared dummy variable that indicates a significant magnitude of an approximately 2.5 basis points difference between centrally cleared and non-centrally cleared transactions. Additionally, to meet data confidentiality rules, the data is aggregated weekly in graphs 4, 5, 6, and 8. The other graphs and regression tables respect the data confidentiality rules without weekly data aggregation.

A critical assumption throughout the analysis is the comparability of non-eligible and eligible securities. In section 4, I show some summary statistics and a mean comparison test of the main variables used across both segments. From the tables, it becomes evident that there are some differences between non-eligible and eligible securities. Although the eligibility criteria are exogenous to the repo market, it creates, by definition, some heterogeneity. For instance, one of the conditions requires that the securities have a credit quality assessment of at least credit quality step 3 in the Eurosystem's harmonized rating scale (ECB/2014/60). Although most of the collateral used in repo transactions is high-quality collateral (ECB 2021), I do not have any information on the credit ratings of the underlying collateral. Non-eligible collateral might therefore have a lower credit rating than eligible collateral by definition of the criteria. Since I expect non-centrally cleared repo transactions with lower-quality collateral to trade at higher repo rates, I likely overestimate the effect of eligibility on repo rates. This bias might play a particular role in the naive regression. However, the regression where I keep the subset of securities that are non-eligible before the exogenous policy change and become eligible after, should not suffer from omitted variables related to "sorting".

7.2 Avenues for further research

Most papers in the literature use daily data on securities purchased by central banks to measure the effect of an increase in purchases of a particular security on the repo rate of that security. In the literature, the supply effect via a decrease in available securities is, thus, well documented. Using the eligibility criteria to analyze the effect of asset purchases on the repo market, the thesis provides a first step to not only measure the supply effects but also the spillover effects to eligible securities that are not bought by the national central banks. Once a security becomes eligible, an increase in its trading volume can be observed (see figure 8). Surprisingly, the increase in trading volume for eligible securities does only translate to an estimated one basis point decline in the repo rates of the newly eligible securities. However, this short analysis is only indicative and leaves for future research to disentangle supply and spillover effects to securities that are eligible but not bought. An exciting strategy could be to combine the eligibility criteria with asset purchase data at the security-day level to measure the spillover effects of the APPs to securities that are not bought but eligible. This approach allows to better distinguish between supply and spillover effects. Supply effect is the effect of an increase in asset purchases on the repo rates via a directly measurable decrease in the available collateral. Demand or spillover effects constitute the remaining decline in repo rates for eligible securities that an increase in central bank purchases cannot explain.

8 Summary and policy conclusions

Explaining the evolution of the repo rates, why they declined below the deposit facility rate, and how this is linked to the APPs is the main subject of the thesis. I use daily security-level data on the repo transactions conducted by the biggest 115 German reporting agents to analyze the link between the Eurosystem's APPs and the low repo rates. Specifically, I show that repo transactions secured by eligible collateral to the ECB's asset purchases are more disconnected from the monetary policy rates. Repo rates collateralized by eligible securities trade significantly below the DFR, the policy rate, while repo rates secured by non-eligible collateral have rates close to the DFR. The estimated difference in the rates between non-eligible and eligible securities is 10 basis points. During the halt of the APPs in 2019, repo rates secured by eligible securities increased, with the difference between non-eligible and eligible securities dropping to 3.69 from 10.7 basis points. As soon as the asset purchases stop, the repo rates of eligible securities increase, approaching the DFR and the rate of non-eligible securities. When the asset purchases pick up again at the end of 2019, repo rates of eligible securities start to decrease. Over the whole period, the rates of non-eligible assets stay on the same level as the DFR, experiencing almost no reaction to the APPs. Securities that are non-eligible and become eligible due to some exogenous policy change do not only experience a significant drop in the repo rates but also are traded much more frequently. However, the increase in trading volume for eligible securities only explains a small fraction of the drop in repo rates for eligible securities (less than one basis point). Overall, the results suggest that the APPs have depressed repo rates by driving a wedge between rates for non-eligible and eligible securities.

Most authors use transaction data of daily purchases at the security-day level to assess the impact of an increase in purchases of a particular asset on the repo rate of that security. In the literature, the supply effect via a decrease in available securities is, thus, well documented. My thesis is one of the only papers that does not look at how much has been purchased at the security level but at the effect of the pure possibility for an asset to be bought by the national central banks. The thesis provides a first step to better understand the unintended side effects of the eligibility criteria, which were designed to avoid market distortions, but actually lead to rate dispersion in the repo market.

In light of rate dispersion in the repo market, policymakers should consider that the unconventional asset purchases also create frictions in money markets leading to unintended consequences such as a disconnection of repo rates from the target policy rate. Two key implications for monetary policy emerge from the findings.

First, market neutrality in the design of the large-scale asset purchases is crucial for the well functioning of the money markets. Baltzer, Schlepper, and Speck (2022) show that security scarcity was particularly relevant in 2016/2017 when the set of eligible securities was more restrictive and the asset purchase volume was high. Increasing the set of targeted securities can help to reduce price pressure and avoid scarcity and shortages of specific securities in the market.

Second, securities lending such as the ECB's securities lending facility can alleviate market pressure. In theory, security specialness only persists because some agents are unwilling to lend the securities they hold. In April 2015, the ECB established the Securities Lending Program, where the securities purchased under the APPs have been made available for lending in a decentralized manner by the national central banks. It is estimated that the program has helped to attenuate the effect of asset purchases, but scarcity premium remain (e.g., Brand, Ferrante, and Hubert 2019; Arrata et al. 2020). In contrast to Europe, specialness in the US due to asset purchases has been less prevalent. One reason is that the Federal Reserves security lending facility programs have offered much more attractive pricing options (e.g., D'Amico, Fan, and Kitsul 2018). In the Eurosystem, the security lending facility system is managed in a decentralized manner. Each central bank has its lending facility, with some regulations being stricter than others. Especially some national central banks lend their securities on more expensive terms as described by Arrata et al. (2020). Relaxing some of the restrictions on the securities lending facilities and harmonizing the standard can alleviate some of the problems caused by the APPs.

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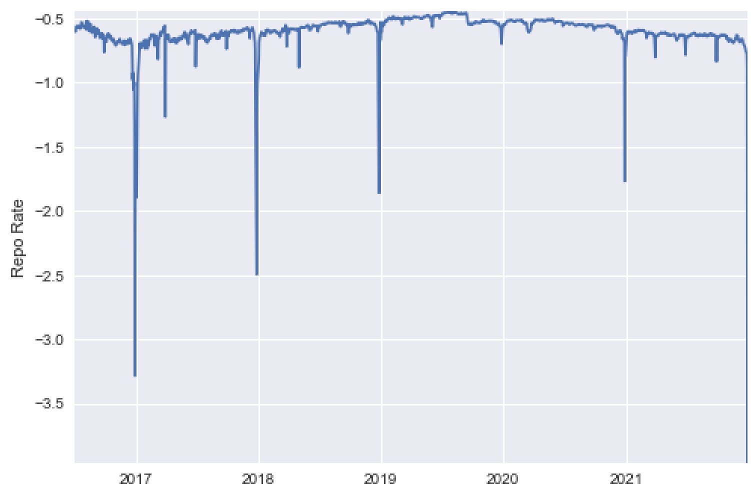
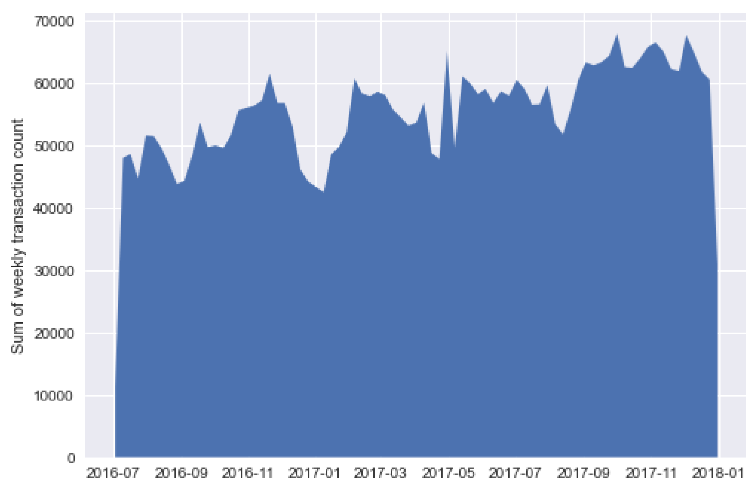
A Appendix: Graphs and Tables



The graph shows the average volume-weighed repo rate, indicating significant window dressing at year-ends. Source: MMSR

Figure 10: Window dressing



The graph shows the sum of the weekly transaction count for all repo trades. Source: MMSR

Figure 11: Transaction Count

	(1) Repo Rate	(2) Repo Rate	(3) Repo Rate	(4) Repo Rate	(5) Repo Rate	(6) Repo Rate	(7) Repo Rate	(8) Repo Rate	(9) Repo Rate
eligible	-0.0844***	-0.0840**	-0.0907*	-0.0224**	-0.0625**	-0.102***	-0.0641**	-0.0765***	-0.0774***
	(0.0115)	(0.0286)	(0.0531)	(0.0108)	(0.0215)	(0.0269)	(0.0251)	(0.0283)	(0.0180)
eligible×gc	0.0577***	0.0363	0.0494	0.0236**	0.0224	0.0497	0.0357	0.0921***	0.0279
	(0.0163)	(0.0245)	(0.0338)	(0.00999)	(0.0164)	(0.0871)	(0.0256)	(0.0315)	(0.0265)
eligible×run	-0.0826**		-0.0640*	-0.0221***	-0.0334*	-0.122*	-0.0965	-0.0799	-0.0337
	(0.0369)		(0.0344)	(0.00463)	(0.0169)	(0.066)	(0.0589)	(0.0566)	(0.0267)
gc_collateral	0.00124	0.0224	0.00583	0.0685***	0.0759***	0.0104	0.0238	-0.0121	0.0325
	(0.00738)	(0.0236)	(0.0323)	(0.00597)	(0.0113)	(0.0703)	(0.0250)	(0.0292)	(0.0242)
on_the_run	-0.0708*		-0.0519*	-0.0255***	0.00775	-0.022**	0.0853	0.0554	0.0205
	(0.0360)		(0.0239)	(0.00472)	(0.00960)	(0.114)	(0.0059)	(0.0524)	(0.0263)
eligible×run_week		-0.0750*							
		(0.0507)							
on_the_run_week		0.0605							
		(0.0582)							
_cons	-0.406***	-0.412***	-0.381***	-0.382***	-0.544***	-0.442***	-0.430***	-0.417***	-0.316***
	(0.0105)	(0.0422)	(0.0576)	(0.0116)	(0.0168)	(0.0243)	(0.0421)	(0.0452)	(0.0411)
N	177780	167291	148626	29154	51642	12153	169663	90749	42635
adj. R^2	0.348	0.351	0.356	0.431	0.376	0.368	0.338	0.435	0.448
Subset	Full	Full	Government	Corporate	DE	ES	EU	O/N	T/N
Entity_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses clustered at the issuer country-sector level.

* $p < .10$, ** $p < .05$, *** $p < .01$

The table reports robustness tests for the naive regression across different bond categories and maturity buckets. All regressions include issuer sector-country fixed effects, time fixed effects, and control variables. The eligible dummy takes the value 1 when the security is eligible and 0 otherwise. The on-the-run dummy takes the value 1 when the security is on-the-run. The general collateral dummy takes the value 1 when the security is GC and 0 when SC.

Table 6: Subset Variations

	(1)	(2)	(3)	(4)	(5)
	Repo Rate	Repo Rate	Repo Rate	Repo Rate	Repo Rate
eligible	-0.0847**	-0.140**	-0.0476**	-0.134**	-0.0923**
	(0.0454)	(0.0599)	(0.0228)	(0.0590)	(0.0481)
eligible×gc	0.0461*	0.0861*	0.0424	0.0793*	
	(0.0273)	(0.0437)	(0.0281)	(0.0436)	
eligible×run	-0.0927*	-0.0213	-0.0913*	-0.0227	
	(0.0514)	(0.0620)	(0.0512)	(0.0602)	
gc_collateral	0.0122	-0.0226	0.00966	-0.0220	
	(0.0260)	(0.0421)	(0.0268)	(0.0423)	
on_the_run	0.0813	0.00146	0.0800	0.00356	
	(0.0490)	(0.0609)	(0.0492)	(0.0590)	
yield	0.0123	0.0507***	0.0208	0.0541***	
	(0.0161)	(0.0101)	(0.0157)	(0.00948)	
cp_is_ccp	0.0252**	0.00462	0.0287**	0.00188	
	(0.0112)	(0.0103)	(0.0112)	(0.0105)	
remaining_maturity	-0.00000593*	-0.0000110***	-0.00000673**	-0.0000117***	
	(0.00000318)	(0.00000169)	(0.00000294)	(0.00000163)	
year_ends			-0.446***	-0.449***	
			(0.0741)	(0.0741)	
Total			-0.000000556***	-0.000000579***	
			(6.44e-08)	(6.81e-08)	
Vstoxx			0.000714**	0.000674**	
			(0.000284)	(0.000293)	
Excess_Liqudity			3.42e-09	3.26e-10	
			(6.38e-09)	(6.71e-09)	
GC_rate			0.0447**	0.0577**	
			(0.0244)	(0.0332)	
_cons	-0.404***	-0.367***	-0.418***	-0.354***	-0.694***
	(0.0402)	(0.0612)	(0.0438)	(0.0613)	(0.0181)
N	177780	177780	177135	177135	236420
adj. R^2	0.358	0.260	0.279	0.179	0.213
Entity_FE	Yes	No	Yes	No	Yes
Time_FE	Yes	Yes	No	No	Yes
Controls	Yes	Yes	Yes	Yes	No
Macro_Controls	No	No	Yes	Yes	No

Standard errors in parentheses clustered at the issuer sector-country level.

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 7: Different subsets and control variables

	(1) Repo Rate	(2) Repo Rate	(3) Repo Rate	(4) Repo Rate	(5) Repo Rate	(6) Repo Rate
eligible	-0.0851**	-0.0851**	-0.106***	-0.106***	-0.182***	-0.182***
	(0.0403)	(0.0321)	(0.0155)	(0.00637)	(0.0460)	(0.00543)
eligible×gc	-0.00456	-0.000685	0.0374*	0.0374**	0.0759**	0.0759***
	(0.00532)	(0.0092)	(0.0154)	(0.00835)	(0.0290)	(0.00383)
eligible×run	-0.00451	-0.00451	-0.0384	-0.0384*	0.0126	0.0126
	(0.00564)	(0.00801)	(0.0388)	(0.0109)	(0.0436)	(0.0358)
gc_collateral	0.0668***	0.0668***	0.0181**	0.0181***	-0.0202	-0.0202*
	(0.0198)	(0.00103)	(0.0091)	(0.00330)	(0.0147)	(0.00872)
on_the_run	-0.00568	-0.00568*	0.0274	0.0274**	-0.0390	-0.0390**
	(0.00499)	(0.00287)	(0.0376)	(0.00984)	(0.0430)	(0.00945)
_cons	-0.712***	-0.712***	-0.371***	-0.371***	-0.387***	-0.387***
	(0.0369)	(0.0259)	(0.0259)	(0.0188)	(0.0468)	(0.0162)
N	326608	226608	339372	339372	339372	339372
adj. R^2	0.432	0.432	0.367	0.367	0.293	0.293
Entity_FE	sec.-country	sec.-country-day	asset-country	asset-country-day	mat.-country	mat.-country-day
Time_FE	day	day	day	day	day	day
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$

The table reports robustness tests for the naive regression across different fixed effects and cluster variations. Regressions (1) and (2) include issuer sector-country and time fixed effects and clusters. Regressions (3) and (4) have collateral types-country and time fixed effects and clusters. The last two regressions include maturity bucket-country and time fixed effects and clusters. The eligible dummy takes the value 1 when the security is eligible and 0 otherwise. The on-the-run dummy takes the value 1 when the security is on-the-run. The general collateral dummy takes the value 1 when the security is GC and 0 when SC.

Table 8: Different fixed effects and cluster variations

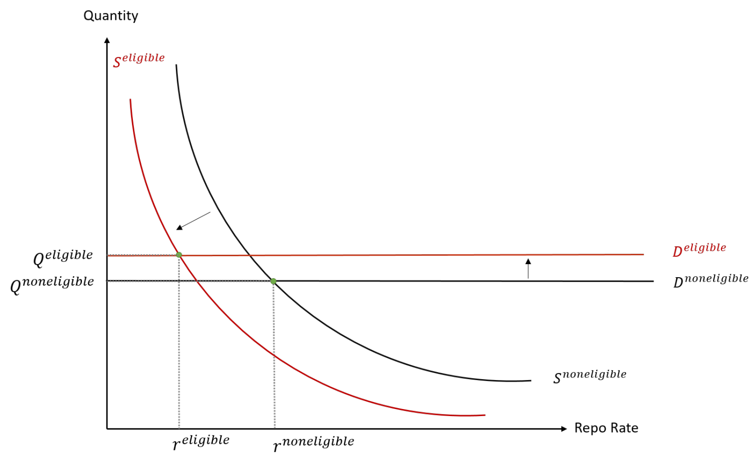
B Appendix: Extra Material

B.1 Theoretical Mechanism: Effect of Asset Purchases on repo rates

Building on the model proposed by Duffie 1996 and Ballensiefen, Ranaldo, and Winterberg 2020, I illustrate how asset eligibility to the ECB asset purchase programs affects repo rates. Figure 12 illustrates a supply and demand diagram: the x-axis depicts the repo rate, and the y-axis the quantity of collateral sold against funding. The supply curve describes the amount of collateral available in the market. The curve has a negative slope because the lower the repo rate, the larger the collateral supply to be sold against funding. The demand for eligible collateral is depicted as a straight line due to the inelasticity of demand from short sellers [42]. The seller in the repo market is looking for funding, that is, he wants to obtain cash in exchange for a security. The buyer is lending the money to the seller. Asset eligibility leads to two effects. First, the asset purchases have decreased the available supply of eligible collateral in

[42] The demand curve is not fully inelastic but for illustrative purposes, I depict it as a straight line.

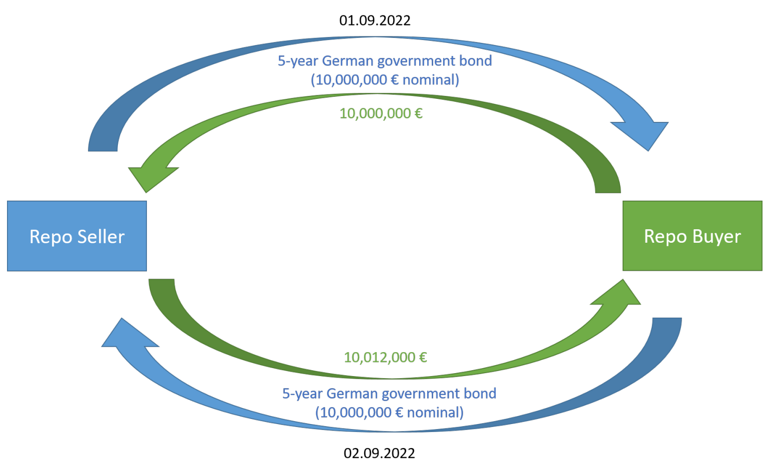
the repo market, leading to a different supply curve. Additionally, following Duffie (1996), some security holders (the seller) are only willing to lend the eligible securities at a premium, that is, at lower rates. Secondly, asset purchases have led to an increase in demand for eligible securities (Arrata et al. 2020), which is graphically illustrated by a second demand curve. The asset eligibility criteria have thus led to a rate divergence between eligible and non-eligible assets used as collateral in repo transactions.



The figure illustrates the impact of asset purchases on the repo rates in a supply and demand diagram: the x-axis depicts the repo rate, and the y-axis the quantity of collateral sold against funding.

Figure 12: Eligibility Criteria - Supply and Demand Effects

B.2 Example of a Repo Transaction



The figure illustrates a repo transaction between two counterparties that exchange a 5-year government bond against 10 million euros.

Figure 13: Repo Transaction

B.3 Overview Literature

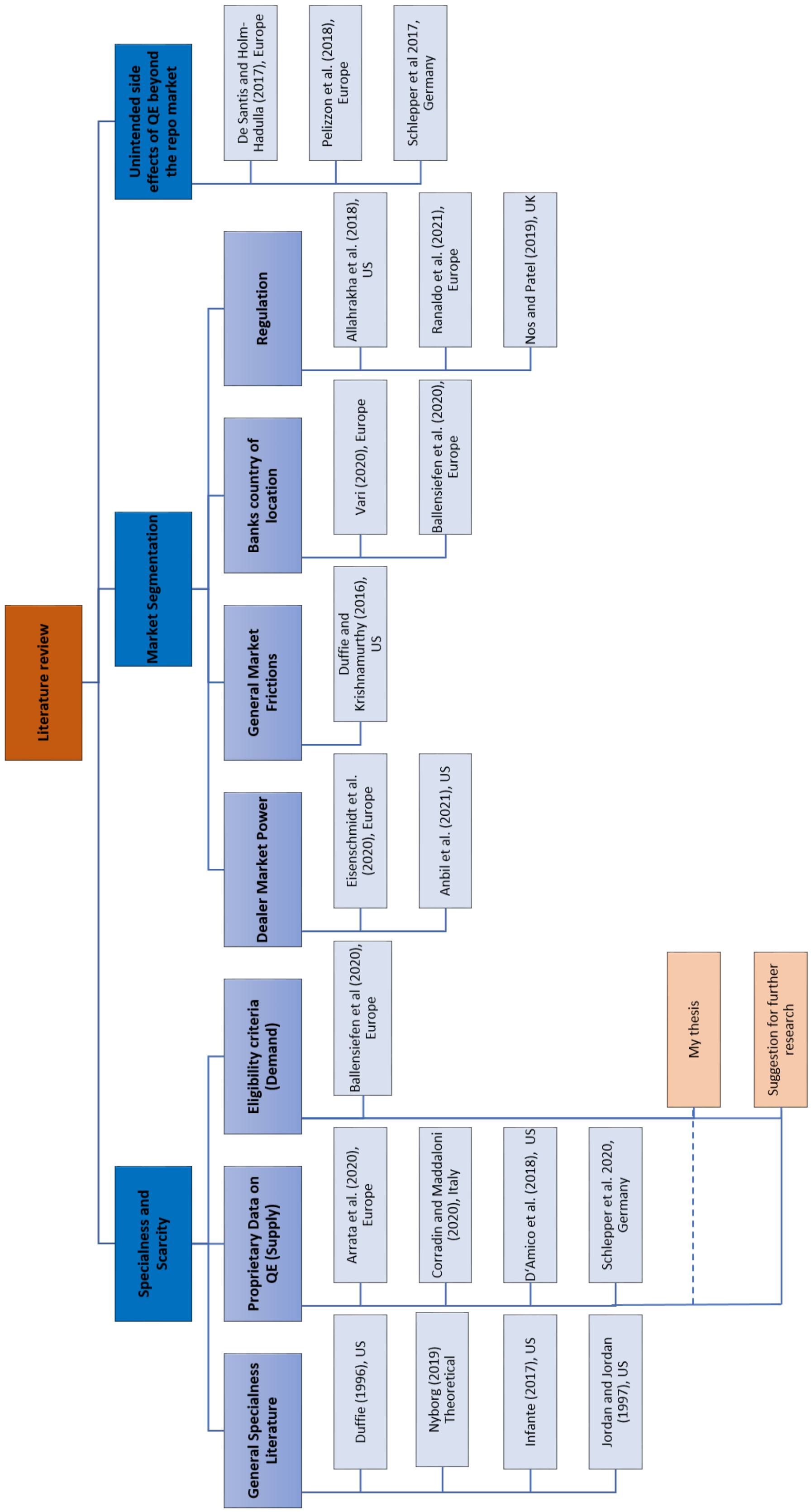


Figure 14: Literature Overview

B.4 Time Frame of Eligibility Changes to PSPP Program

Start date	09.03.2015	13.01.2017	31.12.2018	01.11.2019	03.02.2020
Comments	Start		Stop (Decision on 13.12.2018)	Restart (Decision on 12.09.2019)	Newest version
Law text	2015/774	2017/100			2020/188
Minimum Maturity	2 years	1 year			1 year
Maximum Maturity	30 years	30 years			30 years
Purchase below DFR	Not allowed	Allowed			Allowed
Security Lending	Yes (the securities are made available since the 02.04.2015)	Yes			Yes

Table 9: Time Frame PSPP purchases

The other APPs programs have a similar time frame. The only difference is that the minimum and maximum maturity slightly differs (e.g., 6 months instead of 1 year).

B.5 Table of Variables

Variable	Description	Data Source
Repo Rate	Rate at which the secured transaction was concluded.	MMSR
Trade Date	The date at which the trading parties enter into the repo transaction.	
Transaction Nominal Amount	The amount of euro initially borrowed or lent as an absolute value.	
Collateral ISIN	ISIN number of the underlying collateral.	
Maturity Band Code	The maturity band code include transactions with the respective maturity +/- a specified tolerance around the maturity, e.g. the 9M maturity buck.	

Counterparty is CCP	Indicator Variable equal to one if counterparty is a central clearing counterparty and zero otherwise.	
Collateral Art	This variable identifies the asset class pledged as collateral (Single, Pool and Multiple Collateral).	
GC Pooling Rate	I calculate this rate based on the Eurex GC Pooling basket. I take a weighed average per day for all repo transaction secured by the Eurex GC Pooling basket.	
Counterparty Sector	This variable provides the institutional sector of the counterparty.	
Counterparty Location	This is the ISO 3166-2 country code of the country in which the counterparty is incorporated.	
ISIN	ISIN number of the security.	CSDB
Issuer Date	This is the date when the securities are available for delivery to investors for the first time.	
Original Maturity	The original maturity of an instrument.	
Instrument Class	Classification of the security according to the European System of Accounts version 2010 (ESA 2010).	
Primary Asset Classification	Primary classification of the instrument (e.g. indicating whether the instrument is a debt, equity or fund with some further details).	
Yield to maturity	The yield to maturity of the collateral.	
Issuer Sector	Classification of the institutional sector of the issuer according to the European System of Accounts 2010 (ESA 2010).	
On-the-run-dummy	The variable indicates whether the security is the most recently issued security of a particular issuer and maturity. The variable was constructed by Michael Schmidt at the Bundesbank based on the CSDB data.	
Issuer Country	Country of legal domiciliation of the issuer of the security.	
EADB	Indicator Variable indicating whether the collateral is included in the list of eligible marketable assets (eligibility for Eurosystem credit operations).	EADB Database (ECB Website)
APPs Purchases	Monthly Net Purchases in Million Euros.	ECB Statistical Warehouse

Excess Liquidity	Own calculations based on APPs purchases and deposit facility.	
VSTOXX	The VSTOXX Indices are based on EURO STOXX 50 realtime options prices and are designed to reflect the market expectations of near-term up to long-term volatility.	Qontigo

Table 10: Overview of variables used