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# «MONEY MARKET DISCONNECT»


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WORKING PAPERS ON FINANCE NO. 2020/03

SWISS INSTITUTE OF BANKING AND FINANCE (S/BF - HSG)

SEPTEMBER 04, 2020
THIS VERSION: OCTOBER 20, 2022

# Money Market Disconnect*

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October 20, 2022

**Abstract**

A repurchase agreement (repo) is a source of cash 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, Paul Söderlind, 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. Scheduled conferences include the ECB Money Market Conference (2022). 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."

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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.

The repo is the main money market instrument, it is a secured short-term loan that serves a dual role to obtain cash and collateral. The asset being used as collateral can be a particular government bond ("special repo") or any bond from a predefined basket ("general collateral or GC repo").[1] We focus on the European repo market, which is a centrally cleared money market that eliminates frictions of bilateral, over-the-counter (OTC) markets and thus provides the ideal laboratory to examine the dual nature of repos as the underlying mechanism leading to market segmentation. Banks can either operate as *lenders* of cash in repos to invest liquidity safely at a market-based return (funding motive) or to source the collateral (collateral motive). 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 repo rates and funding-based money market rates is a sign of this segmentation. To document this mechanism, we investigate two crucial aspects of the central bank's institutional framework as a source of this segmentation.

The first source is that only some banks have access to the ECB's deposit facility. In an environment where GC rates drop *below* the central bank's deposit facility rate (DFR) (henceforth GC $<$ DFR), access banks have the outside option to store liquidity at the central bank instead 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. In such an environment, we expect an endogenous selection of access banks into more collateral-driven repo segments that are less connected to funding-based money market rates. At first,

[1] In the U.S., a special repo is sometimes also referred to as a "specific" repo.

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 which is only available for access banks. Banks without access to the deposit facility, by contrast, do not have the option of accessing the deposit facility and, therefore, select themselves into more funding-driven repo segments which behave more like the unsecured market.

In line with this intuition, we show that access banks lend more in collateral-driven repo segments in the GC $<$ DFR environment and as a result, their repo lending rates are more disconnected from the EONIA as the funding-based money market benchmark rate. In such an environment, an increase in the EONIA rate by one percentage point translates into an increase in lending rates involving access banks of only 28 basis points (pointing to market segmentation) compared to an almost one-to-one reaction of banks without access (pointing to high integration).

The second source of our mechanism 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 purchases lead to asset scarcity and repo rates secured by those assets become more special (Arrata et al., 2020; Corradin and Maddaloni, 2020). As a consequence, we expect repos with QE eligible assets as collateral to become predominantly driven by collateral demand disconnecting them from funding-based money market segments.

In line with this idea, 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 QE eligible assets. 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. In addition to the diverging patterns during QE, we observe a similar behavior of (hypothetically) eligible and noneligible assets in the periods prior to QE which suggests a causal impact of central bank asset purchases and resulting asset scarcity on money market segmentation.

Our results are relevant for different monetary policies. We study the introduction of the ECB's two-tier system for remunerating excess reserve holdings in 2019 ("tiering"), which 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. As a result, we show that the lending rates of access banks are more disconnected from the EONIA rate after the introduction of the tiering system. 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.

Since the EONIA rate is the operational target rate of the ECB, our results about money market segmentation also have *suggestive* implications for the monetary policy transmission process. The idea is that 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). To test this, we compute a dispersion indicator of repo rates based on Duffie and Krishnamurthy (2016) by taking into account access status and QE eligibility. The results show that interest rates relevant for the real economy such as non-financial corporate borrowing and housing rates respond less to changes in 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 document the underlying mechanism behind money market segmentation related to repo trades

being predominantly driven by collateral demand. And second, we identify two sources of this disconnecting mechanism, i.e., access to a central bank's deposit facility and asset eligibility for QE. Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) Corradin and Maddaloni (2020) investigate the effects of QE purchases on the level of special repo rates.[2] 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 the transmission process (e.g., Duffie and Krishnamurthy, 2016; Drechsler et al., 2017; Eisenschmidt et al., 2020). We are the first to shed light on how two key features of the central bank framework, i.e., access to central bank facilities and QE purchases, lead to money market segmentation. Our results are relevant for different monetary policies, such as the two-tier system, and the monetary policy transmission.[3]

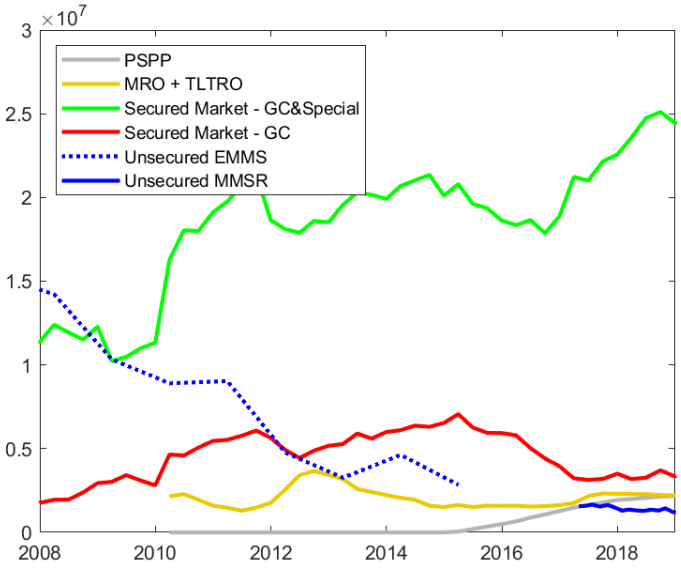
## 1. European money market

The focus of this paper is to provide new insights about money market segmentation, its underlying mechanism, and potential implications for monetary policy. For this, we focus on the European money market, which provides a unique setting to analyze those questions.

Figure 1 gives a market overview, it depicts the aggregate trading volumes in the secured repo market and in the unsecured EONIA money market. 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 (ICMA, 2021), the repo market now

[2]Related is Roh (2021) who points out that the ECB's decision to lend out bonds that it purchased also impacts asset scarcity. In addition, the inactive lending of bonds by nonbanks also adds to the scarcity of those assets (Maddaloni and Roh, 2021).

[3]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.




The figure depicts the aggregate cumulative quarterly trading volumes in the secured and unsecured market segments as well as the total cumulative QE purchases under the Public Sector Purchase Programme (PSPP) 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 the repo market. 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.

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 Public Sector Purchase Programme (PSPP), or of the ECB's main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO).

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.[4]

The idea developed in this paper is that money market segmentation emerges from the repo market and impacts other money market segments such as the EONIA market. To understand this mechanism, we briefly illustrate the key repo market characteristics.

### 1.1 Repo market

In a repo trade, two counterparts exchange cash for collateral for a predefined time period with a fixed repurchase obligation. 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.[5] Due to the collateralized nature, repos serve a dual role for cash and collateral. *Lenders* of cash in repos

[4]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. We consider both rates in our analysis and show that our results are consistent for both rates.

[5]A repo in the euro area represents a true sale and repurchase of the collateral, i.e., the lender becomes the legal owner of the collateral for the repo term.

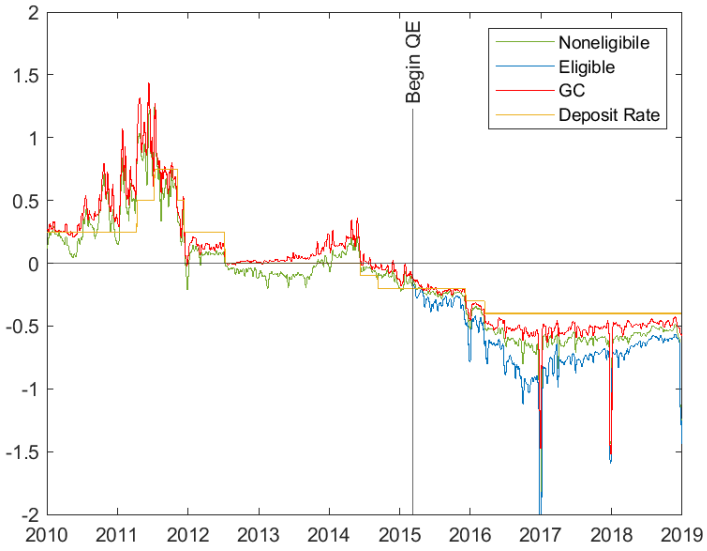
can either look for a safe investment that offers a market-based return or a way to source the asset serving as collateral.

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 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.[6] 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 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.[7]

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 DFR at the height of the European sovereign debt crisis in 2012 and during the period of unconventional monetary policy starting in 2015. This is an important regime change for our analysis that we 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

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

[7] 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.

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 to lend cash against QE eligible than noneligible assets, which points towards *collateral* demand for those eligible assets.[8]

The graphical results suggest that banks with access to the central bank's deposit facility and repos secured by asset eligible for QE behave differently in the money market as those trades are predominantly collateral-driven. Intuitively, we expect repo trades driven by collateral demand to be less connected to funding-based money market segments, thereby giving rise to money market segmentation.

[8]The spread between eligible and noneligible rates has been present since the introduction of QE in 2015 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.

### 1.2 ECB access

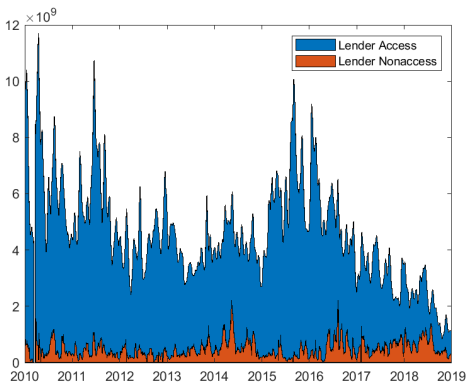
The first source of money market segmentation that we investigate is that only a given set of money market participants are banks that have access to the central bank's refinancing operations and its deposit facility.[9] In the euro area, the ECB operates two standing facilities: The deposit facility 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 the 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.

To study the different behavior of access and nonaccess banks, 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 or (ii) to source a high-quality collateral. Storing funds at the deposit facility is the outside option for banks with access to it.[10] Figure 3a depicts, in this context, the development in GC trading volumes for access and nonaccess lenders (illustratively for Germany).[11] 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

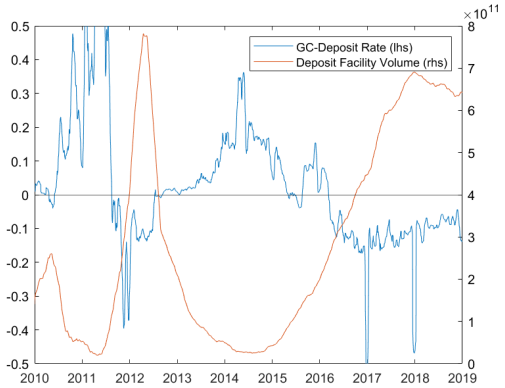
[9]The importance of access to central bank's facilities has been stressed in the literature. The deposit rate as the rate of remuneration for reserves is a general and important feature of financial intermediaries' decision problems that is incorporated into macro-financial models (Cúrdia and Woodford, 2011; Bech and Monnet, 2016; Williamson, 2019). In these models, a single deposit rate applies uniformly to all market participants and serves as the outside option. 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.

[10]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).

[11]We present corresponding volume breakdowns by the borrowing side in the Online Appendix.




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




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

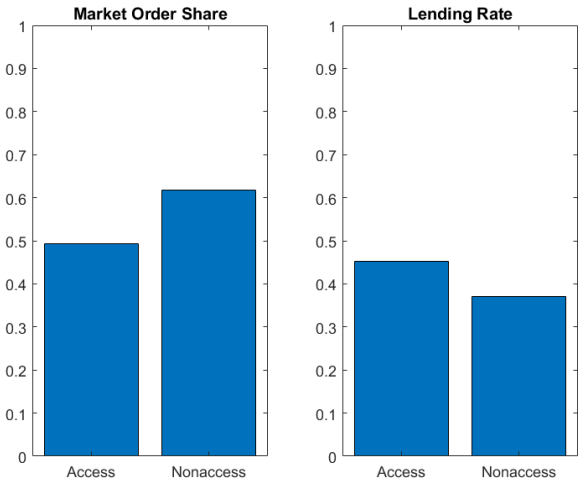
Figure 3a depicts the total trading volume in the German GC market for trades involving a lender with and without access to the ECB facilities. Figure 3b depicts the spread between the German GC rate and the ECB's rate on the deposit facility as well as the total volume deposited at the ECB deposit facility.

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

volume. This drop is accompanied by an increase in the volume of funds deposited at the ECB's deposit facility by access banks (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, whereas nonaccess banks continue to lend in the GC market to obtain a (safe) deposit of liquidity.[12]

The segmentation between access and nonaccess banks relates to the funding-motive in repo trades and 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

[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). In addition, 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.

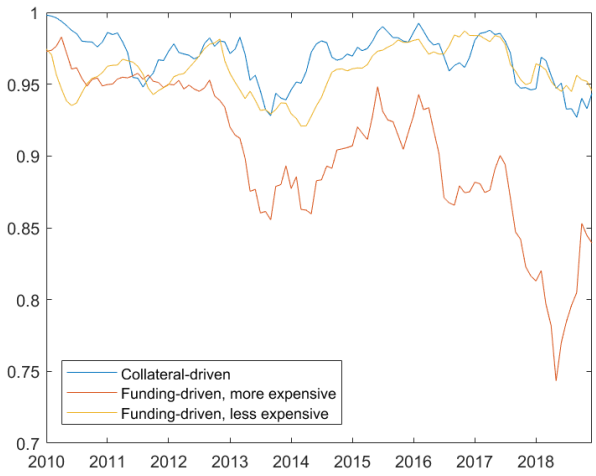



The left panel depicts the share of market orders and the right panel the excess rate frequency, separately for banks with and without access to the deposit facility. The excess rate frequency denotes how often a bank receives a higher interest rate on their lending activity than the daily average rate in a given basket and is computed according to Bechtel et al. (2022). The figure includes data on all overnight GC repo trades for the time-period 2010–2018.

**Figure 4:** Market order share and excess rate frequency.

former. This implies that nonaccess banks have a higher funding immediacy in repo trades. One illustration of this mechanism is to compare the average market order share and repo rate of access and nonaccess banks for the *same collateral basket* as is shown in Figure 4. Nonaccess lenders have a higher funding immediacy, hence, their market order share is higher and the corresponding repo rates are lower.

In the euro area repo market, a variety of *different GC repo baskets* are traded. 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 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 5 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




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 5:** Trading share of access banks.

(iii) baskets of peripheral euro area countries including the GC pooling baskets (yellow line).[13] 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.[14]

We observe that in the recent GC $<$ DFR environment, 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 below the DFR due to their outside option of storing funds at the deposit facility. This means 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

[13]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.

[14]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.

market segments. 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).[15]

### 1.3 Asset eligibility

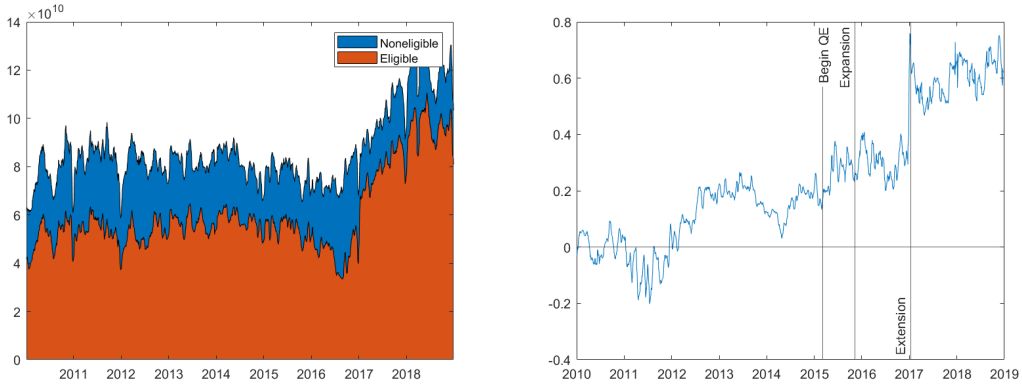
The second source of money market segmentation that we consider are the eligibility criteria of collateral assets for central bank QE purchases.[16] The ECB announced in 2015 its intention to conduct large-scale asset purchases. Since the beginning of these programs, cumulative net purchases amounted to more than 2.5 trillion euro. The PSPP 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 lead to market segmentation. The effect of asset purchases on bond scarcity comes on top of tighter regulation of financial institutions under

[15] 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 5 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 has shown that (repo) arbitrage activity exists but is insufficient to close these "gaps" (Ranaldo et al., 2019).

[16] 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, see, for example, Schlepper, Riordan, Hofer, and Schrimpf (2017), Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020), Corradin and Maddaloni (2020), Roh (2021), and Maddaloni and Roh, 2021. 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).

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.

We exploit the implementation provisions for asset purchases as a source of exogenous variation to classify collateral in a repo transaction into QE *eligible* and *noneligible* depending on the provisions that were valid at a specific point in time.[17] 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 as causal.




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

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

Figure 6a depicts the total trading volume in the special collateral market for trades involving eligible and noneligible collateral. Figure 6b 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 6:** Special collateral repo market.

For this part of the analysis, we focus on the special repo segment that specifies a specific

[17] 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 DFR, 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.

bond as collateral. Figure 6a shows the trading volume for QE eligible and noneligible securities over time, while Figure 6b 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 the 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 increasingly led to 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.

### 1.4 Data

For our analysis, we employ high-frequency, trade-level data for the European repo market for the time period between 2010 and 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 exclude a very small fraction of repo contracts and trading days to ensure the robustness and general validity of our results. First, we focus on the repo 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.[18] Second, we exclude holidays as well as year-end trading days. We further provide

[18]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 segments, whereas trading in the special repo market segment

robustness checks excluding all quarter-end and end of ECB maintenance period trading days, as well as the corresponding weeks.[19] Third, we exclude special repos secured by corporate securities. Fourth, 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.[20] We also perform our analyses for three different groups of countries: (i) Germany, (ii) core European countries, and (iii) all European countries.[21]

To identify banks, we follow the approach of Ranaldo et al. (2019) and Di Filippo et al. (2022) 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.[22] Our data contains repo trades involving 98 different banks, of which 85 are access banks and 13 are nonaccess banks.[23] 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, access lenders trade, on average, at a higher rate than nonaccess banks (0.16% compared to 0.13%) in the GC $>$ DFR environment, which reflects, for example, their lower market order share as shown in Figure 5. In the GC $<$ DFR environment, the

predominantly takes place in the TN and SN segments. We account for this in the empirical part.

[19]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).

[20]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.

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

[22]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.

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

**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).

difference more than doubles as 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 (hypothetically) eligible and noneligible for QE according to the PSPP's implementation provisions. 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. Other bond characteristics such as repo trade size, bond issue size, and bond coupon rate are comparable between the two groups.[24] 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.

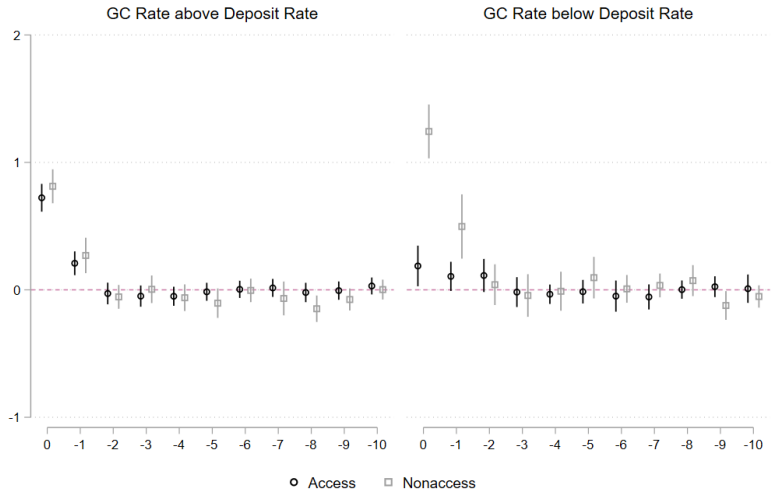
## 2. Empirical results

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

[24] The average tenor is longer for eligible assets as this is one of the implementation criteria.




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

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 7 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

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 GC rates drop below the DFR, the sensitivity of access banks is almost completely muted as they predominately trade for collateral-purposes in the repo market. 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.

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 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.

As a first step, we consider repo transactions collateralized by German government bonds. 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)

[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 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 | ON/TN b/t | ON/TN b/t |
| $\Delta MMRate$ | 0.612*** | 0.762*** | 0.708*** | 0.531*** | 0.741*** | 0.698*** | 0.480*** | 0.641*** | 0.610*** |
| | (15.672) | (10.955) | (8.515) | (24.119) | (17.871) | (15.026) | (26.602) | (18.235) | (16.458) |
| $D^{Dep}$ | −0.027 | | −0.029 | −0.017* | | −0.018* | −0.001 | | −0.001 |
| | (−1.271) | | (−1.366) | (−1.731) | | (−1.783) | (−0.228) | | (−0.228) |
| $\Delta MMRate \cdot D^{Dep}$ | −0.073 | | 0.294** | 0.032 | | 0.318*** | 0.101** | | 0.418*** |
| | (−0.886) | | (2.274) | (0.603) | | (3.976) | (1.994) | | (5.472) |
| $D^{Access}$ | | 0.002 | 0.003 | | −0.002 | −0.001 | | −0.004 | −0.003 |
| | | (0.265) | (0.308) | | (−0.346) | (−0.220) | | (−1.023) | (−0.919) |
| $\Delta MMRate \cdot D^{Access}$ | | −0.216*** | −0.128 | | −0.271*** | −0.217*** | | −0.209*** | −0.176*** |
| | | (−2.697) | (−1.358) | | (−5.758) | (−4.144) | | (−5.252) | (−4.184) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{Dep}$ | | | −0.590*** | | | −0.436*** | | | −0.461*** |
| | | | (−3.730) | | | (−4.328) | | | (−4.753) |
| $N$ | 10,172 | 10,172 | 10,172 | 35,650 | 35,650 | 35,650 | 59,029 | 59,029 | 59,029 |
| $R^2$ | 0.225 | 0.228 | 0.232 | 0.198 | 0.203 | 0.204 | 0.192 | 0.195 | 0.196 |
| $\Delta repo^{GC}$ 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 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.

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 61 basis points. The effect is smaller at 54 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 55 basis points compared to 76 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 react less, their reaction is particularly weak when GC rates are below the DFR. The effect of changes in the money market benchmark rate on GC rates is 71 basis points for nonaccess banks compared to 58 basis points for access banks during periods when GC rates are above the DFR. Once GC rates fall below the DFR, the effect is almost one-to-one for nonaccess banks, while it decreases to 28 basis points for access banks. This indicates that lenders with access to the deposit facility hardly react to changes in the funding-based money market rate in the GC $<$ DFR environment as their trades are predominantly driven by collateral demand, 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 are consistent with the effect being strongest in the German "safe haven" market. The reason for it is that repo rates for Germany are the lowest across the euro area, hence the effect of access banks selecting themselves into more collateral-driven baskets is strongest in this environment.[26]

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

[26] We show in the Online Appendix that the effect is smallest if we only consider periphery euro area countries as (i) repos secured by those assets are predominantly funding-driven and (ii) the corresponding repo rates are trading above or close to the DFR.

First, we ensure that the results are consistent for each term type. Second, we show that the results are 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. All results are reported 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 DFR. Our idea is that the sensitivity of access banks to changes in funding-based money market rates is weaker for periods when the opportunity cost of engaging in a repo trade for funding-purposes is higher. More precisely, we expect access banks to be increasingly active in collateral-based repo market segments, which are more disconnected from funding-based money market rates, the lower GC rates are relative to the DFR.

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;[27] 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

[27] 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 |
| $\Delta MMRate$ | $0.762^{***}$ | $0.762^{***}$ | $0.742^{***}$ | $0.742^{***}$ | $0.641^{***}$ | $0.642^{***}$ |
| | (10.951) | (10.945) | (17.878) | (17.887) | (18.239) | (18.248) |
| $D^{Access}$ | 0.001 | 0.001 | $-0.003$ | $-0.004$ | $-0.005$ | $-0.006$ |
| | (0.103) | (0.092) | $(-0.639)$ | $(-0.791)$ | $(-1.321)$ | $(-1.560)$ |
| $\Delta MMRate \cdot D^{Access}$ | $-0.266^{***}$ | 0.067 | $-0.343^{***}$ | $0.103^{*}$ | $-0.261^{***}$ | $0.124^{**}$ |
| | $(-2.978)$ | (0.742) | $(-6.661)$ | (1.813) | $(-6.022)$ | (2.424) |
| $\Delta MMRate \cdot D^{Access} \cdot DFRDistance$ | $-0.324^{**}$ | | $-0.468^{***}$ | | $-0.294^{***}$ | |
| | $(-2.133)$ | | $(-5.095)$ | | $(-3.665)$ | |
| $\Delta MMRate \cdot D^{Access} \cdot D^{DFR1}$ | | $-0.224^{**}$ | | $-0.147^{**}$ | | $-0.251^{***}$ |
| | | $(-2.248)$ | | $(-2.311)$ | | $(-3.547)$ |
| $\Delta MMRate \cdot D^{Access} \cdot D^{DFR2}$ | | $-0.276^{***}$ | | $-0.419^{***}$ | | $-0.371^{***}$ |
| | | $(-3.495)$ | | $(-8.699)$ | | $(-8.459)$ |
| $\Delta MMRate \cdot D^{Access} \cdot D^{DFR3}$ | | $-0.548^{***}$ | | $-0.494^{***}$ | | $-0.387^{***}$ |
| | | $(-5.355)$ | | $(-7.230)$ | | $(-5.805)$ |
| $N$ | 10,172 | 10,172 | 35,650 | 35,650 | 59,029 | 59,029 |
| $R^2$ | 0.229 | 0.232 | 0.204 | 0.207 | 0.196 | 0.197 |
| $\Delta repo^{GC}$ 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 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 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 distance between the DFR and the GC rate. For example, if the difference between the DFR and the GC rate increases by 10 basis points (e.g., 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 3 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 in 2019 is a natural experiment to illustrate our mechanism. The tiering 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.[28] 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 period around the introduction of the two-tier system covering the two ECB maintenance

[28] For holdings above the allowance, the DFR 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 |
| $\Delta MMRate$ | 0.901*** | 0.765*** | 0.791*** |
| | (17.522) | (13.081) | (17.834) |
| $D^{Tiering}$ | −0.016* | −0.021*** | −0.041*** |
| | (−1.822) | (−3.181) | (−4.330) |
| $\Delta MMRate \cdot D^{Tiering}$ | 0.145 | 0.068 | 0.220 |
| | (0.740) | (0.342) | (0.509) |
| $D^{Access}$ | −0.001 | −0.003 | −0.002 |
| | (−0.267) | (−1.294) | (−0.460) |
| $\Delta MMRate \cdot D^{Access}$ | −0.070 | 0.063 | 0.035 |
| | (−0.588) | (0.681) | (0.477) |
| $\Delta MMRate \cdot D^{Access} \cdot D^{Tiering}$ | −0.210 | −0.566** | −0.944* |
| | (−0.819) | (−2.215) | (−1.648) |
| $N$ | 503 | 1,614 | 2,735 |
| $R^2$ | 0.464 | 0.366 | 0.339 |
| $\Delta repo^{GC}$ 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 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).

periods before and after the introduction.[29] 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 EONIA 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 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 (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 those countries.

### 2.3 Eligible/noneligible assets

The eligibility criteria of the QE program are a second illustration of our mechanism. 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 rates. 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. Similar to the previous analysis, a lower correlation implies a stronger segmentation between the secured and unsecured money market segments. Our main panel regression equations read as follows:

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

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

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

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

where $\Delta r_{t,i,l}^{Special}$ 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: $D_{t,i}^{Eligible}$, which is equal to one if *security* $i$ is (hypothetically) eligible for purchase under the PSPP, and $D_t^{QE}$, 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.[30] 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 period of unconventional monetary policy, the effect has been muted. Overall, special repo rates are more collateral-driven and thus react less strongly to changes in the EONIA rate than more funding-driven GC rates, which confirms our intuition. 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 eligibility for QE in a difference-in-difference setting. The dummy variable $D_{t,i}^{Eligible}$ measures whether the underlying collateral asset fulfills the QE eligibility criteria since the start of the program and whether it had (hypothetically) fulfilled the criteria in the prior period. 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

[30] 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.

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 is associated with a five basis points lower reaction of 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 rate. It highlights that assets become even more collateral-driven and, therefore, disconnected 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. The effect is again strongest for German collateral assets as those assets tend to have the highest collateral demand.

Similar to the previous analyses, we perform a number of additional tests (results are reported in the Online Appendix). First, to manifest the economic determinants of our mechanism, we extend our analysis by looking at asset scarcity associated with unconventional monetary policy in more detail. Asset scarcity is stronger for those assets which have been QE eligible for a longer period. In line with this intuition, we show that 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. And second, we perform the same comprehensive set of robustness checks, which confirm that our results are statistically and economically consistent.

### 2.4 Additional analyses

To underline the relevance of our results, we carry out two additional analyses (results are also reported in the Online Appendix). To analyze the *internal* relevance of our results, we look at the joint impact of banks' access to the central bank's deposit facility and collateral assets' eligibility for QE on money market segmentation. We find that both effects lead to rate

dispersion and add to one another pointing towards a pervasive money market segmentation. In addition, to highlight the *external* relevance of our results, we show that segmentation emerging from the dominant role of repo collateral (as opposed to funding) is present across different money market segments and also *within* the secured market.[31]

## 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 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).

A similar illustration of our mechanism is if foreign banks had access to the deposit facility, such as in Switzerland (Kraenzlin and Nellen, 2015). Amendments to the CRR have also encouraged (access) banks to hold reserves at the central bank. While this is beneficial from a financial stability perspective, any evaluation of this policy should take other effects

[31] For this, 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. Finally, we employ the (vii) rate on the GC Pooling basket which is the primary GC repo funding basket. Any segmentation emerging from the dominant role of repo collateral should also be present in relation to funding-based repo rates.

such as a resulting money market segmentation into account.

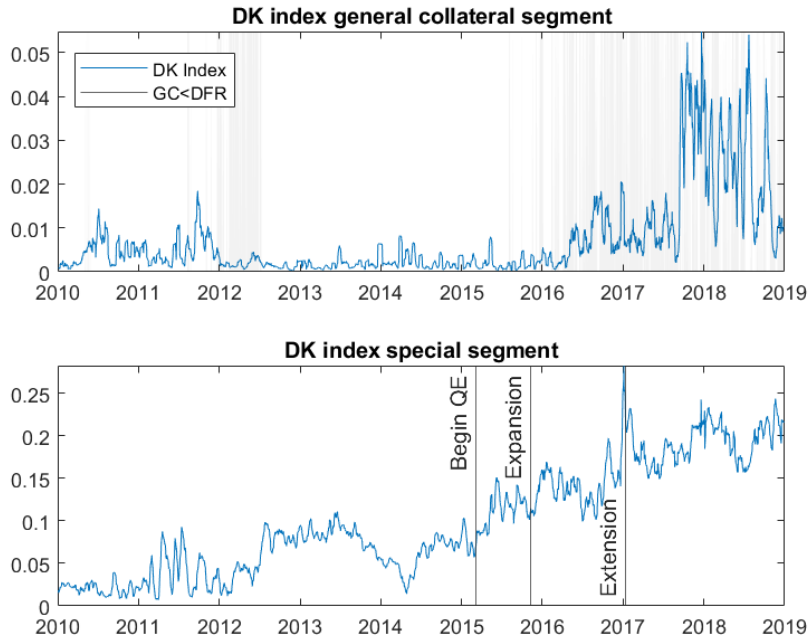
Focusing on QE, the notion that unconventional policies "safeguard the transmission of our monetary policy," as pointed out by ECB President Christine Lagarde (European Central Bank, 2020), should also consider that those programs can create rate dispersion, thereby leading to unintended consequences such as segmentation across different money market segments.

The money market friction which we document in this paper is also informative for the recent discussion about new short-term benchmark rates as it underlines 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.

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.[32] Focusing on the first step, "in an 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.

To graphically document this effect, we calculate one prime indicator for pass-through inefficiency in money markets following Duffie and Krishnamurthy (2016, p.36): a volume-weighted absolute dispersion index. We present dispersion measures for the GC and special repo market segments in Figure 8, 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 expan-

[32] 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.




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 8:** Repo market dispersion.

sions 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. 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 $\Delta r^L$, 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 6 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.[33]

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-

[33]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.

**Table 6:** 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.

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.

# 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 for this 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 a target of the 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 the operational target for the ECB, our findings provide suggestive evidence that money market segmentation weakens the monetary policy transmission. Our results also 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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