# Money market disconnect*

Benedikt Ballensiefen†, Angelo Ranaldo‡, Hannah Winterberg§

June 30, 2022

**Abstract**

A repurchase agreement (repo) is a source of funding and collateral. We document that the money market is more segmented when the collateral motive prevails. Two crucial aspects of the central bank framework lead to this disconnect: banks' access to the central bank's deposit facility and assets' eligibility for Quantitative Easing (QE). We show that repo rates lent by banks with access to the deposit facility and secured by QE eligible assets are more collateral-driven and disconnected from funding-based money market rates. Our results are relevant for different monetary policies and have suggestive implications for the monetary policy pass-through.

Keywords: Money market, Segmentation, Deposit Facility, QE, Monetary policy.
JEL Classification: E40, E43, E50, E52, E58, G18

*We thank Farshid Abdi, Andrea Barbon, Roman Baumann, Alexander Bechtel, Patrick Bolton, Martin Brown, Pierre Collin-Dufresne (discussant), Stefano Corradin, Cody Couture (discussant), Florian Heider, Marie Hoerova, Sebnem Kalemli-Özcan, Christian Keuschnigg, Oliver Krek (discussant), Thomas Nellen, Patrick Schaffner, Olivier Wang (discussant), and Kerstin Westergren (discussant) and conference participants at the American Economic Association (2021), Young Swiss Economist Meeting (2021), ECB-RFS Macro-Finance Conference (2021), Eastern Finance Association (2021), SFI Research Days (2021), Swiss Society of Economics and Statistics Congress (2021), World Finance Conference (2021), 52nd Conference of the Money, Macro and Finance Society (2021), SNB Research Conference (2021), 16th Central Bank Conference on the Microstructure of Financial Markets (2021), and RCEA Conference (2022) as well as seminar participants at the University of St.Gallen (2020), Goethe University Frankfurt (2020), Norges Bank (2021), and Swiss National Bank (2021) for their valuable comments and suggestions. This work is supported by the Swiss National Science Foundation [grant number P1SGP1_188111]. The Online Appendix is available upon request. An earlier version of this paper circulated under the title "Monetary policy disconnect."

†University of St. Gallen and World Bank Group, Unterer Graben 21, CH-9000 St. Gallen, Switzerland. Tel. +41 (0)79 808 92 56. E-mail: benedikt.ballensiefen@unisg.ch.

‡University of St. Gallen and Swiss Finance Institute, Unterer Graben 21, CH-9000 St. Gallen, Switzerland. Tel. +41 (0)71 224 70 10. E-mail: angelo.ranaldo@unisg.ch.

§University of St. Gallen, Varnbüelstrasse 19, CH-9000 St. Gallen, Switzerland. Tel. +41 (0)77 460 08 18. E-mail: hannah.winterberg@unisg.ch.

The money market is crucial for the efficient allocation of funding and financial securities as well as for preserving financial stability. Furthermore, "a deep and integrated money market is a precondition for an efficient monetary policy, since it ensures an even distribution of central bank liquidity and a homogeneous level of short-term interest rates (European Central Bank, 2011)." Given its essential role in the financial and economic system, it is important to understand frictions in the money market and *how* they lead to market segmentation which can create rate dispersion and be detrimental to market quality.

In this paper, we study money market segmentation and the underlying mechanism behind it. A repurchase agreement (repo) is the main money market instrument; it is a secured short-term loan that serves a dual role to obtain funding and collateral. We show that the money market becomes more segmented when the role of collateral in repos dominates the role of funding. We uncover two key aspects of the central bank framework that lead money market participants and securities to disconnect from funding-based money market segments: First, whether banks have access to the central bank's deposit facility; and second, whether the collateral asset is the target of the Quantitative Easing (QE) program. We demonstrate that the lending rates of banks with access to the central bank's deposit facility and secured by assets eligible for QE programs are more collateral-driven and therefore less connected to funding-based benchmark rates. Both effects lead to rate dispersion and add to one another pointing towards a pervasive money market segmentation. Our results have implications for different monetary policies and provide suggestive evidence that money market segmentation weakens the monetary policy transmission.

The ideal laboratory to examine the dual role of repos and the resulting money market segmentation is the European repo market: First, it is the largest repo market worldwide and the main source of short-term funding and collateral for euro area banks.[1] For our analysis, we employ a unique and highly representative transaction- and firm-level data set from 2010

[1]The asset being used as collateral in a repo transaction can be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral or GC repo"). In the U.S., a special repo is sometimes also referred to as a "specific" repo. The GC market is generally more funding-driven while the special market is more collateral-driven. Still, even GC baskets differ in rates as some baskets are more funding-driven while others are more collateral-driven. Our data set covers both the GC and special repo market segments.

to 2020. Second, the repo market infrastructure features central clearing and anonymous centralized order book platforms, which ensures homogeneous counterparty risk and collateral policy, no bargaining power, and an efficient price formation process. Third, euro repos are secured by government bonds issued by various euro area countries with different sovereign risk, scarcity, and liquidity. This heterogeneity of collateral bonds creates cross-sectional and time variation in repo rates and implies that some repos are more funding-driven while others are more collateral-driven;[2] hence, it provides the ideal laboratory to examine the dual nature of repos. And fourth, the euro repo market is affected by monetary policy as the ECB maintains a corridor system for the deposit facility (floor) rate (DFR) and the marginal lending facility (ceiling) rate. The key short-term interest rate benchmark in the euro area is the EONIA rate, an unsecured overnight interest rate. Since the EONIA serves as the operational target rate of the ECB (Cœuré, 2018), our results also have implications for monetary policy.

Conceptually, the idea of this paper is that the money market becomes more segmented when repos are predominantly collateral-driven. Empirically, a weaker correlation between the rates in the secured and unsecured money market is a sign of this segmentation. To document this mechanism, we investigate two crucial aspects of the central bank's institutional framework that induce money market participants and securities to disconnect from funding-driven segments.

The first key aspect is that only some money market participants have access to the ECB's deposit facility. Banks can either operate as *lenders* of cash in GC repos to invest liquidity safely (funding motive) or to obtain collateral (collateral motive). Storing funds at the deposit facility is the outside option for banks with access to it. An important development has been the drop in several GC repo rates *below* the DFR (henceforth GC $<$ DFR). In such an environment, access banks have an incentive to deposit liquidity with the central bank to the detriment of engaging in funding-based repo trades; at the same time, access banks continue to have a motive to trade for collateral-purposes in the repo market. We therefore expect

[2]Empirical evidence about heterogeneity in convenience yields of collateral assets in the euro repo market is provided in Ballensiefen and Ranaldo (2019).

an endogenous selection of access banks into more collateral-driven repo segments that are less connected to funding-based money market rates in the GC $<$ DFR environment. At first, it seems surprising that secured lending rates of access banks are more disconnected from other money market benchmark rates. At the same time, our proposed mechanism is intuitive as the deposit facility is the outside lending option for those banks. In line with this mechanism, we document that the share of access banks' lending decreases and access banks lend more in collateral-driven baskets when GC rates fall below the DFR. Banks without access to the deposit facility, by contrast, do not have the option of access the deposit facility and therefore select themselves into more funding-driven repo segments which behave more like the unsecured market.

To test empirically whether banks with (without) access to the ECB's deposit facility lend at repo rates more (less) disconnected from the EONIA as the unsecured benchmark rate, especially in the GC $<$ DFR environment, we perform a comprehensive panel regression analysis. Our results clearly show that access banks respond less to changes in the EONIA. For instance, in the GC $<$ DFR environment, an increase in the EONIA rate by one percentage point translates into an increase in GC rates involving access banks of only 4 basis points (pointing to market segmentation) compared to 94 basis points for banks without access (pointing to high integration). In addition to the statistical significance, our findings are economically relevant which corroborates the idea that access to the deposit facility is a first illustration of our mechanism that creates money market segmentation.

The second key aspect of the central bank framework relates to the eligibility criteria of the QE program which specify that only a given set of assets can be purchased by the ECB. For this part, we focus on the "special" repo segment. QE eligible assets tend to be scarcer and repo rates secured by those assets are more special (Arrata et al., 2020; Corradin and Maddaloni, 2020). As a consequence, repos with QE eligible assets as collateral become predominantly driven by collateral demand disconnecting them from funding-based money market segments. In line with this idea, we document that the trading volume in the special market has increased since the start of QE, mainly driven by transactions collateralized with

assets eligible for central bank purchases which feature the highest collateral demand.

We perform a similar panel regression analysis to test whether repos secured by assets eligible (noneligible) for QE programs become more (less) disconnect them from the EONIA rate. We also apply the initial QE implementation provisions retrospectively to compare time trends between (hypothetically) eligible and noneligible assets, which creates a difference-in-difference estimation setting. We find that in the period after the introduction of QE, an increase in the EONIA rate by one percentage point is associated with a 50% lower sensitivity of eligible assets. We observe a similar behavior of (hypothetically) eligible and noneligible assets in the periods prior to QE and diverging patterns during QE, suggesting a causal impact of central bank asset purchases and resulting asset scarcity on money market segmentation.

We perform numerous robustness analyses to confirm our results. For example, we study the combined effect of the two disconnecting mechanisms, i.e., access to the central bank's deposit facility and QE eligibility, and find that they together induce a more severe market segmentation. We also employ other money market benchmark rates such as the new €STR rate, secured funding rates, and derivative-based rates which confirm our results.

Our results have implications for different monetary policies. The introduction of the ECB's two-tier system for remunerating excess reserve holdings in 2019 is a natural experiment for our mechanism. By exempting part of the excess reserve holdings held at the ECB from negative rates, it created an even stronger incentive for access banks to store funds at the deposit facility. We analyze the two-tier system's impact in a difference-in-difference estimation setting and find that the repo rates of access banks are more disconnected from the EONIA rate after the introduction of the tiering system. Due to the tiering exceptions, access banks have an additional incentive to store funds at the ECB's deposit facility and thus predominantly trade in collateral-driven parts of the repo market which are less connected to funding-based money market rates. Widening deposit facility access to foreign banks as in Switzerland (Kraenzlin and Nellen, 2015) is a similar illustration of this mechanism. Amendments to the Capital Requirements Regulation (CRR), at the heart of which is the (temporary) exclusion of central bank reserves from the calculation of the leverage ratio,

could also manifest money market segmentation as it encourages banks (with access) to store additional funds at the ECB's deposit facility. Our results are also informative for the recent discussion about new short-term benchmark rates as they underline that measuring the price of cash becomes increasingly difficult in a collateral-driven repo market environment.

Our results about money market segmentation also have *suggestive* implications for the monetary policy transmission process. A consistent and uniform response of money market rates to the monetary policy stance is the first key step of an effective pass-through mechanism. By contrast, a *"wider dispersion in short-term money market rates"* could cause *"a reduction in the efficacy and transmission of monetary policy"* (Bank for International Settlements, 2017, p.32). This is why many central banks target a well-defined money market rate and in the case of the Eurosystem, the operational target rate is the EONIA. It must be stressed that the variation in the EONIA rate is not only due to changes in the monetary policy stance as other factors such as risk premia and illiquidity determine it. However, it seems reasonable to assume that the ECB takes the EONIA rate into account when evaluating the transmission of its monetary policy as it captures more information about money market conditions than other key rates set by the ECB such as the DFR.

We show that in a more collateral-driven environment, repo rates lent by access banks and whose collateral qualifies for the QE program deviate significantly more from the EONIA rate. As such, our findings suggest that the monetary policy transmission could be more difficult when the dispersion of money market rates is wider. We compute a dispersion indicator of repo rates based on Duffie and Krishnamurthy (2016) to capture this. We then show that interest rates relevant for the real economy such as non-financial corporate borrowing and housing rates respond less to changes in the EONIA as the ECB's operational target rate when the dispersion in money market rates is wider. Although not causal, the lower conditional correlation could be relevant for assessing the effectiveness of the monetary policy transmission on a continuous basis.

Our analysis mainly contributes to two strands of the literature. First, we add to the literature on short-term money markets. The innovations we bring are twofold: First, we

show that the money market becomes more segmented when the repo market is predominately collateral-driven. Second, we identify two disconnecting mechanisms as the sources of this segmentation, i.e., access to a central bank's deposit facility and asset eligibility for QE. Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020) investigate the effects of QE purchases on the level of special repo rates.[3] Other papers analyze the unsecured money market; for instance, Kraenzlin and Nellen (2015) examine domestic and foreign banks' behavior in the Swiss franc unsecured money market and Bech and Klee (2011) evaluate the impact of bargaining power in a segmented and unsecured U.S. money market.

Second, we add to the literature on monetary policy, central bank frameworks, and transmission processes (e.g., Duffie and Krishnamurthy, 2016; Drechsler et al., 2017; Eisenschmidt et al., 2020). Our results about money market segmentation are relevant for different monetary policies. We also provide suggestive evidence that the monetary policy pass-through can be impeded by two key features of the central bank framework.[4]

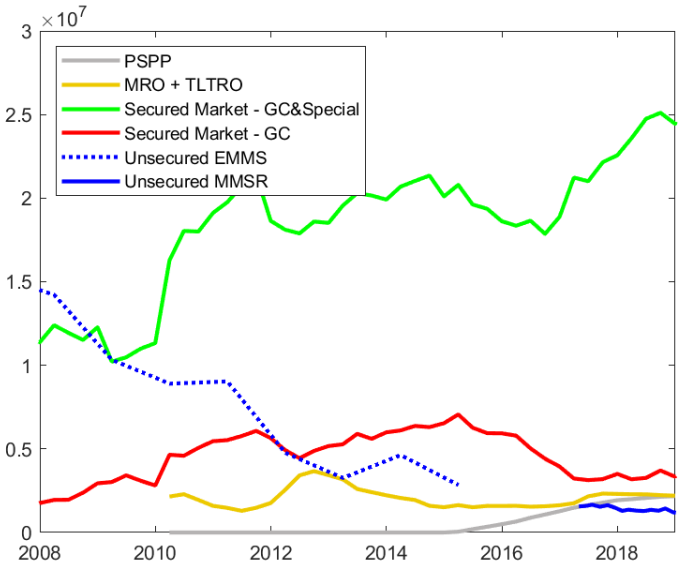
## 1. European money market

The focus of this paper is to provide new insights about money market segmentation, its underlying mechanism as well as potential implications for monetary policy. We therefore start our work by providing an overview of the European money market structure including

[3]Asset scarcity induced by QE is one illustration of the mechanism which we study in this paper. Extending Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020), we study segmentation between the special repo market and other money market segments related to QE purchases and the QE impact on GC rates, and document the underlying mechanism behind it. Roh (2021) points out that the ECB's decision to lend out bonds that it purchased also impacts asset scarcity. Related, the inactive lending of bonds by nonbanks adds to the scarcity of those assets (Maddaloni and Roh, 2021).

[4]The existing literature on the effectiveness of monetary policy has mostly focused on its pass-through in the context of specific events, such as announcements or policy changes. Duffie and Krishnamurthy (2016) analyze the effects of the introduction of the reverse repurchase facility and new Basel regulation on the monetary policy pass-through in the U.S. Drechsler et al. (2017) consider announced changes to the target corridor of the fed funds rate. Eisenschmidt et al. (2020) analyze the monetary policy transmission in the context of the OTC repo market and dealer market power. On a macro-wide level, Avouyi-Dovi et al. (2017) find a slowdown of the overall interest rates transmission mechanism, which Al-Eyd and Berkmen (2013) have associated with segmentation along country lines. Illes et al. (2019) study the cointegration between policy rates and banks' weighted cost of capital. Kalemli-Özcan (2019) analyzes the pass-through in the context of emerging markets. For a detailed literature review on interest rate pass-through, see Andries and Billon (2016) and Horvath et al. (2018).

the secured (repo) and unsecured money market segment. Figure 1 depicts the aggregate trading volumes in the repo market and in the unsecured money market as well as the total cumulative PSPP purchases and volumes of the ECB's main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO) for reference.




The figure depicts the aggregate cumulative quarterly trading volumes in the secured and unsecured market segments as well as the total cumulative PSPP purchases and volumes of the ECB's main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO). The data for the secured market refer to our repo data set as described in Section 1.4. The data for the unsecured market stem from the Euro Money Market Survey (EMMS) until 2015 and from the Money Market Statistical Reporting (MMSR) thereafter. To be conservative, we sum reported borrowing and lending activity in the unsecured market, which may entail double-counting. The data on PSPP purchases and refinancing operations are from the ECB. All data are in euro million.

**Figure 1:** Different market turnovers.

Trading in the European money market has moved towards the secured segment since the Global Financial Crisis. With a size of more than EUR 8.5 trillion in outstanding contracts (International Capital Market Association, 2021), the repo market now plays a crucial role for the efficient allocation of money and financial securities. To put the size of the repo market into perspective, trading volumes by far exceed volumes of cumulative purchases of the largest ECB QE program, the PSPP, or of the ECB's main refinancing operations. While

the repo market has become the main money market segment for banks, the unsecured money market is an important short-term interest rate benchmark. The EONIA rate is the one-day, unsecured interest rate at which banks lend to one another and represents the funding-based money market benchmark in the euro area. It is "the key ECB interest rate"(European Central Bank, 2011) and serves as the operational target rate for the ECB (Cœuré, 2018). Similar to other countries such as the U.S., the period studied involves a transition in the economy's benchmark interest rate. The ECB has chosen to replace the EONIA rate with the €STR rate, another unsecured rate, which highlights the ECB's renewed commitment to an unsecured target rate.[5]

### 1.1 Repo market

In the repo market, two counterparts exchange cash for collateral for a predefined time period with a fixed repurchase obligation. The asset being used as collateral can be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral or GC repo").[6] The lender in a repo transaction provides a short-term, typically one-day, loan (over-)collateralized by a sovereign bond and thus benefits from the ability to use the collateral for the time between the purchase and repurchase. Due to their collateralized nature, repos serve a dual role for funding and collateral. *Lenders* of cash in repos can either look for a safe investment that offers a market-based return or a way to source the asset serving as collateral which provides convenience. In general, the GC market is more funding-driven while the special repo market is more collateral-driven.

The European repo market infrastructure is particularly well suited to analyzing money market segmentation as it eliminates many confounding factors. The core segment is the

[5]The EONIA rate is determined as the weighted average of the interest rates on unsecured overnight lending transactions denominated in euros, as reported by a panel of contributing banks. In 2017, the ECB announced that the euro short-term rate (€STR) will replace the EONIA as the new short-term interest rate benchmark in the euro area. The €STR rate reflects the wholesale euro unsecured overnight borrowing costs of banks located in the euro area, and thus covers the borrowing cost of a larger set of banks as compared to the EONIA. We consider both rates in our analysis and show that our results are valid for both unsecured benchmarks.

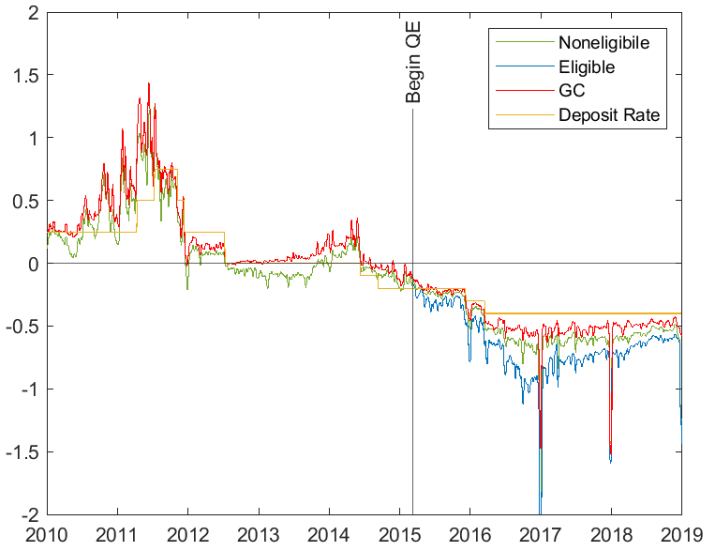
[6]In a special repo, the lender accepts a lower interest rate than in a GC repo since a particular asset is specified as collateral; GC repo rates provide the upper bound for special repo rates.

interbank market in which banks trade anonymously via centralized platforms supporting liquidity and a transparent price discovery process. We focus on trades operated through central counterparties (CCP) which constitute the majority of trades in the euro interbank repo market.[7] CCPs interpose themselves between each lender and borrower which eliminates any concerns regarding individual counterparty risk. The CCP acts as a clearinghouse and applies the same collateral and (credit) risk policies to all CCP members. Our setting therefore eliminates frictions such as bargaining power, counterparty credit risk, and heterogeneous haircuts. The euro area repo market also features a large variety of repos, both in the special and GC segment. The richness of this cross-sectional dispersion across GC and special repo rates allows us to examine the dual role of repos as funding and collateral markets since some repos are more funding-driven while others are more collateral-driven.[8]

Figure 2 shows the repo rate development for the average GC rate as well as for the average special repo rates for QE eligible and noneligible assets (illustratively for Germany) relative to the development of the ECB's DFR. Two developments are important: First, GC rates have fallen *below* the ECB's rate on the deposit facility at the height of the European sovereign debt crisis in 2012 and during the recent period of unconventional monetary policy. This is an important regime change for our analysis that we will refer to as the GC $<$ DFR environment. It speaks to the importance of access to central bank facilities as it indicates that storing funds at the deposit facility is an attractive alternative for those banks with access to it. It also points to the idea that repo lenders increasingly trade for *collateral* purposes, even in the GC segment, since they are willing to accept a lower remuneration for lending cash in the repo market instead of depositing it at the central bank. Second, during the QE period, repo rates secured by assets eligible for QE have fallen below those for noneligible assets (e.g., Arrata et al., 2020 and Corradin and Maddaloni, 2020), thus highlighting the role of asset scarcity induced by QE. Market participants are willing to accept a lower interest rate

[7] CCP-based repos account for more than two-thirds of the total turnover (European Central Bank, 2018). The bilateral, over the counter (OTC) repo segment is very small and does not allow for a clear differentiation between general and special collateral repos.

[8] More detailed information about the European repo market infrastructure can be found in, e.g., European Central Bank (2018), Mancini et al. (2016), Nyborg (2016), and Bank for International Settlements (2017).




The figure shows the development of the average volume-weighted GC rate as well as special repo rates for QE eligible and noneligible assets (illustratively for Germany) relative to the development of the ECB's deposit facility rate.

**Figure 2:** Repo rate development.

to lend cash against eligible than noneligible assets, which points towards *collateral* demand for those QE eligible assets.[9]

Those two observations provide the motivation for our analysis as they suggest that banks with and without access to the central bank's deposit facility and repos secured by asset eligible or not for QE purchases behave differently in the money market.

### 1.2 ECB access

The first key aspect that we investigate is that only a given set of money market participants are banks that have access to the central bank's refinancing operations and its deposit facility.[10] In the euro area, the ECB operates two standing facilities that allow banks to

[9]The spread between eligible and noneligible rates has been present since the introduction of QE and peaked at the end of 2017 when the ECB's Securities Lending Programme was introduced (Brand et al., 2019). For the period prior to QE, we can apply the initial implementation provisions retrospectively to classify assets into *(hypothetically)* eligible and noneligible. The corresponding figure is presented in the Online Appendix and confirms that the dispersion in levels has increased since the inception of the QE program.

[10]The importance of access to central bank's facilities has been stressed in the literature. The deposit rate as the rate of remuneration for reserves is a general and important feature of financial intermediaries' decision problems that is incorporated into macro-financial models (Cúrdia and Woodford, 2011; Bech and Monnet,

deposit or access liquidity on an overnight basis: The deposit facility allows for overnight deposits, while the marginal lending facility provides overnight central bank liquidity. Access to the ECB's facilities is, however, limited to eligible counterparties, most importantly to banks that are subject to the Eurosystem's minimum reserve requirements. The minimum reserve system applies to banks and credit institutions established in the euro area. Whether a bank is formed in- or outside of the euro area is unrelated to monetary policy and the repo market, and thus a source of exogenous variation. We exploit this restriction that only euro area banks can access the deposit facility in order to classify counterparties in a repo transaction into *access* and *nonaccess* banks.

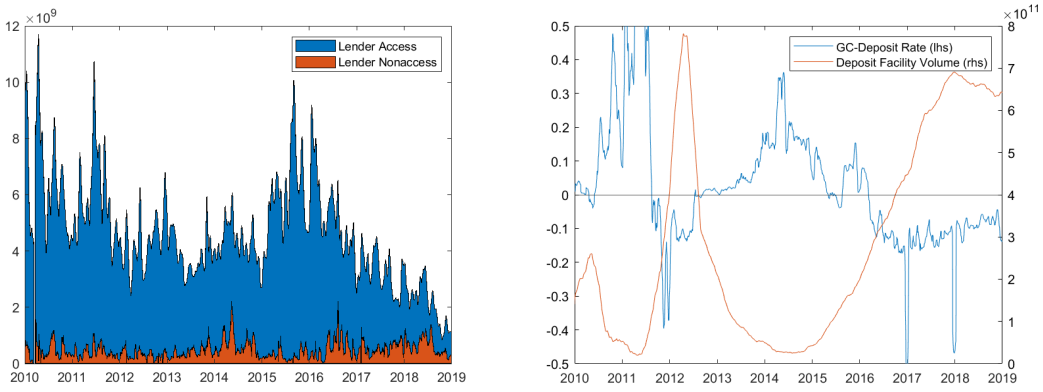
For our analysis, we focus on the *lending-side* in GC repos. Banks in the GC repo market can either operate as lenders of cash (i) to have a short-term, safe investment that offers a market-based rate of return (funding motive) or (ii) to source a high-quality collateral (collateral motive). Storing funds at the deposit facility is the outside option for banks with access to it.[11] The segmentation between access and nonaccess banks comes from the fact that access banks can safely invest liquidity in the repo market or place it at the deposit facility, whereas nonaccess banks can only rely on the former.[12] This mechanism can also be

2016; Williamson, 2019). In these models, a single deposit rate applies uniformly to all market participants and serves as the outside option for those banks. Segmentation induced by different access levels to central bank facilities is also supported empirically. For instance, Bech and Klee (2011) argue that the level of the effective federal funds rate was pushed downward by government agencies that could not receive interest on reserves. The analysis in Bech and Klee (2011) is confined to the unsecured market, while we look at segmentation across different secured and unsecured money market segments. In addition, Bech and Klee (2011) attribute their effect to bargaining power, a friction that does not play a role in a centrally-cleared setting like ours. Kraenzlin and Nellen (2015) find that banks without access to central bank facilities pay more interest in the unsecured money market to borrow liquidity.

[11]Banks could also invest in government bonds directly as opposed to investing liquidity in the repo market or – when having access – placing funds at the deposit facility. However, direct government bond investments have several drawbacks such as higher transaction cost and do not provide the same low-risk and liquid store of value as repos (Bank for International Settlements, 2017).

[12]The regulatory framework plays a negligible role for our analysis for at least three reasons: First, access and nonaccess banks in our sample are similarly regulated. Second, the new Basel regulation considers all assets under inspection to be of the highest quality (Level 1 assets) from the perspective of the Liquidity Coverage Ratio (LCR) (Bank for International Settlements, 2017). Furthermore, all maturities under inspection are shorter than the thirty-day LCR cut-off time. Third, the Basel III leverage ratio does not impact the lender in a repo transaction since reverse repos do not enter the Basel III leverage ratio calculation (Ranaldo et al., 2021). The effect of segmentation between access and nonaccess banks is therefore not driven by the leverage ratio regulation. The introduction of the leverage ratio lead to window dressing effects on repo rates, but those were mainly caused by the borrowing counterparties. We provide several robustness checks in which we exclude those trading days.

shown graphically. Figure 3a depicts the development of the GC trading volume for access and nonaccess lenders (illustratively for Germany).[13] In the two periods during which GC rates fell below the rate on the deposit facility (i.e., in 2012 and since 2015), we observe a drop in GC trading volume. This drop is accompanied by an increase in the volume of funds deposited at the ECB's deposit facility (see Figure 3b). For example, since 2015, we observe a drop in GC trading volume to about a third of its original size. This reduction was mainly driven by banks that had access to the ECB's deposit facility. To our knowledge, this is a new stylized fact suggesting a first form of segmentation between access and nonaccess banks induced by the central bank framework. Access banks increasingly deposit funds at the deposit facility in the GC $<$ DFR environment, while nonaccess banks continue to lend in the GC market to obtain a (safe) deposit of liquidity.




**(a)** General collateral trading volumes.

**(b)** Deposit facility volume and spread between GC rate and DFR.

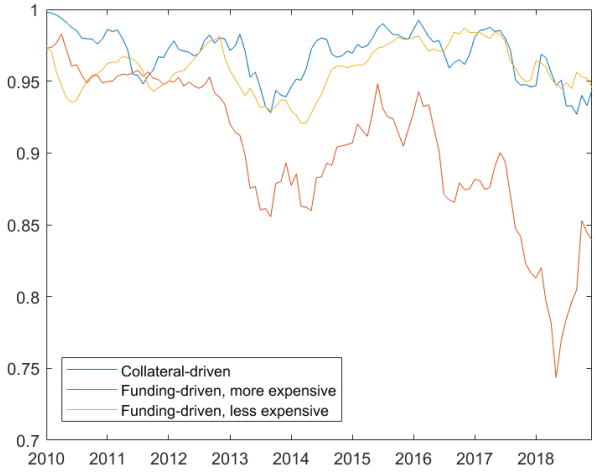
Figure 3a depicts the total trading volume in the German GC market for trades involving a lender with and without access to the ECB facilities. Figure 3b depicts the spread between the German GC rate and the ECB's rate on the deposit facility as well as the total volume deposited at the ECB deposit facility.

**Figure 3:** Repo market and deposit facility volumes.

In the euro area repo market, a variety of different GC repo baskets are traded, each with a different GC rate. Separate GC baskets exist for different euro area countries (e.g., German or Italian GC baskets) and for different types of government bonds (e.g., German

[13] We present corresponding volume breakdowns by the borrowing side in the Online Appendix. However, we focus on the lending side throughout our paper as this allows us to examine market segmentation arising from access banks being able to lend liquidity in the repo market or to deposit it at the central bank.

notes or German long-term bonds). Those GC rates differ and are naturally dispersed. Some of the GC baskets are more collateral-driven (trading at a lower rate) while others are more funding-driven (trading at a higher rate). Figure 4 shows in this context the share of access banks' trading in (i) German government bond baskets (blue line), (ii) baskets of core euro area countries (red line), and (iii) baskets of peripheral euro area countries including the GC pooling baskets (yellow line).[14] GC baskets in (i) are more collateral-driven as they ensure that the lender is receiving a high-quality asset such as a German Bund as collateral, while GC baskets in (ii) and (iii) are more funding-driven as they include, for example, the two GC pooling baskets.[15]




The figure depicts the volume-weighted trading share of access banks in different types of GC baskets. The share is depicted for three subgroups: trades against German government bond baskets ("collateral-driven"), trades involving GC baskets of core euro area countries ("funding-driven, more expensive"), and trades involving collateral baskets of peripheral euro area countries including the GC pooling baskets ("funding-driven, less expensive").

**Figure 4:** Trading share of access banks.

We observe that in the recent environment where several GC rates dropped below the

[14]The Eurex GC pooling baskets are the main funding baskets in the euro area. They allow for highly rated assets (i.e., investment grade bonds), including assets issued by regional governments or "Pfandbrief" instruments of credit institutions, to be delivered.

[15]We present alternative classifications into collateral-driven and funding-driven trades in the Online Appendix. The results for all specifications are consistent. The share of nonaccess banks is defined as 100% minus the access banks' share.

ECB's DFR, access banks continued to have a collateral motive for lending in the repo market and remained active in collateral-driven baskets; at the same time, they moved out of more expensive, funding-driven baskets trading at lower rates due to their outside option of storing funds at the deposit facility. The idea here is that access banks select themselves into more collateral-driven segments of the repo market in the GC $<$ DFR environment which are less connected to funding-based money market segments. This mechanism is interesting, if not surprising, since one would expect the secured lending rates of euro area banks to be more connected to other euro area money market rates. At the same time, the proposed mechanism is intuitive as the DFR is the attractive outside lending option to funding-based repo trades for access banks. This explains why access banks remain active in funding-driven baskets which yield higher rates than the DFR (those of peripheral euro area countries), while they move out of funding-driven baskets trading at lower rates close to or below the DFR (those of core euro area countries).[16] We provide a theoretical discussion of these mechanisms in the Online Appendix.

### 1.3 Asset eligibility

The second key aspect that we consider are the eligibility criteria of collateral assets for central bank QE purchases.[17] The ECB announced in 2015 its intention to conduct large-scale

[16] As some repo rates have been lower than the deposit rate for an extended period, the question arises whether an arbitrage opportunity for access banks exists by borrowing in the repo market and storing the borrowed funds at the deposit facility. This direct comparison of the repo rate and the deposit rate abstracts, however, from the value of the collateral as it assumes that central bank reserves are equivalent to repo loans. As Figure 4 shows, access banks, still trade in the repo market in the GC $<$ DFR environment to obtain collateral. In fact, access banks are willing to accept a lower repo rate compared to the DFR to obtain the collateral, which they would forego by delivering the collateral in a repo trade. Prior research shows that (repo) arbitrage activity exists but is insufficient to close these "gaps" (Ranaldo et al., 2019).

[17] The interplay of central bank asset purchases, financial intermediation, and collateral has been featured prominently in the theoretical literature. Gertler and Karadi (2013) show that if limits to arbitrage exist in the banking sector, central bank purchases of securities cause yields to fall. Araújo et al. (2015) stress that the direction of the impact of asset purchases depends on the way collateral constraints are affected. Piquard and Salakhova (2019) highlight how monetary policy affects unsecured and secured markets in a different way once the central bank purchases marketable collateral. Their mechanism is motivated by an increase in the opportunity cost of pledging collateral. Divergent QE effects on financial markets are also supported empirically. For instance, Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020) show that asset purchases lowered special repo rates, an effect that they relate to asset scarcity. Roh (2021) points out that the ECB's decision to not lend out bonds that it purchased also increased their scarcity. Related, nonbanks' reluctance to lend bonds adds to the scarcity of those assets (Maddaloni and Roh, 2021).Focusing on the bond market, Schlepper, Riordan, Hofer, and Schrimpf (2017) show that QE

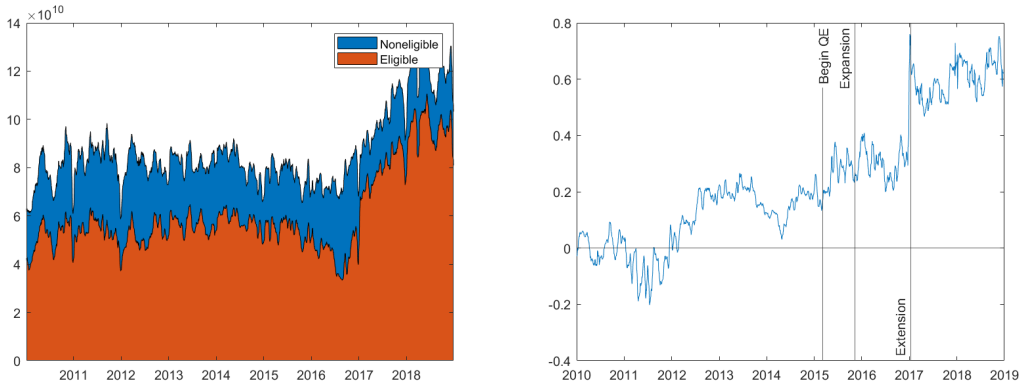
asset purchases. Since the beginning of these programs, cumulative net purchases amounted to more than 2.5 trillion euro. The Public Sector Purchase Program is the largest of the programs implemented in the Eurosystem; it focuses on the purchase of government bonds. The sheer size of these purchases has contributed to scarcity effects for government bonds, which are an important category of safe assets and serve as collateral in repo transactions. QE programs in general aim to influence longer-term rates in an environment where short-term rates are at the zero lower bound (by affecting term premia, see Eser et al., 2019). An impact of QE-induced asset scarcity on short-term rates is thus an unintended side effect that can increase rate dispersion and thereby leading to market segmentation. The effect of asset purchases on bond scarcity comes on top of tighter regulation of financial institutions under the new Basel framework (e.g., the introduction of the leverage ratio rules). The ECB has therefore constituted implementation provisions to limit market impacts and distortions. These provisions specify the assets which the ECB is allowed to purchase (via local central banks). The implementation provisions for asset purchases therefore provide a source of exogenous variation as to which securities meet the respective criteria.

In our analysis, we exploit the implementation provisions to classify collateral in a repo transaction into *eligible* and *noneligible* depending on the provisions that were valid at a specific point in time.[18] We further apply the initial implementation provisions retrospectively to compare time trends between *(hypothetically) eligible* and *noneligible* assets, which creates a difference-in-difference estimation setting. Observing similar reactions of both types of assets before QE would imply common trends and would allow us to interpret the QE impact

increased prices and lowered liquidity in purchased German bonds. Koijen, Koulischer, Nguyen, and Yogo (2017) show that in response to the ECB's purchasing programs, foreign investors sold most of their QE eligible bond holdings to domestic investors pointing to a strong home bias in eligible securities. This shift was also documented in aggregate data by Avdjiev et al. (2019).

[18]Under the umbrella of the PSPP, the ECB started in 2015 to buy nominal and inflation-linked government bonds as well as securities issued by recognized agencies, regional and local governments, international organizations, and multilateral development banks located in the euro area. Overall, around 90% of purchases correspond to government bonds. The implementation provisions specify the conditions under which the ECB (via local central banks) is allowed to purchase government bonds: they contain (i) a maturity restriction that specifies the minimum and maximum remaining maturity of a security, (ii) a yield restriction that states that the yield of a security needs to be above the ECB's deposit facility rate, and (iii) it only allows for the purchase of bonds denominated in euro. Over time, the ECB has adjusted and modified the initial implementation provisions. For example, the yield restriction ceased to exist at the end of 2017.

as causal.




**(a)** Special collateral trading volume.

**(b)** Spread between (hypothetically) eligible and noneligible assets.

Figure 5a depicts the total trading volume in the special collateral market for trades involving eligible and noneligible collateral. Figure 5b depicts the spread between the average repo rate on noneligible and eligible securities (average rate for noneligible collateral minus average rate for eligible collateral).

**Figure 5:** Special collateral repo market.

For this part of the analysis, we focus on the special repo segment that specifies a specific asset as collateral. The idea is that assets eligible for QE tend to be scarcer and repos secured by those assets become predominantly driven by collateral demand disconnecting them from funding-based money market segments. Figure 5a shows in this context the development of the trading volume in special collateral for eligible and noneligible securities while Figure 5b depicts the spread between the average repo rate on noneligible and eligible securities. A second, new stylized fact emerges as we observe an increase in special collateral trading volume since the start of QE, an increase that is predominantly driven by QE eligible assets. We also observe that since the start of QE, repo rates for QE eligible assets have fallen below those of noneligible assets in line with Arrata et al. (2020) and Corradin and Maddaloni (2020). The spread between noneligible and eligible assets was always positive during the QE period and has increased further after the expansion and extension of the program. This is in line with our idea that QE eligible assets become scarcer due to central bank asset purchases and the demand to source those assets in the repo market has therefore increased leading to a higher repo specialness. Naturally, one expects collateral types that are scarcer to be

more collateral-driven and thus less connected to funding-based money market segments. We provide a theoretical discussion of these mechanisms in the Online Appendix.

### 1.4 Data

For our analysis, we employ high-frequency data for the European repo market for the time period from 2010 to 2020. Our data includes all electronically traded repo transactions in euro on the three main trading platforms (i.e., BrokerTec, Eurex, and MTS) and covers more than 70% of the entire repo market universe. For each transaction, we observe the trade date, the term, the trade volume, the rate, the collateral identified by a unique ISIN (for special repos) or basket (for GC repos), the lender, the borrower, the aggressor type and the trading platform. We focus on the term types Overnight (ON), Tomorrow-Next (TN), and Spot-Next (SN), with the purchase date being tonight, tomorrow, or the day after tomorrow, respectively, and the repurchase date one day thereafter.[19]

We exclude a very small fraction of repo contracts and trading days to ensure the robustness and general validity of our results. First, we exclude holidays as well as year-end trading days. We further provide robustness checks excluding all quarter-end and end of ECB maintenance period trading days, as well as the corresponding weeks.[20] Second, we exclude special repos secured by corporate securities. Third, we exclude repos with floating rates, repos with open term type, bilaterally pre-arranged repos as well as repos that are not cleared via a CCP. Finally, we exclude repos that are traded infrequently.[21] We also perform our analyses for three different groups of countries: (i) Germany, (ii) core European countries, and (iii) all European countries.[22]

[19] These three term types make up 97% of the entire repo market trading volume. Trading in the GC market predominantly takes place in the ON and TN market segments, whereas trading in the special repo market segment predominantly takes place in the TN and SN market segments. We account for this in the empirical part.

[20] On quarter- and year-end days as well as on end of ECB maintenance period days, window dressing impacts repo rates (Ranaldo, Schaffner, and Vasios, 2021).

[21] To be included in our analysis, a repo needs to be traded at least 100 times. In addition, between the issuance and maturity of the underlying collateral, a repo needs to be traded at least once every two weeks in 95% of the time. Our results are robust to different specifications.

[22] Core European countries include Austria, Belgium, Finland, France, Germany, and the Netherlands, all European countries include in addition EU, Ireland, Italy, Portugal, and Spain.

**Table 1:** Breakdown of the repo data.

| | Access banks | Nonaccess banks |
|---|---|---|
| General collateral euro area repos | | |
| Trade size (mn) | 206.0 | 133.7 |
| Repo rate (GC > DFR) | 0.16% | 0.13% |
| Repo rate (GC < DFR) | −0.22% | −0.29% |
| Interquartile range | 0.51% | 0.66% |
| # Baskets traded in per month | 4.0 | 3.7 |
| Total assets (bn) | 290.6 | 241.2 |
| Leverage ratio | 16.7 | 17.2 |

| | QE eligible assets | QE noneligible assets |
|---|---|---|
| Special collateral euro area repos | | |
| Trade size (mn) | 22.3 | 21.6 |
| Repo rate (pre-QE) | 0.16% | 0.26% |
| Repo rate (post-QE) | −0.58% | −0.13% |
| Interquartile range | 0.60% | 0.74% |
| Bond issue size (bn) | 37.8 | 36.7 |
| Bond tenor (years) | 12.6 | 6.4 |
| Bond coupon rate | 3.2% | 3.1% |

The table shows the breakdown of the repo data denominated in euro. For the classification between access and nonaccess banks, we focus on the lending-side in GC repos; for the classification between eligible and noneligible assets, we focus on special repos. For all repo trades, we show the average daily trade size (in million euro), the volume-weighted, average daily repo rate for periods when the average GC rate is above / below the deposit facility rate (for periods prior to and after the introduction of the PSPP QE program), and the average daily interquartile range defined as the difference between the 25th and 75th percentile repo rate. For access and nonaccess banks, we further show the average number of different GC baskets each bank is trading in during a month as well as the average total asset size (in billion euro) and leverage ratio at the end of our sample period. For eligible and noneligible assets, we show each bond's issue size (in billion euro), tenor (in years), and coupon rate (if bonds are fixed-rate).

To identify banks, we follow the approach of Ranaldo et al. (2019) and Di Filippo et al. (2021) based on supervisory data. We then classify banks into access and nonaccess institutions depending on whether they need to fulfill the reserve requirements of the Eurosystem and have access to the deposit facility.[23] Our data contains repo trades involving 98 different banks, of which 85 are access banks and 13 are nonaccess banks.[24] We observe information on both the lending and borrowing bank for trades featuring 59% of the entire trading volume; among those trades, 22% are associated with a nonaccess bank. The upper part of Table 1 provides a comparison of the two groups. We see that the characteristics of access and nonaccess banks are similar. For instance, at the end of our sample period, access banks had, on average, assets worth 290.6 billion euro compared to 241.2 billion euro for nonaccess banks, the leverage ratios were about 17 for both types of banks. Interestingly, in the GC $<$ DFR environment, the average repo rate of trades involving access lenders is $-0.22\%$ compared to $-0.29\%$ for nonaccess lenders. This points to the idea that access lenders move away from funding-driven baskets trading below the DFR and substitute their investments with DFR deposits that yield a higher remuneration.

Moreover, we classify assets as eligible and noneligible for QE according to the PSPP's implementation provisions. We also apply the initial implementation provisions retrospectively to compare hypothetically eligible and noneligible assets. Our data set contains special repo trades involving more than 2,000 different collateral assets (ISINs). Seventy-six percent of our sample involves repo trades collateralized by (hypothetically) eligible assets, 24% collateralized by noneligible assets. The lower part of Table 1 compares characteristics between eligible and noneligible collateral assets. We observe that repo rates for QE eligible assets have fallen below those of noneligible assets since the start of QE. The average tenor is longer for eligible assets as this is one of the implementation criteria. Other bond characteristics

[23]Banks trading in the repo market are, for example, Deutsche Bank AG and Nordea Bank Danmark A/S. The former is a euro area bank with access to the deposit facility, while the latter is a foreign bank without access. For our classification, we assume that local subsidiaries of global banking institutions operate independently in the short-run. Thus, euro area subsidiaries of foreign banking groups have access to the deposit facility while foreign subsidiaries of euro area banking groups do not have access to the deposit facility.

[24]The number of nonaccess banks is constant over the course of our sample, thereby mitigating endogeneity concerns of nonaccess banks switching their location to access the deposit facility.

such as repo trade size, bond issue size, and bond coupon rate are comparable between the two groups. Since we only consider government bonds as collateral, all assets are broadly accepted as collateral and are treated in the same way for regulatory purposes.

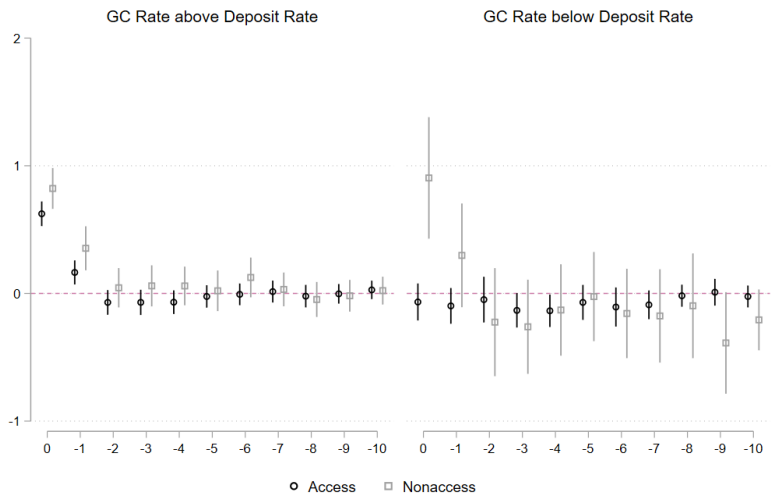
## 2. Empirical results

The idea of this paper is that a weaker correlation between money market rates is a sign of segmentation that emerges when the role of collateral in repos becomes dominant to the role of funding. To document this mechanism, we begin by looking at the correlation between secured repo rates and the unsecured money market benchmark rate (EONIA) before broadening our view to other money market segments.

### 2.1 Access/nonaccess banks

We first want to understand whether the access restrictions to the central bank's deposit facility lead to money market segmentation. Access banks always have the option to store funds at the deposit facility which is particularly attractive in the GC $<$ DFR environment; during those periods, we expect access banks to predominantly trade in the repo market for collateral purposes. Our first testing hypothesis is therefore that lending rates of access banks are more collateral-driven and thus less connected to the funding-based EONIA benchmark rate, in particular when repo rates fall below the DFR.

We provide a first graphical intuition of this mechanism in Figure 6 that illustrates the lower sensitivity of access banks to changes in the EONIA rate in the form of impulse response functions. We compute impulse response functions for trades involving access and nonaccess banks separately for periods during which the average GC rate is above the deposit rate (left panel) and below the deposit rate (right panel). The coefficients are derived from a time series regression of current repo rate changes on the concurrent and the ten preceding EONIA rate changes. The left panel highlights that access and nonaccess banks react similarly during periods when the GC rate is above the deposit rate with the point estimate for access banks being slightly smaller. Even if the deposit facility provides a smaller remuneration than a




The figure depicts the impulse response function of repo rates to changes in the money market benchmark rate for trades involving access and nonaccess banks in the period when the average GC rate is above (left panel) and below the rate on the deposit facility (right panel). The coefficients are derived from a time series regression of current repo rate changes on the concurrent and the ten preceding EONIA rate changes controlling for basket-month-term fixed effects. The regression includes heteroscedasticity-robust standard errors. Data include GC repo transactions for Germany for the term types ON and TN for the time-period 2010–2018.

**Figure 6:** Impulse response for trades involving access/nonaccess banks.

repo trade, the storage of liquidity at the facility is convenient for banks with access to it, thus explaining the overall lower sensitivity of access banks. However, once the GC rate drops below the rate on the deposit facility, the sensitivity of access banks is completely muted as they predominately trade for collateral-purposes. By contrast, banks without the outside option of storing funds at the deposit facility are still active in funding-based repo market segments keeping them more connected to changes in the EONIA rate. The graphical results point towards money market segmentation associated with access banks reacting less to changes in funding-based money market rates, in particular during periods when GC rates fall below the DFR, and a resulting rate dispersion between access and nonaccess banks.

We formalize the graphical intuition in a set of panel regressions. Our main regression equations read as follows:

$$\Delta r^{GC}_{t,i,l} = \beta_1 \cdot \Delta MMRate_t + \beta_2 \cdot D^{Dep}_{t,n} + \beta_3 \cdot \Delta MMRate_t \cdot D^{Dep}_{t,n} + \beta_4 \cdot \Delta r^{GC}_{t-1,i,l} + \epsilon_t \tag{1}$$

$$\Delta r^{GC}_{t,i,l} = \beta_1 \cdot \Delta MMRate_t + \beta_2 \cdot D^{Access}_{t,l} + \beta_3 \cdot \Delta MMRate_t \cdot D^{Access}_{t,l} + \beta_4 \cdot \Delta r^{GC}_{t-1,i,l} + \epsilon_t \tag{2}$$

$$\begin{aligned}\Delta r^{GC}_{t,i,l} = {} & \beta_1 \cdot \Delta MMRate_t + \beta_2 \cdot D^{Dep}_{t,n} + \beta_3 \cdot D^{Access}_{t,l} + \beta_4 \cdot \Delta MMRate_t \cdot D^{Dep}_{t,n} \\ & + \beta_5 \cdot \Delta MMRate_t \cdot D^{Access}_{t,l} + \beta_6 \cdot \Delta MMRate_t \cdot D^{Dep}_{t,n} \cdot D^{Access}_{t,l} + \beta_7 \cdot \Delta r^{GC}_{t-1,i,l} + \epsilon_t,\end{aligned} \tag{3}$$

where $\Delta r^{GC}_{t,i,l}$ denotes the log-change in GC repo rates of basket $i$ and lender type (access / nonaccess) $l$ at time $t$ and $\Delta MMRate_t$ denotes the log-change in the EONIA rate which we refer to as the money market benchmark rate. Moreover, we employ two dummy variables: $D^{Dep}_{t,n}$, which is equal to one if country $n$'s average GC rate is below the deposit facility rate, and $D^{Access}_{t,l}$, which is equal to one if the lender $l$ has access to the deposit facility.[25] We add basket-month-term fixed effects and employ heteroscedasticity-robust standard errors. Since trading in the GC repo market is concentrated in the ON and TN term types, we show our main results as a pooled regression of both term types in Table 2. We report our results for (i) Germany in columns 1–3, (ii) core European countries in columns 4–6, and (iii) all countries in columns 7–9.

[25]The denominations are: $\Delta r^{GC}_{t,i,l}$ is the log change in the volume weighted average daily repo rate per basket and lender type in percentage points. Correspondingly, $\Delta MMRate_t$ refers to the log change in the EONIA rate denoted in percentage points.

**Table 2:** ECB access.

| | Germany | | | Core | | | All | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ |
| | ON/TN | ON/TN | ON/TN | ON/TN | ON/TN | ON/TN | ON/TN | ON/TN | ON/TN |
| | b/t | b/t | b/t | b/t | b/t | b/t | b/t | b/t | b/t |
| $\Delta MMRate$ | 0.539*** | 0.717*** | 0.675*** | 0.473*** | 0.683*** | 0.646*** | 0.426*** | 0.589*** | 0.563*** |
| | (15.699) | (10.745) | (8.781) | (23.146) | (16.875) | (14.515) | (24.823) | (16.778) | (15.341) |
| $D^{Dep}$ | −0.046** | | −0.047** | −0.031*** | | −0.031*** | 0.003 | | 0.002 |
| | (−2.265) | | (−2.338) | (−2.851) | | (−2.917) | (0.304) | | (0.287) |
| $\Delta MMRate \cdot D^{Dep}$ | −0.176** | | 0.265** | −0.061 | | 0.312*** | −0.013 | | 0.399*** |
| | (−2.216) | | (2.082) | (−1.141) | | (3.952) | (−0.257) | | (5.370) |
| $D^{Access}$ | | −0.001 | −0.000 | | −0.005 | −0.004 | | −0.003 | −0.003 |
| | | (−0.071) | (−0.035) | | (−0.819) | (−0.720) | | (−0.746) | (−0.669) |
| $\Delta MMRate \cdot D^{Access}$ | | −0.264*** | −0.177** | | −0.284*** | −0.224*** | | −0.223*** | −0.187*** |
| | | (−3.549) | (−2.100) | | (−6.242) | (−4.520) | | (−5.687) | (−4.548) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{Dep}$ | | | −0.719*** | | | −0.574*** | | | −0.616*** |
| | | | (−4.970) | | | (−5.860) | | | (−6.607) |
| $N$ | 10,007 | 10,007 | 10,007 | 35,102 | 35,102 | 35,102 | 58,216 | 58,216 | 58,216 |
| $R^2$ | 0.210 | 0.213 | 0.220 | 0.180 | 0.185 | 0.187 | 0.174 | 0.177 | 0.179 |
| $\Delta repo^{GC}$ lagged | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the regression results examining the impact of access to the ECB's deposit facility on money market segmentation. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta MMRate$ denotes the change in the EONIA rate. $D^{Dep}$ equals 1 if a country's average GC rate is below the deposit facility rate. $D^{Access}$ equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for Germany, core European countries and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

As a first step, we consider repo transactions collateralized by German government securities. Since German collateral is considered to be safe and liquid, this limits any concerns about cross-country differences in sovereign risk and liquidity impacting our results. Regression (1) relates changes in GC rates to changes in the money market benchmark rate, depending on whether the GC rate is above or below the DFR. The results highlight that GC rates react strongly: A one-percentage-point increase in the EONIA rate is accompanied by an increase in GC rates of about 54 basis points. The effect is smaller at 36 basis points when the GC rate is below the DFR. This confirms our intuition that GC repo trades have a strong funding motive, which, however, becomes less important in the GC $<$ DFR environment.

In Regression (2), we analyze the different reactions of access and nonaccess banks. GC rates lent by banks with access to the deposit facility react less strongly. An increase in the funding-based benchmark rate by one percentage point relates to an increase in GC rates involving access banks of 45 basis points as compared to 72 basis points for nonaccess banks.

Considering our main Regression (3), which includes both dummy variables, we observe a combined effect: GC rates involving lenders with access tend to react less, their reaction is particularly weak when GC rates are below the rate on the deposit facility. The effect of changes in the money market benchmark rate on GC rates is 68 basis points for nonaccess banks as compared to 50 basis points for access banks for periods when GC rates are above the deposit rate. Once GC rates are below the DFR, the effect increases to 94 basis points for nonaccess banks while it decreases to 4 basis points for access banks. This indicates that lenders with access to the deposit facility do not react to changes in the funding-based money market segment in the GC $<$ DFR environment as their trades are predominantly collateral-driven, while lenders without access are very sensitive to it.

Columns 4–9 expand our analysis by looking at larger samples consisting of core European countries and all European countries. Overall, the results remain statistically and economically consistent. This indicates that the impact of having access to central bank facilities is not only present in the German "safe haven" market but across European countries as well.

We perform a number of additional robustness checks which confirm our main results.

First, we ensure that the results are consistent for each term type and regional classification. Second, we show that the results are also robust for different standard error and fixed effect specifications. Third, we repeat our analysis in a sample without quarter end and end of ECB maintenance period days and weeks. Our results are robust to removing those days that are characterized by higher idiosyncratic rate movements and spikes. And finally, we replicate our results for the sub-period until 2016 to account for the lower volatility and trading volume in the EONIA rate in recent years. We report all results in the Online Appendix.

To gain additional insight into our mechanism and the role of the DFR reflecting the opportunity cost of engaging in a repo trade for funding-purposes, we extend our analysis by looking at the distance between GC rates and the rate on the deposit facility. Our idea is that the sensitivity of access banks to changes in the funding-based money market rate is weaker for periods when the opportunity cost of engaging in a repo trade for funding-purposes is higher. More precisely, we expect that the lower GC rates are relative to the DFR, the more access banks will be active in collateral-based repo market segments which are more disconnected from funding-based money market segments.

Table 3 reports the regression results which focus on the distance of repo rates to the DFR. We show two regression specifications: (i) by employing a new, continuous variable "DFR Distance" which measures the difference between the DFR and the GC rate;[26] and (ii) by employing three buckets with $DFR1$ indicating periods when the GC rate is 25-50 basis points above the DFR, $DFR2$ indicating periods when the GC rate is 0-25 basis points above the DFR, and $DFR3$ indicating periods when the GC rate is below the DFR. For all regressions, we replace our previous $D^{Dep}$ dummy with the newly introduced DFR Distance variable or the respective DFR Distance buckets, interacted with the change in the EONIA rate $\Delta MMRate_t$. We report our results for (i) Germany in columns 1 and 2, (ii) core European countries in columns 3 and 4, and (iii) all countries in columns 5 and 6.

Our results highlight that the distance of GC rates to the DFR has a significant impact on access banks. Regression (1) shows that the sensitivity of access banks to changes in the

[26] Positive values of the DFR Distance variable indicating that GC rates are below the DFR.

**Table 3:** ECB access: Distance to deposit facility rate.

| | Germany | | Core | | All | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ |
| | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t |
| $\Delta MMRate$ | 0.716*** | 0.716*** | 0.684*** | 0.684*** | 0.589*** | 0.589*** |
| | (10.706) | (10.726) | (16.862) | (16.875) | (16.782) | (16.795) |
| $D^{Access}$ | −0.005 | −0.004 | −0.007 | −0.007 | −0.006 | −0.006 |
| | (−0.424) | (−0.350) | (−1.254) | (−1.282) | (−1.280) | (−1.348) |
| $\Delta MMRate \cdot D^{Access}$ | −0.386*** | 0.108 | −0.411*** | 0.149** | −0.334*** | 0.172*** |
| | (−4.772) | (1.183) | (−8.421) | (2.575) | (−8.083) | (3.210) |
| $\Delta MMRate \cdot D^{Access} \cdot DFRDistance$ | −0.719*** | | −0.783*** | | −0.608*** | |
| | (−5.718) | | (−9.091) | | (−8.245) | |
| $\Delta MMRate \cdot D^{Access} \cdot D^{DFR1}$ | | −0.235** | | −0.137** | | −0.244*** |
| | | (−2.235) | | (−1.992) | | (−3.207) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{DFR2}$ | | −0.375*** | | −0.483*** | | −0.443*** |
| | | (−4.831) | | (−9.861) | | (−9.692) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{DFR3}$ | | −0.785*** | | −0.683*** | | −0.612*** |
| | | (−8.907) | | (−10.004) | | (−9.205) |
| $N$ | 10,007 | 10,007 | 35,102 | 35,102 | 58,216 | 58,216 |
| $R^2$ | 0.218 | 0.221 | 0.190 | 0.192 | 0.180 | 0.181 |
| $\Delta repo^{GC}$ lagged | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the regression results examining the impact of access to the ECB's deposit facility on money market segmentation with a focus on the distance of repo rates to the deposit facility rate (DFR). The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta MMRate$ denotes the change in the EONIA rate. $D^{Access}$ equals 1 if a lending bank has access to the deposit facility. $DFRDistance$ refers to the difference between the DFR and a country's average GC rate. $D^{DFR1}$ indicates time periods when the GC rate is between 25-50 basis points above the DFR, $D^{DFR2}$ indicates time periods when the GC rate is between 0-25 basis points above the DFR, and $D^{DFR3}$ indicates time periods when the GC rate is below the DFR. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for Germany, core European countries and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

money market benchmark rate decreases in the difference between the DFR and the GC rate. For example, if the difference between the DFR and the GC rate increases by 10 basis points (i.e., GC rates drop by 10 basis points relative to the DFR), the sensitivity of access banks to changes in the funding-based money market rate reduces by 7 basis points. Regression (2) confirms that access banks already become less reactive to changes in the EONIA when GC rates get closer to the DFR. This effect is intensified once GC rates drop below the DFR. Both results confirm that access banks select themselves into more collateral-driven repo market segments when the opportunity cost of engaging in funding-based repo trades are higher, which leads to a disconnect of their repo lending rates from funding-based money market rates.

### 2.2 Introduction of ECB tiering as natural experiment

The introduction of the ECB's two-tier system for remunerating excess reserve holdings ("tiering") in 2019 is a natural experiment to illustrate our mechanism. The two-tier system provides each access bank with an allowance to store excess reserves at the ECB without paying the negative deposit rate that would generally apply to them.[27] The introduction of the tiering implies that the deposit facility becomes an even more attractive option for access banks to store liquidity, in particular for those access banks that still have unused allowances. Fuster et al. (2021) find that an increase in exemption allowances in Switzerland induced banks to deposit more funds at the deposit facility and to restrict their lending activities. In the context of our mechanism, access banks have an additional incentive to store funds at the ECB's deposit facility due to the tiering exceptions. Consequently, we expect access banks to move out of funding-based repo market segments after the tiering exemptions were introduced while continuing to trade in collateral-driven parts of the repo market which are less connected to funding-based money market rates, thereby exacerbating money market segmentation.

To isolate the impact of the tiering system, we adapt our empirical analysis for the time

[27] For holdings above the allowance, the deposit facility rate continues to apply.

**Table 4:** ECB access: Introduction of ECB tiering system.

| | Germany | Core | All |
|---|---|---|---|
| | (1) | (2) | (3) |
| | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ |
| | ON/TN b/t | ON/TN b/t | ON/TN b/t |
| $\Delta MMRate$ | 0.887*** | 0.752*** | 0.774*** |
| | (17.552) | (13.238) | (17.169) |
| $D^{Tiering}$ | −0.017* | −0.022*** | −0.043*** |
| | (−1.961) | (−3.406) | (−4.550) |
| $\Delta MMRate \cdot D^{Tiering}$ | 0.086 | −0.034 | −0.001 |
| | (0.629) | (−0.268) | (−0.004) |
| $D^{Access}$ | 0.002 | −0.003 | 0.000 |
| | (0.344) | (−1.023) | (0.053) |
| $\Delta MMRate \cdot D^{Access}$ | −0.076 | 0.048 | 0.035 |
| | (−0.672) | (0.544) | (0.509) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{Tiering}$ | −0.350 | −0.566** | −0.758** |
| | (−1.181) | (−2.451) | (−2.294) |
| $N$ | 516 | 1,657 | 2,811 |
| $R^2$ | 0.470 | 0.357 | 0.334 |
| $\Delta repo^{GC}$ lagged | Yes | Yes | Yes |

The table reports the regression results examining the impact of the ECB's introduction of the tiering program on money market segmentation. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta MMRate$ denotes the change in the money market rate. $D^{Tiering}$ equals 1 during the period the tiering was in place beginning on October 30th, 2019. $D^{Access}$ equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include basket, month, and term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for Germany, core European countries and all European countries pooled across the term types ON and TN for the time-period of the two ECB maintenance periods preceding the ECB Tiering introduction as well as the two ECB maintenance periods thereafter (August 2019 to January 2020).

period around the introduction of the two-tier system covering the two ECB maintenance periods before and after the introduction.[28] For this, we introduce the dummy variable $D^{Tiering}$, which is equal to one after the introduction of the tiering system on October 30th, 2019. For all regressions, we replace our previous $D^{Dep}$ dummy with the newly introduced $D^{Tiering}$ dummy, interacted with changes in the benchmark rate.

The results in Table 4 show that access banks are less responsive to EONIA rate changes after the introduction of the tiering. This effect is significant for core and all European countries in line with the idea that banks in those peripheral countries have benefited most from the introduction of the tiering and thus became less reactive to changes in funding-based money market rates. The two-tier system has a strong impact on banks that still have room in their allowance, which is more common in the periphery, for example in Italy (Cœuré, 2018). Due to the home bias observed among European financial institutions (Koijen et al., 2017), this implies that the segmentation becomes particularly noticeable in GC baskets associated with periphery countries.

### 2.3 Eligible/noneligible assets

The eligibility criteria of the QE program are a second illustration of our mechanism leading to money market segmentation. Eligible collateral is scarce and in high demand; repos secured by those scarce assets are more collateral-driven and thus less connected to funding-based money market segments. Our second testing hypothesis is therefore that repo rates secured by QE eligible assets are more disconnected from other money market rates such as the EONIA rate. Similar to the previous analysis, a lower correlation implies a stronger segmentation between the secured and unsecured money market segments. Our main panel

[28] The tiering is an out-of-sample analysis, hence it does not impact our main results.

regression equations read as follows:

$$\Delta r^{Special}_{t,i,l} = \beta_1 \cdot \Delta MMRate_t + \beta_2 \cdot D^{QE}_t + \beta_3 \cdot \Delta MMRate_t \cdot D^{QE}_t + \beta_4 \cdot \Delta r^{Special}_{t-1,i,l} + \epsilon_t \tag{4}$$

$$\begin{aligned}\Delta r^{Special}_{t,i,l} &= \beta_1 \cdot \Delta MMRate_t + \beta_2 \cdot D^{Eligible}_{t,i} + \beta_3 \cdot \Delta MMRate_t \cdot D^{Eligible}_{t,i} \\ &\quad + \beta_4 \cdot \Delta MMRate_t \cdot D^{QE}_t \cdot D^{Eligible}_{t,i} + \beta_5 \cdot \Delta r^{Special}_{t-1,i,l} + \epsilon_t\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta r^{Special}_{t,i,l} &= \beta_1 \cdot \Delta MMRate_t + \beta_2 \cdot D^{QE}_t + \beta_3 \cdot D^{Eligible}_{t,i} + \beta_4 \cdot \Delta MMRate_t \cdot D^{QE}_t \\ &\quad + \beta_5 \cdot \Delta MMRate_t \cdot D^{Eligible}_{t,i} + \beta_6 \cdot \Delta MMRate_t \cdot D^{QE}_t \cdot D^{Eligible}_{t,i} + \beta_7 \cdot \Delta r^{Special}_{t-1,i,l} + \epsilon_t,\end{aligned} \tag{6}$$

where $\Delta r^{Special}_{t,i,l}$ denotes the log-change in special repo rates and $\Delta MMRate_t$ denotes the log-change in the EONIA rate. Moreover, we employ two dummy variables: $D^{Eligible}_{t,i}$, which is equal to one if *security* $i$ is (hypothetically) eligible for purchase under the PSPP, and $D^{QE}_t$, which is equal to one after the introduction of the PSPP in March 2015. Additionally, we add ISIN-month-term fixed effects and heteroscedasticity-robust standard errors.[29] Trading in the special repo market is concentrated in the TN and SN term types, we therefore show our main results as a pooled regression of both term types in Table 5. We report our results for (i) Germany in columns 1–3, (ii) core European countries in columns 4–6, and (iii) all countries in columns 7–9.

Regression (1) relates changes in special repo rates to changes in the money market benchmark rate in the period prior to and after the introduction of the QE program. An increase in the unsecured benchmark rate by one percentage point translates into an increase of around 11 basis points in special repo rates in the period prior to the PSPP. During the current period of unconventional monetary policy, the effect has been muted. Although well expected based on our idea, a new stylized fact emerges as special repo rates are more collateral-driven and thus react less strongly to changes in the EONIA rate than more funding-driven GC rates. Still, also a special repo trade involves a funding motive and reacts to changes in funding conditions.

In Regression (2), we consider the impact of market segmentation along the lines of asset

[29] The fixed effects capture all bond-specific properties that are constant within a month, for example, issue size or on-the-run status.

**Table 5:** Asset eligibility.

| | Germany | | | Core | | | All | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ |
| | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN |
| | b/t | b/t | b/t | b/t | b/t | b/t | b/t | b/t | b/t |
| $\Delta MMRate$ | 0.106*** | 0.098*** | 0.109*** | 0.105*** | 0.095*** | 0.103*** | 0.099*** | 0.094*** | 0.101*** |
| | (19.746) | (13.001) | (13.196) | (31.250) | (17.688) | (17.850) | (30.217) | (18.379) | (18.370) |
| $D^{QE}$ | −0.016 | | −0.016 | −0.008 | | −0.008 | −0.020** | | −0.020** |
| | (−1.448) | | (−1.420) | (−1.176) | | (−1.157) | (−2.001) | | (−1.996) |
| $\Delta MMRate \cdot D^{QE}$ | −0.150*** | | −0.120*** | −0.126*** | | −0.106*** | −0.108*** | | −0.091*** |
| | (−15.860) | | (−8.160) | (−19.822) | | (−9.820) | (−17.347) | | (−8.349) |
| $D^{Eligible}$ | | 0.004 | 0.004 | | 0.003 | 0.003 | | 0.001 | 0.001 |
| | | (0.443) | (0.428) | | (0.580) | (0.578) | | (0.236) | (0.214) |
| $\Delta MMRate \cdot D^{Eligible}$ | | 0.006 | −0.005 | | 0.011 | 0.002 | | 0.004 | −0.004 |
| | | (0.537) | (−0.462) | | (1.622) | (0.299) | | (0.594) | (−0.556) |
| $\Delta MMRate \cdot D^{Eligible} \cdot D^{QE}$ | | −0.172*** | −0.052*** | | −0.136*** | −0.030** | | −0.116*** | −0.026* |
| | | (−14.030) | (−2.736) | | (−17.421) | (−2.211) | | (−15.232) | (−1.936) |
| $N$ | 301,766 | 301,766 | 301,766 | 706,015 | 706,015 | 706,015 | 943,926 | 943,926 | 943,926 |
| $R^2$ | 0.116 | 0.116 | 0.116 | 0.113 | 0.113 | 0.113 | 0.117 | 0.117 | 0.117 |
| $\Delta repo^{Special}$ lagged | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the regression results examining the impact of asset eligibility for quantitative easing programs on money market segmentation. The dependent variable is the change in the special rate $\Delta repo^{Special}$. $\Delta MMRate$ denotes the change in the EONIA rate. $D^{QE}$ equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for Germany, core European countries and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

eligibility for QE in a difference-in-difference setting. The dummy variable $D_{t,i}^{Eligible}$ measures whether the underlying collateral asset fulfills the eligibility criteria since the start of the program and whether it had (hypothetically) fulfilled the criteria in the prior periods. In order to be able to interpret the effect of asset eligibility as causal, we need to verify that the common trend assumption holds. This assumption holds if eligible and noneligible assets behave similarly in the period prior to QE. We therefore apply the initial implementation provisions retrospectively. We observe that trades involving hypothetically eligible assets do not exhibit significantly different changes in repo rates prior to QE; eligible and noneligible collateral assets also respond similarly to changes in the benchmark rate during that period. In the pre-QE period, the common trend assumption therefore holds. However, since the start of QE, repo trades involving eligible assets have a 17-basis-points lower sensitivity to changes in the EONIA rate compared to noneligible assets. This speaks to an effect caused by unconventional monetary policy.

Our main Regression (3) captures both effects. The impact of changes in the money market benchmark rate on special repo rates is almost muted during QE, which is in particular driven by trades involving QE eligible assets. In the period after the QE introduction, an increase in the benchmark rate by one percentage point implies an increase in the rates of noneligible assets by five basis points more relative to QE eligible assets. While the overall size of this effect seems small, it represents a 50% reduction relative to the overall sensitivity of special repo rates to changes in the unsecured money market segment. It highlights that assets become even more collateral-driven and therefore disconnect from overall money market movements when they are targeted by QE leading to their scarcity.

Columns 4–9 extend our analysis to core and all European countries, respectively, and confirm our results.

Similar to the previous analyses, we perform a number of additional robustness checks. First, we repeat our analysis for each term type and regional classification; second, for different standard error and fixed effect specifications; third, in a sample without quarter end and end of ECB maintenance period trading days and weeks; and finally, for a shorter sub-period

until 2016. Overall, the results remain statistically and economically consistent.[30]

To further manifest the economic determinants of our mechanism, we extend our analysis by looking at asset scarcity associated with unconventional monetary policy in more detail. Our idea is that asset scarcity is stronger for those assets which have been QE eligible for a longer period. Presumably, repos secured by scarcer assets are even more collateral-driven and thus less connected to funding-based money market segments.

Table 6 reports the regression results focusing on asset scarcity effects. We show two regression specifications: (i) by employing a new variable "time since eligibility" (TSE) which captures the number of days an asset has been eligible for purchase under the PSPP;[31] and (ii) by employing three TSE buckets with $TSE^1_{Bucket}$ for assets which have been QE eligible for up to 200 trading days, $TSE^2_{Bucket}$ for assets which have been eligible for up to 400 days, and $TSE^3_{Bucket}$ for assets which have been eligible for more than 400 days. For all regressions, we replace our previous $D^{Eligible}_{t,i}$ dummy with the newly introduced TSE variable or the respective TSE buckets, interacted with the change in the EONIA rate $\Delta MMRate_t$.

Regression (1) relates changes in special repo rates to changes in the money market benchmark rate under consideration of the continuous TSE variable. We observe that the connection of repo rates to the EONIA rate is weaker for those assets that have been eligible for purchase for a longer period. A one-percentage-point change in the benchmark rate translates into a 0.1 basis points lower sensitivity in special repo rates for each day an asset is eligible for purchase. To put this number into perspective: Assets which are 100 days eligible for purchase have a 10 basis points lower sensitivity. Regression (2) shows that the lower sensitivity of eligible assets is particularly driven by those assets which have been eligible for the longest period. For example, assets which have been eligible for less than 200 trading days do not show a significantly different sensitivity to changes in the EONIA rate. However, assets which have been eligible for up to 400 days have a 28-basis-points lower sensitivity. For assets which have been eligible for more than 400 days, the effect increases to 47-basis-points.

[30] All robustness checks are reported in the Online Appendix.

[31] TSE is a continuous variable which increases by one if asset $i$ on day $t$ was eligible for purchase under the PSPP. If an asset was eligible in the past but is not at the moment, the TSE variable keeps its value.

**Table 6:** Asset eligibility: Time since eligibility.

| | Germany | | Core | | All | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ |
| | TN/SN b/t | TN/SN b/t | TN/SN b/t | TN/SN b/t | TN/SN b/t | TN/SN b/t |
| $\Delta MMRate$ | 0.106*** | 0.106*** | 0.105*** | 0.105*** | 0.099*** | 0.099*** |
| | (19.745) | (19.745) | (31.250) | (31.250) | (30.217) | (30.217) |
| $D^{QE}$ | −0.015 | −0.016 | −0.008 | −0.008 | −0.020* | −0.020** |
| | (−1.365) | (−1.409) | (−1.091) | (−1.146) | (−1.951) | (−1.987) |
| $\Delta MMRate \cdot D^{QE}$ | −0.093*** | −0.120*** | −0.080*** | −0.104*** | −0.070*** | −0.082*** |
| | (−9.025) | (−8.483) | (−11.334) | (−9.789) | (−10.101) | (−7.532) |
| $\Delta MMRate \cdot TSE$ | −0.001*** | | −0.001*** | | −0.001*** | |
| | (−9.655) | | (−9.894) | | (−10.604) | |
| $\Delta MMRate*$ | | | | | | |
| $TSE^1_{Bucket}$ | | −0.008 | | −0.010 | | −0.022* |
| | | (−0.467) | | (−0.817) | | (−1.776) |
| $TSE^2_{Bucket}$ | | −0.279*** | | −0.087** | | −0.037 |
| | | (−5.995) | | (−2.515) | | (−1.376) |
| $TSE^3_{Bucket}$ | | −0.465*** | | −0.455*** | | −0.377*** |
| | | (−6.458) | | (−9.473) | | (−11.092) |
| $N$ | 301,766 | 301,766 | 706,015 | 706,015 | 943,926 | 943,926 |
| $R^2$ | 0.116 | 0.116 | 0.113 | 0.113 | 0.117 | 0.117 |
| $\Delta repo^{Special}$ lagged | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the regression results examining the impact of asset eligibility for quantitative easing on money market segmentation under particular consideration of the number of days an asset is eligible for QE purchase. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta MMRate$ denotes the change in the EONIA rate. $D^{QE}$ equals 1 during the PSPP. $TSE$ refers to the time since eligibility (i.e, the cumulative time an asset is eligible for purchase under the PSPP), which we split in three buckets: $TSE^1_{Bucket}$ for assets which have (cumulatively) been eligible for up to 200 days, $TSE^2_{Bucket}$ for assets which have been eligible for up to 400 days, and $TSE^3_{Bucket}$ for assets which have been eligible for more than 400 days. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for all European countries pooled across the term types TN and SN for the time-period 2010–2018.

The results are consistent for core and all European countries as shown in columns 3–6.

Clearly, our results speak to the role of asset scarcity, as repos secured by assets which have been eligible for purchase by the ECB for a longer period become more collateral-driven and their rates are less connected to the funding-based money market segment.

### 2.4 Joint effects

We now analyze the joint impact of banks' access to central bank deposits and collateral assets' eligibility for QE programs on money market segmentation.

In the GC market, certain baskets contain a higher share of collateral assets (out of the list of assets eligible to be delivered as collateral into a basket) that are eligible for QE purchases; thus, trading in these baskets increases the likelihood of sourcing assets that have become scarcer due to QE programs. This implies that those baskets become more collateral-driven and lenders might accept lower rates on those baskets, which would be an additional source of rate dispersion leading to money market segmentation.

To analyze this idea, we compute the share of securities eligible for QE programs within the pool of collateral assets potentially deliverable into a GC basket as an indicator for the likelihood of obtaining a QE eligible asset as collateral in a GC transaction. Our data features a cross-section of 46 GC baskets for which we compute, at each point in time, the volume-weighted share of the securities that can be used as collateral that are also (hypothetically) eligible for central bank asset purchases.[32] Using a similar panel regression set-up, we analyze whether baskets with a higher share of eligible securities react less strongly to changes in the funding-based EONIA rate, even after accounting for the banks' access to the ECB's deposit facility as a first form of market segmentation. For the regression, we introduce the dummy variable $D_{t,i}^{Eligible}$ for the GC market, which is equal to one if basket $i$ at time $t$ has a (hypothetical) eligibility share higher than the median eligibility share across all baskets of

[32]Consider, for example, the Eurex GC Basket "German Bond GC." All bonds issued by the German sovereign with a fixed or zero coupon and a minimum issue size of 100 million euro can be used as collateral for this basket. For each trading day and basket, we compile a list of all bonds that meet these basket-specific criteria and evaluate whether these securities are (hypothetically) eligible for QE purchases. The sample is slightly smaller compared to the previous analysis for the GC market due to data availability.

**Table 7:** Joint effects of both forms of market segmentation.

| | Germany | | | Core | | | All | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1a) | (1b) | (2) | (3a) | (3b) | (4) | (5a) | (5b) | (6) |
| | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{Special}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{Special}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{Special}$ |
| | ON/TN b/t | ON/TN b/t | TN/SN b/t | ON/TN b/t | ON/TN b/t | TN/SN b/t | ON/TN b/t | ON/TN b/t | TN/SN b/t |
| $\Delta MMRate$ | 0.475*** | 0.594*** | 0.158*** | 0.582*** | 0.604*** | 0.153*** | 0.612*** | 0.654*** | 0.159*** |
| | (5.030) | (5.998) | (12.932) | (10.815) | (10.541) | (17.592) | (12.817) | (12.609) | (18.622) |
| $D^{Dep}$ | −0.067** | −0.066** | 0.019*** | −0.037*** | −0.038*** | 0.006** | −0.024** | −0.024** | 0.008*** |
| | (−2.456) | (−2.396) | (3.611) | (−2.720) | (−2.772) | (2.049) | (−1.997) | (−2.025) | (2.709) |
| $\Delta MMRate \cdot D^{Dep}$ | 0.361*** | 0.284* | 0.027 | 0.394*** | 0.349*** | 0.115*** | 0.358*** | 0.312*** | 0.116*** |
| | (2.692) | (1.946) | (0.969) | (4.099) | (3.628) | (5.035) | (3.891) | (3.300) | (5.169) |
| $D^{Access}$ | −0.004 | −0.003 | −0.005*** | −0.006 | −0.006 | −0.005*** | −0.005 | −0.004 | −0.005*** |
| | (−0.265) | (−0.201) | (−2.673) | (−1.002) | (−0.949) | (−4.207) | (−0.846) | (−0.756) | (−4.517) |
| $\Delta MMRate \cdot D^{Access}$ | −0.181** | −0.182* | −0.061*** | −0.264*** | −0.268*** | −0.062*** | −0.316*** | −0.315*** | −0.072*** |
| | (−2.015) | (−1.836) | (−5.132) | (−4.726) | (−4.840) | (−7.841) | (−6.318) | (−6.312) | (−9.181) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{Dep}$ | −0.606*** | -0.626*** | −0.191*** | −0.466*** | −0.486*** | −0.245*** | −0.413*** | −0.431*** | −0.239*** |
| | (−3.775) | (−3.586) | (−6.483) | (−4.260) | (−4.347) | (−10.253) | (−3.909) | (−3.927) | (−9.984) |
| $D^{QE}$ | −0.113 | −0.117 | −0.013 | −0.047 | −0.053 | −0.007 | −0.056 | −0.062 | −0.011 |
| | (−1.489) | (−1.495) | (−1.218) | (−1.336) | (−1.494) | (−0.979) | (−1.069) | (−1.185) | (−1.301) |
| $D^{Eligible}$ | −0.017 | −0.008 | 0.003 | −0.010** | 0.010* | 0.004 | −0.010** | 0.007 | 0.004 |
| | (−1.509) | (−0.683) | (0.374) | (−2.048) | (1.900) | (0.655) | (−2.183) | (1.592) | (0.611) |
| $\Delta MMRate \cdot D^{Eligible}$ | 0.252*** | 0.056 | −0.006 | 0.138*** | 0.084* | 0.006 | 0.099** | 0.010 | 0.005 |
| | (3.338) | (0.609) | (−0.531) | (3.199) | (1.943) | (0.849) | (2.510) | (0.250) | (0.684) |
| $\Delta MMRate \cdot D^{Eligible} \cdot D^{QE}$ | −0.315*** | −0.024 | −0.097*** | −0.432*** | −0.298*** | −0.105*** | −0.349*** | −0.215*** | −0.109*** |
| | (−2.872) | (−0.159) | (−6.258) | (−6.809) | (−5.044) | (−10.268) | (−5.437) | (−3.486) | (−11.589) |
| $N$ | 6,802 | 6,802 | 301,525 | 30,314 | 30,314 | 628,424 | 37,453 | 37,453 | 758,182 |
| $R^2$ | 0.262 | 0.257 | 0.116 | 0.239 | 0.237 | 0.113 | 0.233 | 0.232 | 0.116 |
| $\Delta repo$ lagged | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the regression results examining the joint impact of bank access and QE asset eligibility on money market segmentation. The dependent variable is the change in the GC rate $\Delta repo^{GC}$ respectively the change in the special rate $\Delta repo^{Special}$. $\Delta MMRate$ denotes the change in the EONIA rate. $D^{Dep}$ equals 1 if a country's average GC rate is below the deposit facility rate. $D^{Access}$ equals 1 if a lending bank has access to the deposit facility. $D^{QE}$ equals 1 during the PSPP. $D^{Eligible}$ equals 1 in the GC segment in columns 1a/3a/5a if a basket $i$ at point $t$ has a higher share of eligible securities than the median basket for that country. In columns 1b/3b/5b it equals 1 if the cheapest-to-deliver bond in basket $i$ at point $t$ is eligible. In the special segment $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. Note, that the term $\Delta PolRate * D^{QE}$ was not included because it overlaps with $\Delta PolRate * D^{Dep}$ which complicates the identification and interpretation of the two coefficients. Including $\Delta PolRate \cdot D^{QE}$ instead of $\Delta PolRate \cdot D^{Dep}$ leads to consistent results. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include basket-/ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC and special repo transactions for Germany, core European countries and all European countries pooled across the term types ON, TN, and SN for the time-period 2010–2018.

that country at time $t$. Table 7 reports our results; for (i) Germany in column 1a, (ii) core European countries in column 3a, and (iii) all countries in column 5a.

In addition to confirming our previous results, we find in Regression (1a) that trades involving baskets with high and low eligibility shares respond differently to changes in the funding-based money market benchmark rate, even after controlling for the banks' access to the deposit facility. Since the start of QE, repo trades involving baskets with a higher share of eligible securities are less sensitive to changes in the EONIA rate. This points to the idea that GC baskets with a higher share of QE eligible assets become more collateral-driven, which is consistent with the effect for QE eligible assets in the special repo segment. Comparing the economic magnitude, access to central bank facilities remains the more pronounced effect.

In a GC repo, certain assets may be more likely to be delivered as collateral than others. In particular, it is possible to identify the "cheapest-to-deliver" collateral asset, which is the asset that commands the highest special repo rate and thus features the smallest repo specialness. We therefore employ the QE eligibility of the cheapest-to-deliver bond as an alternative to capture the effect of asset scarcity on GC repos. The results which are reported for (i) Germany in column 1b, (ii) core European countries in column 3b, and (iii) all countries in column 5b, confirm our previous results.

We now turn to the joint effects on special repos. To do this, we account for the lenders' access to the central bank's deposit facility in addition to the collateral assets' eligibility for QE.[33] The results are shown for (i) Germany in column 2, (ii) core European countries in column 4, and (iii) all countries in column 6. Regression (2) confirms that both forms of market segmentation are also present in the special repo market. A one-percentage-point change in the money market benchmark rate translates into a 19-basis-points lower sensitivity of access banks relative to nonaccess banks during periods when the GC rate is below the rate on the deposit facility and into a 10-basis-points lower sensitivity of QE eligible collateral assets relative to noneligible assets during the recent period of unconventional monetary policy. Columns 3–6 expand our analysis by looking at larger samples. Again, the results

[33] In this setting, $D_{t,i}^{Eligible}$ is specified as in our main regressions and equals one if *security* $i$ is (hypothetically) eligible for purchase under the PSPP.

remain statistically and economically consistent.

Overall, two new findings arise from our analysis of the joint effects: First, the QE implementation has increased money market segmentation in the GC segment suggesting a pervasive effect of asset scarcity coming from QE on the entire repo market. Second, the segmentation through special repos also depends on the access to a central bank's operations. To our knowledge, we are the first to document the QE impact on GC repos and the impact of access to central bank facilities on special repo rates. Both forms of segmentation lead repos to become more collateral-driven and thus less connected to funding-based money market segments.

### 2.5 Other money market segments

To underline the robustness of our results and show that segmentation is also present across other money market segments, we experiment with alternative rates to capture funding-based money market conditions. We employ the short-term interest rate benchmark (EONIA) as (i) our baseline rate. In 2017, the ECB announced that the euro short-term rate (€STR) will replace the EONIA as the new short-term benchmark in the euro area. Historical €STR rates date back to March 13th, 2017. As a (ii) second rate, we therefore consider an EONIA-€STR combination with the €STR rate replacing the EONIA rate after its publication. As a (iii) third, unsecured reference rate, we consider the overnight euro LIBOR rate. We also consider a set of derivatives-based, forward-looking overnight interest rates. We employ (iv) the overnight point of the Overnight Index Swap (OIS)–implied zero curve which uses one-month, three-month, and six-month OIS derivatives, as well as (v) the overnight point of the EURIBOR-implied zero curve, which uses one-month, three-month, and six-month EURIBOR derivatives. We also consider (vi) the one-week OIS rate.[34] Finally, we employ the (vii) rate on the GC Pooling basket which is the primary GC repo funding basket featuring a large trading volume and no counterparty credit risk due to central clearing. Any segmentation

[34]Since we observe daily closing prices for the derivatives-based measures from Thomson Reuters/Refinitiv Eikon, we relate changes in those derivatives-based money market rates over two days to daily rate changes in repo rates.

**Table 8:** ECB access: Different money market rates.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | EONIA | €STR | euro LIBOR | zero OIS | zero EURIBOR | OIS 1W | GC Pooling |
| | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ | $\Delta repo^{GC}$ |
| | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t | ON/TN b/t |
| $\Delta MMRate$ | 0.675*** | 0.675*** | 0.481*** | 0.298*** | 0.152*** | 0.402*** | 0.754*** |
| | (8.781) | (8.781) | (9.252) | (5.751) | (4.765) | (5.358) | (15.465) |
| $D^{Dep}$ | −0.047** | −0.047** | −0.050** | −0.043** | −0.049** | −0.045** | −0.041** |
| | (−2.338) | (−2.341) | (−2.497) | (−2.021) | (−2.088) | (−2.139) | (−2.109) |
| $\Delta MMRate \cdot D^{Dep}$ | 0.265** | 0.284** | 0.355*** | 0.338*** | 0.186** | 0.296** | 0.244** |
| | (2.082) | (2.218) | (3.996) | (3.482) | (2.236) | (2.571) | (2.052) |
| $D^{Access}$ | −0.000 | 0.000 | 0.004 | 0.005 | 0.001 | 0.002 | −0.001 |
| | (−0.035) | (0.004) | (0.335) | (0.466) | (0.080) | (0.193) | (−0.141) |
| $\Delta MMRate \cdot D^{Access}$ | −0.177** | −0.177** | −0.115* | −0.194*** | −0.067* | −0.184** | −0.152** |
| | (−2.100) | (−2.100) | (−1.708) | (−3.510) | (−1.937) | (−2.157) | (−2.567) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{Dep}$ | −0.719*** | −0.721*** | −0.679*** | −0.416*** | −0.251*** | −0.282* | −0.666*** |
| | (−4.970) | (−4.955) | (−5.731) | (−4.040) | (−2.904) | (−1.777) | (−4.235) |
| $N$ | 10,007 | 10,007 | 9,958 | 9,848 | 9,615 | 9,938 | 9,988 |
| $R^2$ | 0.220 | 0.220 | 0.188 | 0.131 | 0.129 | 0.156 | 0.308 |
| $\Delta repo^{GC}$ lagged | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the robustness results examining the impact of access to the ECB's deposit facility on money market segmentation for different money market rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta MMRate$ denotes the change in different money market rates. $D^{Dep}$ equals 1 if a country's average GC rate is below the deposit facility rate. $D^{Access}$ equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

**Table 9:** Asset eligibility: Different money market rates.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | EONIA | €STR | euro LIBOR | zero OIS | zero EURIBOR | OIS 1W | GC Pooling |
| | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ | $\Delta repo^{Special}$ |
| | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN | TN/SN |
| | b/t | b/t | b/t | b/t | b/t | b/t | b/t |
| $\Delta MMRate$ | 0.109*** | 0.109*** | 0.104*** | 0.050*** | 0.046*** | 0.110*** | 0.201*** |
| | (13.196) | (13.196) | (11.539) | (9.063) | (9.272) | (13.665) | (19.083) |
| $D^{QE}$ | −0.016 | −0.016 | −0.039*** | −0.028** | −0.030** | −0.039*** | −0.014 |
| | (−1.420) | (−1.407) | (−3.102) | (−2.327) | (−2.451) | (−3.466) | (−1.274) |
| $\Delta MMRate \cdot D^{QE}$ | −0.120*** | −0.115*** | −0.109*** | −0.022*** | −0.019*** | −0.050*** | 0.453*** |
| | (−8.160) | (−7.874) | (−9.379) | (−3.136) | (−2.937) | (−3.203) | (9.917) |
| $D^{Eligible}$ | 0.004 | 0.004 | 0.003 | 0.003 | 0.002 | 0.002 | 0.005 |
| | (0.428) | (0.424) | (0.304) | (0.317) | (0.247) | (0.223) | (0.562) |
| $\Delta MMRate \cdot D^{Eligible}$ | −0.005 | −0.005 | 0.000 | 0.014* | 0.002 | −0.018* | −0.008 |
| | (−0.462) | (−0.462) | (0.005) | (1.960) | (0.393) | (−1.777) | (−0.555) |
| $\Delta MMRate \cdot D^{Eligible} \cdot D^{QE}$ | −0.052*** | −0.044** | −0.023 | −0.031*** | −0.017** | −0.022 | −0.311*** |
| | (−2.736) | (−2.287) | (−1.491) | (−3.321) | (−2.045) | (−0.998) | (−5.435) |
| $N$ | 301,766 | 301,766 | 300,047 | 295,606 | 289,216 | 299,622 | 301,192 |
| $R^2$ | 0.116 | 0.116 | 0.117 | 0.116 | 0.116 | 0.114 | 0.123 |
| $\Delta repo^{Special}$ lagged | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

The table reports the robustness results examining the impact of asset eligibility for quantitative easing on money market segmentation for different money market rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta MMRate$ denotes the change in different money market rates. $D^{QE}$ equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

emerging from the dominant role of repo collateral (as opposed to funding) should also be present in relation to funding-based repo rates.

Table 8 shows that our results on banks' access to the deposit facility are statistically and economically consistent across all specifications.[35] All regressions arrive at the same conclusion that access banks are less sensitive to changes in funding-based money market rates in the GC $<$ DFR environment, which reinforces our idea that access banks lean towards more collateral-driven repo trades during those periods. Our results on QE eligibility are reported in Table 9 and are also fully consistent. QE eligible securities are less sensitive to changes in funding-based money market rates since the start of the ECB's QE program. This lower sensitivity has not been present in prior periods and thus reinforces our idea that asset scarcity leads repos to become more collateral-driven.

Across both specifications, repo rates are more sensitive to changes in unsecured overnight rates as compared to derivative-based implied overnight rates. This is intuitive since the funding conditions in the unsecured segment influence repo transactions. In line with this intuition, the explanatory power of our panel regressions is largest for changes in unsecured overnight rates which confirms our approach of employing the EONIA rate across our baseline specifications. Our results also hold true if we employ the rate on the ECB GC Pooling basket as our funding-based benchmark rate. This supports the interpretation that the two disconnecting mechanisms, i.e., DFR access and QE asset eligibility, are sources of money market segmentation also *within* the secured market.

## 3. Implications for monetary policy

Our results are relevant for the interpretation of different monetary policies. The introduction of the tiering system is one example that we have analyzed in this paper. Due to the tiering exceptions, access banks have an additional incentive to store funds at the deposit facility and thus predominantly trade in collateral-driven parts of the repo market which are less

[35] We present the results for German repo transactions for illustrative purposes. The results for core and all European countries are presented in the Online Appendix.

connected to funding-based money market rates. The observed effects are not a failure of the tiering policy which had the goal of supporting "the transmission of monetary policy through banks to firms and households by lowering banks' costs caused by negative interest rates" (Bank of Finland, 2019), but at the same time, it is important to understand those patterns in money markets which help us evaluate the overall effects of such policies. For example, the excessive usage of the deposit facility by access banks raises concerns about discouraging interbank trading which inhibits price determination (Keister et al., 2008). Widening the access to the deposit facility to include foreign banks such as in Switzerland (Kraenzlin and Nellen, 2015) is a similar illustration of this mechanism. Amendments to the Capital Requirements Regulation (CRR), at the heart of which is the (temporary) exclusion of central bank reserves from the calculation of the leverage ratio, could also manifest money market segmentation as it encourages banks (with access) to store additional funds at the ECB's deposit facility.

Focusing on QE, the notion that unconventional policies "safeguard the transmission of our monetary policy," as pointed out by ECB President Christine Lagarde (European Central Bank, 2020) should also consider that those programs can create rate dispersion, thereby leading to unintended consequences such as segmentation across different money market segments. Our results are also informative for the recent discussion about new short-term benchmark rates as they underline that measuring the price of cash becomes increasingly difficult in a collateral-driven repo market environment. Consequently, the ECB decided to choose an unsecured rate as their new benchmark.

Broadening the view, our results also have *suggestive* implications for the monetary policy transmission process. The "monetary policy transmission pipeline" involves three distinct steps: (i) the central bank's monetary policy actions pass-through into the money market, (ii) the conditions in the money market impact debt and equity markets, and (iii) monetary policy changes then propagate into the real sector.[36] Focusing on the first step, "in an

[36]We thank our discussant Olivier Wang for suggesting this metaphor. While the main focus of this paper is on the money market, other recent papers such as Wang (2018) consider the longer-run impacts of an inhibited monetary policy transmission, such as the impact on inflation.

idealized money market, any change in the main monetary policy rate should pass through perfectly to all money market rates" (Corradin et al., 2020, p.13). Our empirical analysis of money market segmentation, by contrast, indicates a dispersion in short-term rates which would suggest less control of the monetary policy transmission for central banks and pass-through inefficiencies.[37]

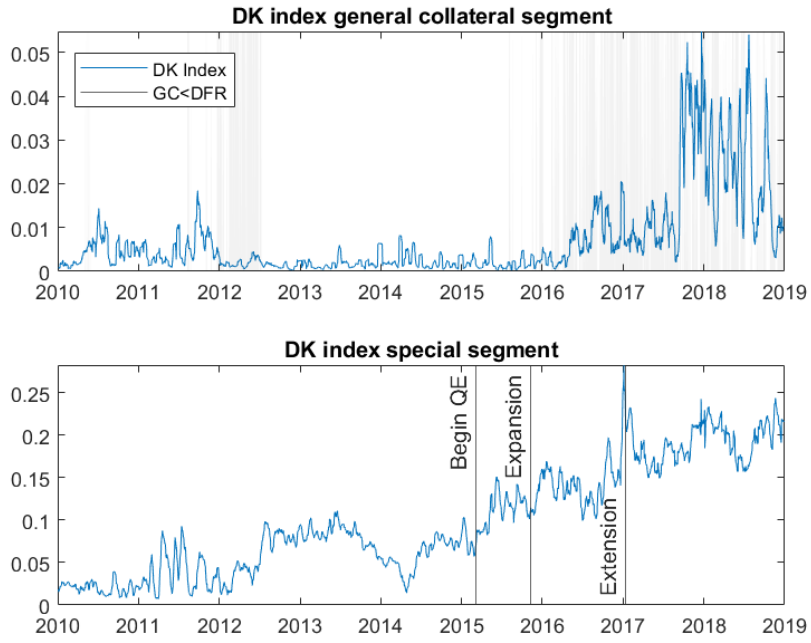
In our analysis, we employ the EONIA rate as the main short-term interest rate benchmark. In addition to being an important money market rate, the EONIA rate is "the key ECB interest rate"(European Central Bank, 2011) used as its operational target (Cœuré, 2018). For this reason, our results have implications for monetary policy.[38] The ECB directly sets the rates on the deposit and marginal lending facility which define the corridor for the EONIA rate.[39] The two rates, however, do not lend themselves to a pass-through analysis since they are set by the ECB in infrequent and discrete jumps. The EONIA rate, by contrast, evolves continuously and is informative to central banks (and market participants) about time-varying money market conditions and unconventional monetary policy effects. It must be stressed that variations in the EONIA rate are not only due to changes in the monetary policy stance as other factors such as risk premia and illiquidity determine it. However, it is reasonable to assume that the ECB takes the EONIA rate into account when evaluating

[37]The repo market is important for the transmission of monetary policy for two other reasons: First, repo market frictions not only impact the funding conditions of banks, but also the borrowing conditions faced by other financial institutions and governments, as has been shown for the U.S. Treasury market by He et al. (2021). Given that governments are the largest debt issuers, this is another avenue through which the repo market affects monetary policy transmission. Second, the repo market in the euro area plays an important role for the redistribution of reserves (Bank for International Settlements, 2017, p.16) which is also an important step in the process of monetary policy implementation.

[38]There are other aspects that render the EONIA rate important to ECB monetary policy framework. First, the EONIA comovement with other interest rates has been shown in, for example, Hristov et al. (2014) and Altavilla et al. (2020). Second, the EONIA is a standard choice on interest rate pass-through in the literature (see, e.g., Hristov, Hülsewig, and Wollmershäuser, 2014, Altavilla, Canova, and Ciccarelli, 2020, as well as Ciccarelli, Maddaloni, and Peydró, 2015; all three papers employ the EONIA rate as the ECB's policy instrument. And third, an unsecured money market rate such as the EONIA or the U.S. federal funds rate are commonly considered as the main policy rule to fulfill the central bank's mandate, which is well reflected in the widely used Taylor rule (Taylor, 1999).

[39]Within the corridor, the ECB steers the short-run liquidity conditions with its open market operations by providing liquidity for a period of one week or three months. Although these transactions are secured, open market operations are distinct from regular repo transactions in three ways: First, since October 2008 open market operations are conducted via fixed-rate full-allotment or benchmark allotment auctions, which are executed at the same rate for all participants. Second, these auctions occur on a weekly to monthly basis and thus do not provide for a viable alternative to obtain day-to-day short-term funding. And third, the maturities of one week or three months are longer term than typical overnight repo transactions.

the transmission of its monetary policy.

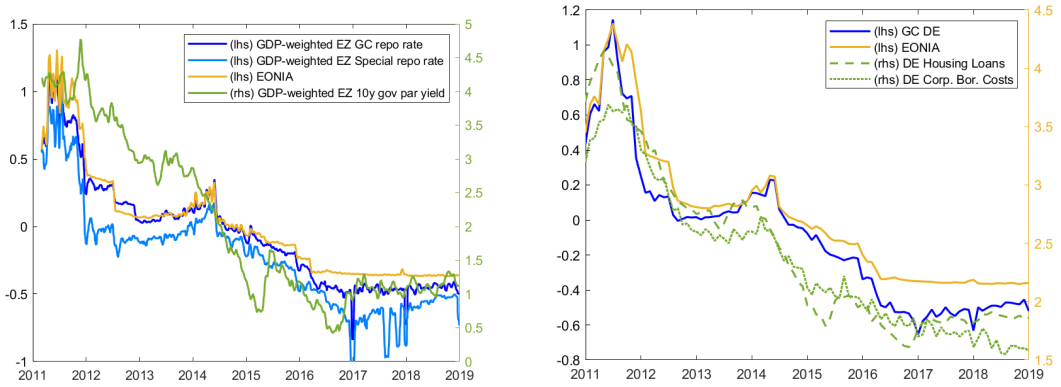



The figure depicts two DK dispersion indices defined as the volume-weighted average of the absolute deviation of repo rates from the volume-weighted mean repo rate in the spirit of Duffie and Krishnamurthy (2016, p.36). For the first DK index in the special market, we differentiate between rates on repos secured by QE eligible and noneligible collateral. For the GC segment, we consider rates of trades involving access and nonaccess lenders.

**Figure 7:** Repo market dispersion.

One prime indicator for pass-through inefficiency in money markets has been proposed by Duffie and Krishnamurthy (2016, p.36): a volume-weighted absolute dispersion index. Inspired by this, we present dispersion measures for the GC and special repo market segments in Figure 7 which we accordingly refer to as "DK index." We observe that the dispersion in the GC segment increases in the GC $<$ DFR environment (as indicated by the grey shaded area). Similarly, we observe an increase in the dispersion in the special segment since the introduction of QE that has further increased with extensions and expansions of the QE program. Both indices point towards rate dispersion and thus a potential weakening in the monetary policy transmission associated with the two disconnecting mechanisms which we analyze, i.e., access to central bank facilities and QE eligibility. What has emerged from our

preceding analysis, and what may be relevant to a deeper understanding of monetary policy transmission, is that access to central bank facilities and QE eligibility lead repo trades to become more collateral-driven.




**(a)** Eurozone government bond rates. **(b)** German real sector lending rates.

Figure 8a depicts the GDP-weighted average government bond yield within the Eurozone as well as the GDP-weighted mean GC and Special repo rates. Figure 8b depicts the co-movement of the mean German GC rate with two real sector lending rates, one depicting the borrowing costs for private homeowners and one for non-financial corporations in Germany. Both lending rates stem from the ECB's MFI Interest Rate Statistics (MIR). The mean GC rate refers to the volume-weighted mean observed in our dataset. For reference, we also include the EONIA rate in both graphs.

**Figure 8:** Interest rate co-movements.

To highlight the importance of the repo market for the monetary policy transmission into the real sector, Figure 8a shows the co-movement of GC and special repo rates with a GDP-weighted average Eurozone government bond yield, while Figure 8b illustrates that repo rates correlate with credit conditions faced by corporate borrowers and private households (illustratively for Germany). The graphical intuition points towards the repo rate playing an important role for the transmission of monetary policy into borrowing cost and bank lending rates. This raises the question how the second and third step of the monetary policy pass-through pipeline are impacted by the dispersion in money market rates that arises when the role of collateral in repos becomes dominant over the role of funding.

To empirically analyze this idea, we examine the pass-through of changes in the EONIA rate into lending rates faced by corporate borrowers and private households, depending on the conditions in the repo market. The dependent variable is the change of a given lending rate

**Table 10:** Repo dispersion and the pass-through to lending rates.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Non-Fin. | Non-Fin. | New | New |
| | Corporate | Corporate | Housing | Housing |
| | $\Delta r^L$ | $\Delta r^L$ | $\Delta r^L$ | $\Delta r^L$ |
| | b/t | b/t | b/t | b/t |
| $\Delta MMRate$ | $0.506^{***}$ | $0.501^{***}$ | $0.787^{**}$ | $0.792^{**}$ |
| | (3.431) | (3.327) | (2.804) | (2.778) |
| $\Delta MMRate \cdot D^{DK_{GC}}$ | $-0.522^{***}$ | | $-0.690^{**}$ | |
| | $(-3.254)$ | | $(-2.326)$ | |
| $\Delta MMRate \cdot D^{DK_{Special}}$ | $-0.445$ | | $-0.570^{***}$ | |
| | $(-1.653)$ | | $(-3.318)$ | |
| $\Delta MMRate \cdot D^{DK_{Repo}}$ | | $-0.526^{**}$ | | $-0.723^{**}$ |
| | | $(-3.072)$ | | $(-2.286)$ |
| $N$ | 1,101 | 1,101 | 1,017 | 1,017 |
| $R^2$ | 0.126 | 0.125 | 0.174 | 0.173 |

The table reports the regression results examining the pass-through of changes in the EONIA rate into lending rates faced by corporate borrowers and private households. The dependent variable is the change of a given lending rate $\Delta r^L$. Non-financial corporate borrowing rates refer to the annualized borrowing costs of non-financial firms for new loans, while new housing rates refer to bank interest rates on new loans to households for house purchases with an initial rate fixation period of between one and five years. Both lending rates are available from the ECB's monetary financial institutions (MFI) interest rate statistics. $\Delta MMRate$ denotes the change in the EONIA rate. $D^{DK_{GC}}$ equals 1 if the dispersion measure for the GC market is above its median. $D^{DK_{Special}}$ equals 1 if the dispersion measure for the Special market is above its median. $D^{DK_{Repo}}$ equals 1 if any of the GC and special repo market dispersion measures is above its median. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; $t$-statistics are in parentheses. All regressions include country-year fixed effects and standard errors accounting for clustering at the year level. Data are at a monthly frequency for all European countries for the time-period 2010–2020.

$\Delta r^L$, for which we consider borrowing costs of non-financial firms and loans to households for house purchases. $\Delta MMRate_t$ denotes the change in the EONIA rate. $D^{DK_{GC}}$ equals 1 if the dispersion measure for the GC market is above its median, $D^{DK_{Special}}$ equals 1 if the dispersion measure for the special market is above its median, and dummy $D^{DK_{Repo}}$ equals 1 if at least one of the two (GC and special) repo market dispersion measures is 1.

Table 10 reports the results of our panel regressions. Regression (1) relates changes in non-financial corporate borrowing rates to changes in the money market benchmark rate, depending on the dispersion in GC and special repo rates; regression (2) considers our repo market dispersion dummy. The results highlight that lending rates react strongly to changes in money market funding conditions: A one-percentage-point increase in the EONIA rate is accompanied by an increase in corporate borrowing rates of about 50 basis points. The effect is, however, almost muted when the dispersion in repo rates is high. Regression (3) and (4) confirm our results for residential housing rates.[40]

Both results provide suggestive support for Duffie and Krishnamurthy (2016) who highlight that a dispersion across money market interest rates is a primary indicator of the inefficiency of monetary policy pass-through. Although the monetary policy transmission into the real economy involves additional steps that deserve a detailed analysis beyond short-term rates, our results clearly speak to the importance of the repo market for the monetary policy transmission. Since the repo market is the predominant source of short-term funding, the repo market determines bank funding conditions and ultimately seems to impact the transmission of monetary policy into the real sector. Our results suggest that the money market is more segmented in a collateral-dominant environment and that the consequent rate dispersion is associated with a reduced responsiveness of real-sector lending rates to changes in EONIA rate which serves as the operational target for monetary policy.

[40]In all regressions, we account for country-year fixed effects. We also show in the Online Appendix that our results remain statistically and economically consistent if we consider other money market rates and if we shorten the sample period to the end of 2016.

# 4. Conclusion

"(T)he repo market has a number of unique characteristics related to the motivation for entering into a trade" (European Central Bank, 2022). Our analysis has shown that when the motivation to obtain collateral rather than cash is prevalent, the money market becomes more segmented. We uncover two important sources of money market segmentation: whether the money market participant is a bank that has access to the central bank's deposit facility and whether the collateral asset is the target of the Quantitative Easing (QE) program. We demonstrate that the lending rates of banks with access to the central bank's deposit facility and repo rates secured by assets eligible for QE programs are more collateral-driven and thus disconnected from funding-based benchmark rates.

Since the EONIA is also the operational target for the ECB's monetary policy, our findings provide suggestive evidence that money market segmentation weakens the monetary policy transmission. Our results underline that measuring the price of cash becomes increasingly difficult in a collateral-driven repo market environment. It is therefore important to consider the mechanism brought to light in this study when evaluating different monetary policies, which is also relevant for other regions such as the U.S. market.

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