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«Monetary Policy Disconnect»

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Monetary policy disconnect

Abstract

Although designed to support monetary policy, two crucial aspects of the central bank framework can disconnect the monetary policy transmission: banks' access to central bank deposits and Quantitative Easing (QE). We show how both hinder the monetary policy transmission through the main short-term funding market, the repurchase agreement (repo) market. First, lending rates of banks with access to the deposit facility are less responsive to the monetary policy rate. Second, repo rates secured by assets eligible for QE programs are more disconnected from the policy rate. Both effects create rate dispersion and add to one another in weakening the monetary policy transmission.

Keywords: Interest rate pass-through, Monetary policy, Disconnect, Short-term interest rates, Repo.
JEL classification: E40, E43, E50, E52, E58, G18

"...there is a risk that, under the current framework, some short-term market rates would **not respond fully** to changes in our key interest rates or, even if they would, that a continued dispersion of short-term rates would **adversely impact** the transmission of our monetary policy stance."

—Benoît Cœuré in May 2018

An important question at the center of the political and academic debate is what makes the transmission of monetary policy effective. To answer this question, we need to consider the money market because it "plays a crucial part in the transmission of monetary policy decisions" and "changes in the monetary policy instruments affect the money market first" (European Central Bank, 2011). In outlining its monetary policy framework, the ECB also emphasizes that "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". However, some aspects of the institutional and political framework can generate dispersed money market rates raising the risk of central banks losing control over short-term interest rates (Cœuré, 2018).

This paper is the first empirical study showing that two key aspects that were designed to support the monetary policy transmission can actually *disconnect* it. To do this, we analyze how two elements of the monetary policy framework affect the main short-term funding market, the repurchase agreement (repo) market. The first hurdle for the monetary policy transmission stems from the access to the central bank's refinancing operations and its deposit facility. We demonstrate that the lending rates of banks with access to the central bank's facilities are less responsive to the monetary policy target rate, especially when money market rates are below the central bank's deposit rate discouraging interbank lending. The second hurdle comes from unconventional measures such as Quantitative Easing (QE) targeting the purchase of only certain assets and creating their scarcity. We show that short-term rates secured by assets eligible for QE programs diverge more from the monetary policy rate. Both effects lead to rate dispersion and add to one another, suggesting a joint impact in disconnecting the monetary policy transmission.

Understanding whether and how the institutional design and policy framework impact the monetary policy transmission through the money market is relevant for central banks and market participants. First, unresponsive short-term rates limit the central bank's ability to fulfill its mandate because "the level of short-term interest rates is set so as to ensure that price stability is maintained" (European Central Bank, 2011). Second, since the Global Financial Crisis of 2007/2008, the repo market has emerged as the predominant source of funding liquidity.[1] Thus, the repo market is key for an efficient allocation of money and assets. In addition, the repo rate acts as a benchmark in financial markets and for (funding) valuation adjustments, for example, in derivatives pricing.

The rationale of our analysis is that the way the institutional setting is conceived and policies are implemented determines the effectiveness of the monetary policy transmission. These effects should arise in the part of the financial system through which monetary policy is channeled in the first place, i.e., the money market. A consistent and uniform response of money market rates to the monetary policy stance is the first sign 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). The ideal laboratory to examine this idea is the ECB and the repo market for at least three reasons: First, the repo is the ECB's instrument to conduct the main refinancing operations, establishing a straight link between monetary policy and short-term rates. Second, with the sheer size of more than EUR 7.5 trillion in outstanding contracts (International Capital Market Association, 2019) the European repo market is the largest repo market worldwide and it represents the main channel for the monetary policy transmission throughout the entire interest rate term structure. Third, the infrastructure of the European repo market features central clearing and anonymous centralized order book platforms, which ensures homogeneous counterparty risk and collateral policy, no bargaining issues, and an efficient price formation process. In this setting, a large variety of sovereign debt securities are eligible as collateral. The asset being used as collateral can either be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral or GC repo"). While the GC repo is a funding instrument, since borrowing or lending cash is its main purpose, special repos can be collateral-driven. To achieve a comprehensive result, we study how both markets influence the transmission of monetary policy.

The first key aspect of the institutional framework we investigate is that only a given set of banks have exclusive access to the ECB refinancing operations and its deposit facility. We expand the theoretical framework proposed in Duffie (1996) to outline two separate demand curves for

[1] E.g., the euro repo market is 20 times bigger than the unsecured segment (European Central Bank, 2018).

investing liquidity (lending) in the *GC market*, one for access and one for nonaccess banks. In the wake of a negative supply shock (i.e., fewer banks need to borrow liquidity), the GC rate decreases and it can fall below the deposit facility rate. Rather than encouraging interbank lending, this creates an incentive to deposit liquidity at the central bank for banks that have the opportunity to do so. The demand of nonaccess banks for investing liquidity instead remains inelastic and at lending rates closer to the monetary policy rate.[2] As a consequence, the dispersion of repo rates increases as access banks lend less and at higher rates compared to nonaccess banks. Hence, our first testing hypothesis is that banks with (without) access to the ECB deposit facility lend at repo rates less (more) aligned to the monetary policy target rate.

The second key aspect of the policy framework is represented by the eligibility criteria of the QE program. We model this mechanism with two distinct demand curves in the *special* market, one for eligible assets and one for noneligible assets.[3] Assets being targeted by QE programs are scarcer, thus leading to a higher demand (positive demand shock) for those assets in the repo market. The overall effect is that repo rates for eligible assets fall below those for noneligible assets (Arrata et al., 2020; Corradin and Maddaloni, 2020). As a consequence, the specialness premium of eligible assets increases and the repo rates secured by eligible assets become predominantly driven by collateral demand disconnecting them from the policy rate. Our second testing hypothesis is therefore that rates of repos whose collateral asset is (not) eligible for QE programs are less (more) responsive to the monetary policy rate.

To study the monetary policy pass-through, we analyze a unique and highly representative data set for the entire Euro repo market including all repos exchanged on the three major trading platforms (BrokerTec, Eurex, and MTS) from the beginning of 2010 to the end of 2018. We proceed in three steps. First, we introduce our analysis by showing that various interest rates relevant for the entire real economy (e.g., corporate borrowing rates) are indeed connected to the repo rate.

[2] As discussed in more detail later, the literature provides various reasons for an inelastic demand including several benefits from obtaining collateral (Bechtel, Eisenschmidt, and Ranaldo, 2019; Piquard and Salakhova, 2019), net demand for safe assets (Infante, 2020) that becomes even more important in the impossibility to access central bank reserves and when safe assets are scarce, regulatory reasons (Ranaldo, Schaffner, and Vasios, 2020), and capacity constraints as well as limits to arbitrage (Nyborg, 2019).

[3] One may argue that the special market is less relevant for funding than the GC market. However, special trades are the predominant type of repos and they also involve a funding motive on the part of the borrower. Thus, even if less funding-oriented, special repo rates are still sensitive towards funding conditions.

Furthermore, we show that a wider dispersion of money market rates tends to weaken the policy pass-through. All this provides suggestive evidence of the crucial role of the repo market for the monetary policy transmission and that dispersed money market rates hinder it. Then, we document two new stylized facts in line with our theoretical predictions: (i) The share of access banks' lending in the GC market decreased when GC rates fell below the rate on the deposit facility. During those periods, the size of the GC market declined, while the total volume invested at the deposit facility by access banks increased. (ii) The trading volume in the special market has increased since the start of QE, predominantly driven by transactions collateralized with assets eligible for central bank purchases.

Second, we perform a comprehensive panel regression analysis to test our first hypothesis. As a first step, we identify which banks benefit from access to the deposit facility and at which rate they lend in the interbank market. Then, we regress (changes in) *GC* repo rates on (changes in) the monetary policy rate to determine systematic differences between access and non-access banks. We clearly find that access banks lend at rates less aligned to the policy rate corroborating the monetary policy disconnect featured by those banks. In addition to the statistical significance, our findings appear economically relevant. For instance, a more accommodative monetary policy that results in a decrease in the target rate by one percentage point translates into a decrease in GC rates involving access banks of 45 basis points. For banks without access, the decrease is 72 basis points. Once GC rates are below the rate on the deposit facility, the effect magnifies as the rates of nonaccess banks decrease by 94 basis points (pointing to an almost one-to-one pass-through) while the rates of access banks only decrease by 4 basis points.

Third, we carry out a set of panel analyses to test our second hypothesis. After identifying which specific collateral asset is eligible for QE and at which interbank rate it is traded, we regress (changes in) *special* repo rates on (changes in) the monetary policy rate. Our results clearly show that repo rates secured by eligible assets diverge more from the policy rate validating the monetary policy disconnect induced by QE asset purchases. We also apply the initial 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, a loose monetary policy with a decrease of the target rate by one percentage point is associated with a decrease in the rates of noneligible assets by five basis points more relative to eligible assets. While this effect seems to be small, it represents a 50% decrease relative to the overall sensitivity of special repo rates to changes in funding conditions. 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 on the monetary policy disconnect. To augment our idea of a positive demand shock for eligible assets, we show that their sensitivity to the monetary policy rate decreases with the time an asset is eligible for QE purchases.

We conclude our work by considering the combined effects of QE and accessibility to central bank's facilities on repo rates. We find that when the share of securities eligible for QE programs in a GC basket is large, then the GC rate is less reactive to the monetary policy target rate after controlling for the effect of bank's access to the deposit facility. Similarly, when the 'cheapest-to-deliver' collateral asset in a basket is eligible for QE, then the GC rate of that basket reacts less. In the special market, repo rates of access banks are less responsive to the monetary policy rate even after accounting for asset eligibility for QE programs. One interpretation of these findings is that asset scarcity associated with QE purchases together with the incentive to hold reserves on the central bank's deposit facility (rather than e.g., interbank lending) jointly weigh on monetary policy pass-through efficiency.

We perform a number of additional analyses ensuring the comprehensiveness and robustness of our results. These analyses can be summarized in four categories: (1) We conduct our analyses for different groups of countries including (i) Germany, (ii) core European countries, and (iii) all European countries and (2) different term types; (3) we replicate of our panel regression analyses by considering all conceivable combinations of standard error and fixed effect specifications; (4) and regarding the policy rate that the ECB could possibly target, we experiment with all secured and unsecured overnight interest rates as well as derivatives-based, forward-looking overnight interest rates.[4] In all specifications, the results remain statistically and economically consistent indicating

[4] In addition to the EONIA rate as the key ECB target rate (European Central Bank, 2011), we analyze all measures

their general validity and dispelling any doubts that they depend on a specific way to measure the monetary policy stance.

Notice that our setting allows us to take advantage of the legal and technical rules that the Eurosystem imposes to avoid any endogeneity concerns related to reverse causality. In particular, the set of nonaccess banks is constant over our sample period, whether a bank is legally formed in- or outside of the euro area is unrelated to monetary policy and the repo market, and thus a source of exogenous variation. Similarly, the implementation provisions for asset purchases are a source of exogenous variation as to which securities meet the respective criteria.

Our analysis mainly contributes to two strands of the literature. First, we add to the literature on the effectiveness of monetary policy. Focusing on the introduction of the reverse repurchase facility and new Basel regulation, Duffie and Krishnamurthy (2016) analyze the pass-through of monetary policy in the United States. Drechsler, Savov, and Schnabl (2017) show that the pass-through of the interest rate on excess reserves to the interest paid on saving accounts is imperfect due to market power in deposit markets. By considering a cross-country perspective, Kalemli-Özcan (2019) explains a disconnect of short-term rates across currencies with U.S. monetary policy spillovers that affect risk premia.[5] This is the first paper showing and quantifying how the transmission of monetary policy into the secured short-term funding market is impeded by two key features of the policy framework, i.e. QE and accessibility to central bank's facilities.

Second, we contribute to the literature on short-term funding markets. 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. Other papers analyze the unsecured money market; for instance, Kraenzlin and Nellen (2015) examine market segmentation coming from different access levels to the facilities of the Swiss National Bank and Bech and Klee (2011) evaluate the impact of bargaining power in a segmented and unsecured market in the U.S. The novelty in our analysis is

commonly used in the high-frequency monetary policy event study literature, for example, Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) and Leombroni, Vedolin, Venter, and Whelan (2020).

[5]On a macro-wide level, Avouyi-Dovi, Horny, and Sevestre (2017) find a slowdown of the overall interest rates transmission mechanism, which Al-Eyd and Berkmen (2013) have associated with segmentation along country lines. By analyzing the cointegration between policy rates and banks' weighted cost of capital, Illes, Lombardi, and Mizen (2019) find that the sensitivity of banks' average funding costs to policy rates has declined in recent years. For a detailed literature review on interest rate pass-through, see Andries and Billon (2016) and Horvath, Kotlebova, and Siranova (2018).

threefold: First, it is the first study on the reactiveness of repo rates to monetary policy depending on who lends (access versus nonaccess banks) and on which assets secure the loan (eligible or not for QE purchases).[6] Second, contrary to Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020) we study QE impact on GC rates (in addition to special repos) and how this depends on whether the bank has access to the central bank's facilities. Third, we show how the two above-mentioned features of the monetary framework create dispersion and adverse effects on repo rates.[7]

1. Monetary policy

Monetary policy aims to promote stable prices and growth by influencing the real sector, in particular lending conditions faced by businesses and consumers. The interest rate environment plays an important role in investment and price setting decisions. As bank loans are the main source of funding for large parts of the economy, the pass-through of monetary policy to the banking sector is crucial. To effectively fulfill their mandate, central banks rely on a predictability of the monetary policy pass-through, a disconnect from lending conditions would constrain the effective implementation of monetary policy.

Although we analyze many other monetary policy rates later, for the moment we focus on the short-term interest rate benchmark (EONIA) as the monetary policy target rate. While 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 in different VAR settings[8]), it warrants a discussion since the ECB does not directly control it. The ECB sets three key interest rates: The rates on the main refinancing operations, the deposit and marginal

[6]While we analyze the predominant part of the European repo market, Eisenschmidt, Ma, and Zhang (2020) focus on the OTC segment and the effects of dealers' bargaining power.

[7]Recent papers on repo rate dispersion include e.g., Mancini, Ranaldo, and Wrampelmeyer (2016); Boissel et al. (2017) in Europe and in the United States e.g., Bartolini et al. (2011); Gorton and Metrick (2012); Copeland, Martin, and Walker (2014); Krishnamurthy, Nagel, and Orlov (2014); Infante (2020); Ranaldo, Schaffner, and Vasios (2020).

[8]Ciccarelli, Maddaloni, and Peydró (2015) also employ the 3-month Euribor rate and the overnight interest swap rate as robustness checks, which we present as well.

lending facility. The rates on the deposit and marginal lending facility define the corridor for the EONIA as the unsecured, overnight interest rate at which banks lend to each other.[9] The two rates do not lend themselves to a pass-through analysis since they only move in infrequent, discrete jumps. The deposit facility rate is an exogenous rate set by the ECB, only the amounts deposited at the deposit facility are endogenously determined by banks. Policy interventions such as QE programs are not reflected in the deposit facility rate, it only changes rarely. The EONIA rate, by contrast, evolves continuously and is an endogenously determined rate which is more informative to central banks and market participants as it also captures, for example, time-varying funding conditions, risk premia, and unconventional monetary policy effects. These aspects make the EONIA rate the most appropriate choice for our main monetary policy target rate. It is also referred to as the operational target by the ECB (Cœuré, 2019) and its comovement with other interest rates has been shown in, for example, Hristov, Hülsewig, and Wollmershäuser (2014) and Altavilla, Canova, and Ciccarelli (2020). The EONIA is the equivalent of the effective federal funds rate in the U.S.[10]

For completeness and robustness purposes, we also experiment with alternative measures (Section 5). In particular, the period studied involves a transition in the economy's benchmark interest rate. The ECB has chosen the €STR rate, an unsecured rate, as the new short-term interest rate benchmark to replace the EONIA rate, thereby highlighting the ECB's renewed commitment to an unsecured target rate. We show that our results are valid for the EONIA in the prior benchmark's period and for the €STR since its inception. In addition, to account for monetary policy not being centered around one (unsecured) interest rate, we employ different policy rates such as the rate on the ECB GC pooling basket. We thereby ensure that the monetary policy disconnect stems from institutional aspects within the central bank framework as opposed to a segmentation between the secured and unsecured market.

[9]The evolution of the EONIA within the corridor is depicted in the Appendix in Figure 1.1. 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, 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.

[10]The Swiss National Bank uses a framework that is similar to the ECB framework as it also targets an unsecured rate moving within the facility rate corridor, the CHF-Libor.

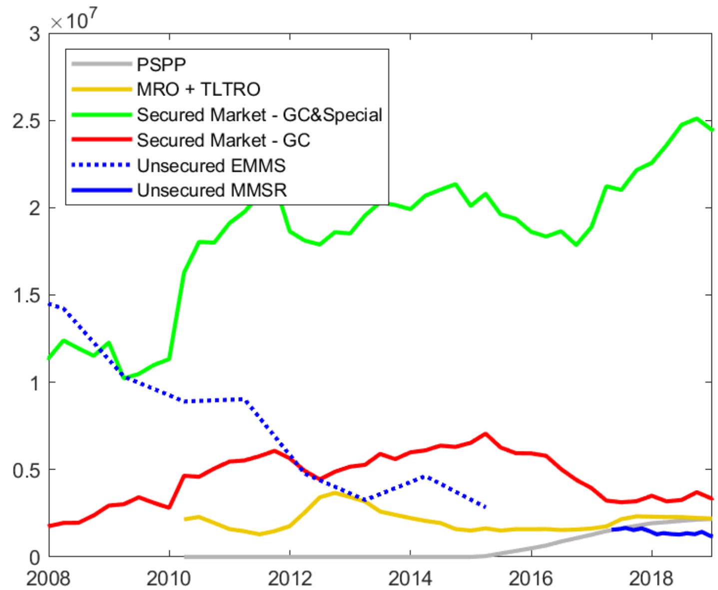


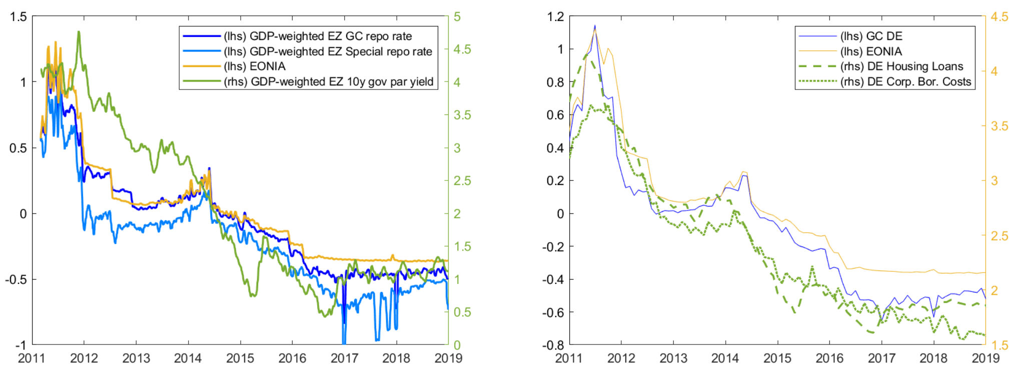
Fig. 1 depicts the aggregate cumulative quarterly trading volumes in the secured and unsecured market segments as well as the total cumulative PSPP purchases and volumes of the ECB's main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO). The data for the secured market refer to our total data set as described in Section 3. 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.

Fig. 1. Different market turnovers

In our analysis, we consider the monetary policy pass-through. The first but crucial step in this transmission relies on the linkage between monetary policy and the money market, which we analyze in this paper. The most important instrument used in the money market is the repo, the repo market is the main short-term funding market for banks.[11] It plays a more important role for the transmission of monetary policy than the unsecured market for three reasons: First, Fig. 1 illustrates that trading in the European money market has moved towards the secured market segment since the Global Financial Crisis. According to the Euro Money Market Survey, the size of the secured market is about twenty times the size of the unsecured market. In particular, an

[11]The influence of the EONIA on repo rates is also reflected in the EONIA being the reference rate for floating rate repos.

increase in risk aversion after the recent crisis shifted bank activity towards the secured segment (European Central Bank, 2018).[12] Thus, the repo market is now the predominant source of funding liquidity and is therefore key for the central bank's monetary abilities. To put this into perspective, repo trading volume by far exceeds, for example, volumes of cumulative purchases of the largest ECB QE program, the Public Sector Purchase Program (PSPP) or of the ECB's main refinancing operations. Second, repo market frictions not only impact the funding conditions of banks, but also the borrowing conditions faced by governments, as has been shown for the U.S. Treasury market by He, Nagel, and Song (2020). Given that governments are the largest debt issuers, this is another avenue through which the repo market affects monetary policy transmission. Finally, 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 another important step in the process of monetary policy implementation.



(a) Eurozone government bond rates

(b) German real sector lending rates

Fig. 2a depicts the GDP-weighted average government bond yield within the Eurozone as well as the GDP-weighted mean GC and Special repo rates. Fig. 2b 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 corporates 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.

Fig. 2. Interest rate co-movements

[12]The decision problem of banks involved in secured and unsecured markets has been in the focus of the theoretical literature, highlighting that the linkage between the two markets can be impacted by opportunity cost of collateral (Piquard and Salakhova, 2019) or constrained arbitrage (Nyborg, 2019). Commercial banks do indeed trade in both the secured and the unsecured markets, actively linking the two segments (Di Filippo, Ranaldo, and Wrampelmeyer, 2018).

To support the importance of the repo market for the monetary policy transmission into the real sector, Fig. 2a shows the co-movement of GC and special repo rates with a GDP-weighted average Eurozone government bond yield, while Fig. 2b illustrates for Germany that repo rates correlate with credit conditions faced by corporate borrowers and private households. The graphical intuition points towards the repo market playing an important role in the transmission of monetary policy into bank lending rates, we thus expect a dispersion in short-term repo rates to impede the monetary policy pass-through.

To formalize this intuition in an empirical setting, we examine the pass-through of changes in the monetary policy target rate into lending rates faced by corporate borrowers and private households, depending on the conditions in the repo market resulting from policy conditions and the monetary policy framework. The dependent variable is the change of a given lending rate Δr^L, for which we consider borrowing costs of non-financial firms and loans to households for house purchases. $\Delta PolRate$ denotes the change in the policy rate. $D^{Dispersion}$ equals 1 if a country's dispersion in GC repo rates is above its mean and $PSPP^{Volume}$ denotes the monthly purchasing volumes of the PSPP. QE purchases have been associated with an increased dispersion in the special market in Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020).

Table 1 reports the results of our panel regressions. Regression (1) relates changes in non-financial corporate borrowing rates to changes in the monetary policy target rate, depending on the dispersion in GC repo rates and PSPP purchasing volumes. The results highlight that lending rates react strongly: A one-percentage-point decrease in the target rate is accompanied by a decrease in corporate borrowing rates of about 47 basis points. The effect is 35 basis points smaller when the dispersion in repo rates is high. The sensitivity also shrinks by about 3 basis points for each euro bn of PSPP purchases. Regression (2) confirms our results for residential housing rates. In both regressions, we account for country-year fixed effects and employ heteroskedastic-robust standard errors. The results provide empirical support for Duffie and Krishnamurthy (2016) who highlight that a dispersion across money market interest rates is a primary indicator of the level of monetary policy pass-through inefficiency. Although the monetary policy transmission into the real economy involves additional steps that deserve a detailed analysis beyond short-term rates, our results clearly

Table 1. Repo dispersion and the pass-through to lending rates

	(1)	(2)
	Non-Fin. Corporate Δr^L b/t	New Housing Δr^L b/t
$\Delta PolRate$	0.470***	0.729***
	(5.335)	(8.118)
$\Delta PolRate \cdot D^{Dispersion}$	-0.351***	-0.444***
	(-2.739)	(-3.379)
$\Delta PolRate \cdot PSPP^{Volume}$	-0.034*	-0.042**
	(-1.651)	(-2.066)
N	991	907
adj. R^2	0.073	0.089

The table reports the regression results examining the pass-through of changes in the monetary policy target rate into lending rates faced by corporate borrowers and private households. The dependent variable is the change of a given lending rate Δr^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. $\Delta PolRate$ denotes the change in the policy rate. $D^{Dispersion}$ equals 1 if a country's dispersion in GC rates between access and nonaccess banks is above its mean. $PSPP^{Volume}$ denotes the monthly purchasing volumes of the PSPP in euro bn. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include country-year fixed effects and heteroskedastic-robust standard errors. Data are at a monthly frequency for all European countries for the time-period 2010–2018.

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 impacts the transmission of monetary policy into the real sector.

Our results highlight that the monetary policy disconnect is associated with an increased dispersion in repo rates that reduce the sensitivity of lending rates to changes in the monetary policy rate. In the remainder of the paper, we look at two forms of segmentation within the central bank framework which have contributed to a dispersion in repo rates and thus a weakening monetary policy transmission.

2. Repo market

In the repo market, two counterparts exchange cash for collateral (first leg) for a predefined time period with a fixed repurchase obligation (second leg). 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"). The lender in a repo transaction provides a short-term loan (over-)collateralized by sovereign debt and thus benefits from the convenience of the collateral for the time between the purchase and repurchase. 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. The GC market is generally more funding-driven while the special repo market is more collateral-driven. However, in each transaction there is always a funding motive on the part of the borrower. The European market infrastructure features (i) central clearing, (ii) anonymous electronic order book trading, and (iii) a large variety of eligible collateral (Mancini, Ranaldo, and Wrampelmeyer, 2016).[13]

Fig. 3 shows the development of the GC rate and the average repo rates for eligible and

[13] Our setting provides several benefits compared to the bilateral (OTC) repo market: First, its anonymity alleviates frictions associated with bargaining power. Second, since all market participants have the same counterparty (the CCP), the observed rates are not confounded by risk adjustments. Third, the comparability of rates is ensured by homogeneous haircuts. And finally, the bilateral repo market is very small and does not allow for a clear differentiation between general and special collateral repos. More detailed information about the European repo market infrastructure can be found in, for example, Nyborg, 2016; Bank for International Settlements, 2017 and European Central Bank, 2018.

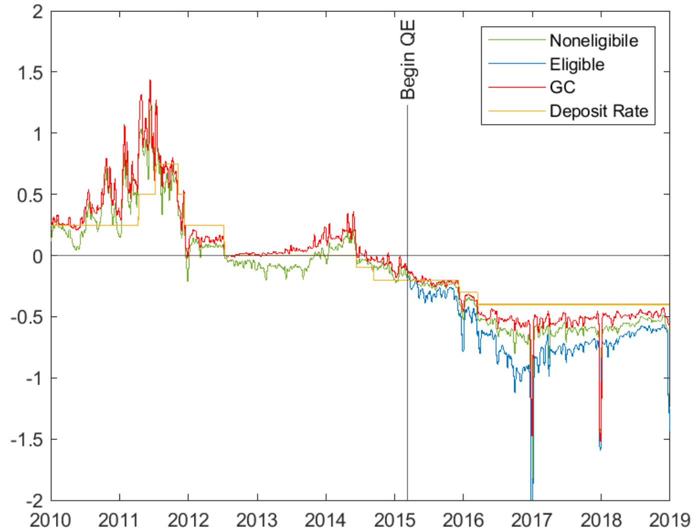


Fig. 3 shows the development of the German GC rate and the average volume-weighted repo rates for eligible and noneligible German assets relative to the development of the ECB's deposit facility rate.

Fig. 3. Repo rate development for Germany

noneligible assets relative to the development of the ECB's deposit facility rate. We observe that (i) 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, during which (ii) repo rates secured by assets eligible for QE have fallen below those for noneligible assets. Each observation points to a different feature of the institutional framework. The first observation speaks to the importance of access levels to central bank facilities and a segmentation between access and nonaccess banks, as it indicates that depositing funds at the deposit facility is attractive, in particular when the GC rate is below the deposit rate. The second observation highlights the role of asset scarcity induced by QE programs. Market participants are willing to accept a lower interest rate to lend cash against eligible than against noneligible assets. 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, Ferrante, and Hubert, 2019).

2.1. ECB access

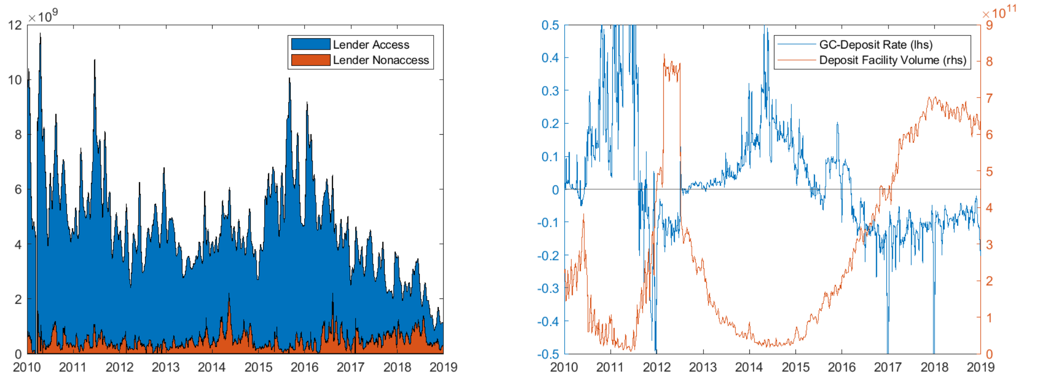
The ECB operates two standing facilities that allow banks to deposit or access liquidity on an overnight basis: The deposit facility allows for overnight deposits, while the marginal lending facility provides overnight central bank liquidity. Access to the ECB's facilities is, however, limited to eligible counterparties, most importantly to those 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.[14] 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.

In our analysis, we exploit the eligibility criteria for access to the deposit facility. In particular, we consider the restriction that only euro area banks can access the deposit facility in order to classify lenders in a repo transaction into *access* and *nonaccess* banks. This implies 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.[15] Depositing money at the deposit facility typically offers a smaller return than other overnight lending or investment options since central bank reserves are considered the safest and most liquid asset. However, since 2015, repo rates in almost the entire European repo market have fallen below the rate on the deposit facility. This implies that the deposit facility provides an attractive remuneration for funds not invested otherwise.

Fig. 4a shows the development of the total GC trading volume for access and nonaccess banks while Fig. 4b depicts the spread between the GC rate and the ECB's rate on the deposit facility and the total volume of funds deposited at the ECB's deposit facility. 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

[14] Additional criteria, for example on financial soundness, allow the ECB to suspend eligibility for institutions under certain circumstances. The full set of eligibility criteria can be found in EU Guideline 2015/510 of the European Central Bank on the implementation of the Eurosystem monetary policy framework available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014O0060.

[15] 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, investing in government bonds exposes banks to a different set of risks (e.g., market risks or duration risk / interest rate risk) which makes bond investments riskier and more volatile compared to repos. In addition, bond trades involve comparatively large transactions cost, in particular when bonds are purchased and sold on a daily basis to manage liquidity. Bond and repo markets also differ in terms of their market structure. For example, bond trades are over the counter (OTC) and banks do not benefit from netting or central clearing. Direct government bond investments therefore do not provide the same low-risk and liquid store of value as repos (Bank for International Settlements, 2017).



(a) General collateral trading volume (b) Spread between GC and deposit facility rate

Fig. 4a depicts the total trading volume in the German GC market for trades involving a lender with and without access to the ECB facilities. Fig. 4b 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.

Fig. 4. General collateral repo market

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. For example, since 2015, we observe a drop in general collateral 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. Correspondingly, the share of lending volume by access banks dropped by around 15 percentage points (see Section A.2 in the Appendix). To our knowledge, this is a new stylized fact, which suggests 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 when repo rates fall below the rate on the deposit facility, while nonaccess banks continue to use the lending side in GC repo transactions to deposit their liquidity.

It is worth noting that the regulatory framework plays a negligible role in our analysis for at least three reasons: First, access and nonaccess banks in our sample are similarly regulated. Nonaccess banks also need to fulfill Basel regulations in their home countries (even though those countries are outside the euro area). Second, the new Basel (liquidity and capital) regulation considers all assets under inspection to be of the highest quality (Level 1 assets) from the perspective of the Liquidity Coverage Ratio (LCR) and liquidity regulation (Bank for International Settlements, 2017).

For example, we depict results which only consider repo transactions collateralized by German government bonds (which are safe and liquid). Furthermore, all maturities under inspection are shorter than the thirty-day LCR cut-off time. Third, by focusing our analysis on the lending side, the banks' incentive to reduce the leverage ratio (window-dressing) does not apply. In fact, reverse repos do not enter the Basel III leverage ratio calculation because the lender is not exposed to the risk of collateral (Ranaldo, Schaffner, and Vasios, 2020).

The importance of the access to the central bank's facilities is 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. However, different values of the rate would entail different equilibria, in line with the segmentation that we discuss. Segmentation induced by different access levels to central bank facilities is supported empirically in Bech and Klee (2011)[16] and Kraenzlin and Nellen (2015). The former argue that the level of the effective federal funds rate was pushed downward by government agencies that could not receive interest on reserves, while the latter find that banks without access to central bank facilities pay more interest in the unsecured money market to borrow liquidity.

2.2. Asset eligibility

The ECB followed other major central banks in 2015 by announcing 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 Public Sector Purchase Program is the largest of the programs implemented in the Eurosystem, it focuses on the purchase of government bonds.[17] The sheer size of these purchases has contributed to scarcity effects for government bonds, which are

[16] While the effect discussed in Bech and Klee (2011) seems to be of similar spirit, their setting is different in key aspects. First, they evaluate different interest rate levels, not the pass-through of a policy rate to another short-term interest rate. Second, their analysis is confined to the unsecured market, while we look at the secured funding market. Finally, the financial friction to which their effects are attributed is bargaining power, a friction that should not occur in a centrally-cleared setting like ours.

[17] Under the umbrella of the PSPP, the ECB buys 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.

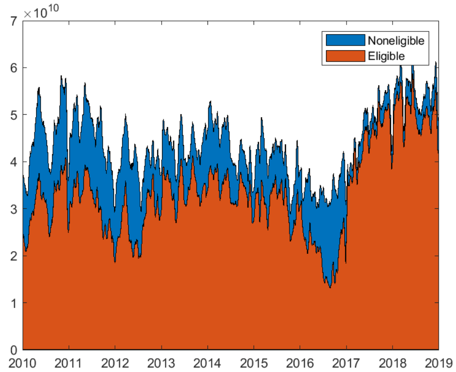
an important category of safe assets and serve as collateral in repo transactions. QE programs in general aim to influence longer-term rates in an environment where short-term rates are at the zero lower bound. An impact of QE-induced asset scarcity on short-term rates is thus an unintended side effect. 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 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.[18] The implementation provisions for asset purchases 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. 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 post-QE results as causal.

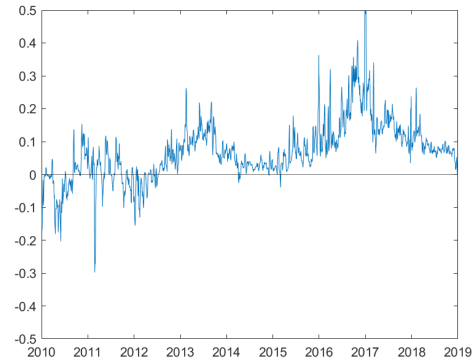
Fig. 5a shows the development of the total trading volume in special collateral for eligible and noneligible securities while Fig. 5b depicts the spread between the average repo rate on noneligible and eligible securities. During the recent period of unconventional monetary policy, repo rates for eligible assets have fallen below those of noneligible assets. The spread between eligible and noneligible assets has peaked at the end of 2017. We do not observe similar systematic patterns in the period prior to the introduction of QE. 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 eligible assets.[19]

[18]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.

[19]Since the implementation provisions have changed during the course of the program, the increase in the trading share of eligible assets is partly driven by an easing of the restrictions. The decline in eligible trading volume towards



(a) Special collateral trading volume



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

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

Fig. 5. Special collateral repo market

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, Schommer, and Woodford (2015) stress that the direction of the impact of asset purchases depends on the way collateral constraints are impacted. 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. In the bond market, 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. Thus, they document a strong home bias in eligible securities. This shift was also documented in aggregate data by Avdjiev, Everett, and Shin (2019). Pelizzon, Riedel, Simon, and Subrahmanyam (2020) document effects on corporate bonds. Schlepper, Riordan, Hofer, and Schrimpf (2017) show that QE increased prices and lowered liquidity in purchased German bonds.

the end of 2017 was driven by German collateral trading at a yield below the ECB's deposit facility. The ECB therefore decided in January 2017 to void the yield restriction.

In the special repo market segment, Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020) show that asset purchases lowered the rates of repos collateralized with purchased assets.

2.3. Theoretical mechanisms at work

Building on the framework proposed in Duffie (1996), the two market features in the GC and special repo market can also be illustrated in a supply and demand diagram. While Duffie (1996) focuses on the special market, we extend his framework to GC repos.

Fig. 6 depicts the supply and demand diagram in the GC market: the x-axis shows the GC rate, the y-axis the quantity. The borrower in the GC market is searching for funding, the supply curve therefore has a negative slope (i.e., the lower the repo rate on a loan, the larger the supply of collateral to be temporarily sold).[20] On the demand side, we present two distinct demand curves: one for access banks and one for nonaccess banks. This is needed since the decision problem of those two types of banks is different; one is able to deposit funds at the deposit facility while the other is not. Both determine the aggregate demand curve which intersects with the supply curve in the equilibrium.

The demand of nonaccess banks for investing liquidity is inelastic. While we do not model the behavior of nonaccess banks explicitly, this is suggested for several reasons: First, banks without central bank access face the decision problem of investing in the secured or unsecured money market. Repos are mostly secured by government bonds, which are safe assets per se, carrying convenience yields in the form of safety and liquidity benefits. The benefits from obtaining collateral (Bechtel, Eisenschmidt, and Ranaldo, 2019; Piquard and Salakhova, 2019) therefore create a net demand for safe assets (Infante, 2020), which is particularly inelastic when QE programs render them scarce. Second, financial regulation incentivizes directly and indirectly banks to hold secured deposits (Ranaldo, Schaffner, and Vasios, 2020). Finally, capacity constraints as well as limits to arbitrage in the unsecured money market can even lead the unsecured rate to fall below the secured rate (Nyborg, 2019), rendering unsecured investments unattractive. Access banks can always access the

[20] In the traditional model of Duffie (1996), the supply curve is upward-sloping since the x-axis shows the "specialness" instead of the GC rate (reverse direction).

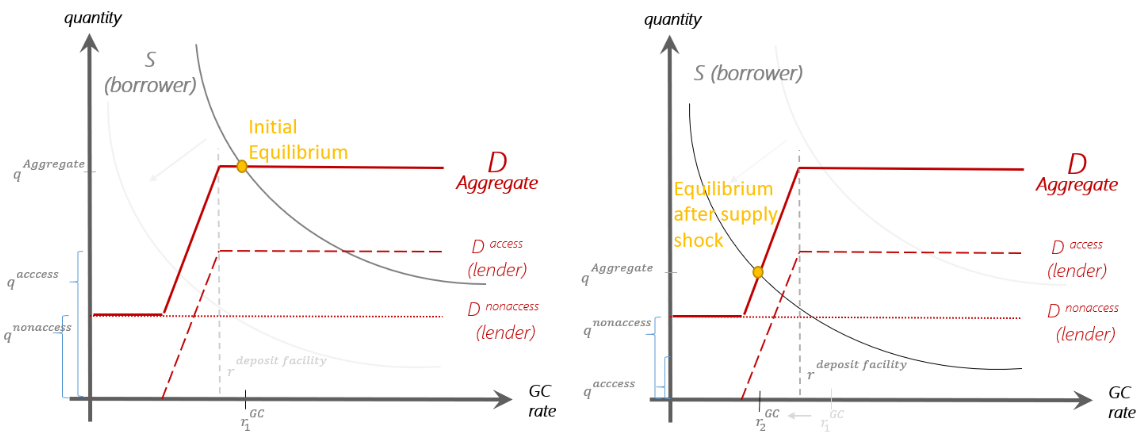


Fig. 6. Impact of supply shock in the GC repo market

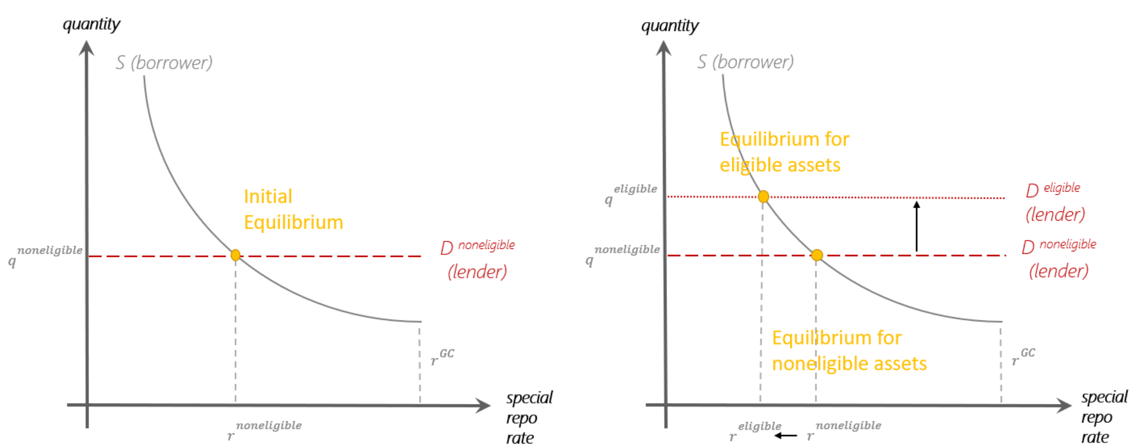


Fig. 7. Impact of demand shock in the special repo market

deposit facility. This option becomes more attractive when the GC rate falls below the rate on the deposit facility, leading to a lower demand of access banks. We illustrate this change in the demand via a kink in the demand curve.[21] The demand of access banks to deposit liquidity in the repo market does not immediately vanish due to benefits of obtaining collateral over holding cash, for example, to pledge it in margin accounts.[22]

Since the start of QE, excess liquidity in the euro area has strongly risen (e.g., Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020). This is graphically illustrated in a negative supply shock, that is, fewer banks need to borrow liquidity in the repo market. Three effects emerge from this negative supply shock (see the right-hand panel in Fig. 6): First, the GC rate can fall below the rate on the deposit facility. Second, this leads access banks to deposit an increasing share of their liquidity at the deposit facility, thus the size of the GC market and the trading share of access banks in the GC market declines. Third, and important to our regression analysis, interest rates between access and nonaccess banks diverge in the sense that the former institutions tend to lend at rates closer to the central bank deposit rate. As preliminary evidence, Fig. 4a shows the decline in the size of the GC market accompanied with a decrease in the trading share of access banks, while Fig. 4b illustrates that GC rates have fallen below the deposit facility rate.

Fig. 7 depicts the supply and demand diagram in the special market: the x-axis now shows the special rate, the y-axis the quantity. In the special market, the trading behavior is characterized by the collateral leg of the repo transaction: Following Duffie (1996), some security holders are only willing to lend (supply) those securities at a premium (i.e., at a repo rate below the GC rate). This translates into a negatively sloped supply curve. The demand in the form of short sellers is completely inelastic. Asset purchases of eligible securities have led to asset scarcity and an additional demand for eligible assets (Bank for International Settlements, 2017, p.16). This is graphically illustrated in two demand curves (see the right-hand panel in Fig. 7), one at a higher level (for eligible assets) and one at a lower level (for noneligible assets). Two effects emerge from

[21] To provide empirical evidence for the kinked demand curve, we show that the share of access banks as lenders in repo transactions declines once the GC rate falls below the deposit facility rate (since access banks can place their funds at the central bank), while their share as borrowers remains constant (Section A.2 in the Appendix).

[22] The current spread at Eurex on cash denominated in euro pledged in margin accounts is, for example, 20 basis points, thus rendering cash collateral less attractive (https://www.eurex.com/ec-en/services/collateral-management/cash-collateral/interest-rates-on-cash-collateral).

this positive demand shock for eligible assets: First, the size of the special market increases with an increasing share of trading in eligible (collateral) assets. Second, repo rates diverge as rates for eligible assets fall below those for noneligible assets (i.e., eligible asset is more "special"). Fig. 5a shows the increase in the size of the special market accompanied by an increase in the trading share in eligible assets, while Fig. 5b illustrates that repo rates for eligible assets have fallen below repo rates for noneligible assets since the start of QE.

3. Data

We employ high-frequency data for the European repo market for the time period from 2010 to 2018. 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 or basket, 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. 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 exclude three sub-groups of repos that represent a very small share of our data: First, we exclude special repos secured by corporate securities. Second, 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 central counterparty (CCP). Finally, we exclude repos that are traded infrequently.[23] We perform our analyses for three different groups of countries: (i) Germany, (ii) core European countries, and (iii) all European countries.[24]

[23]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 95% of the time. Our results are robust to different specifications.

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

To split our sample into access and nonaccess banks, we follow the approach of Di Filippo, Ranaldo, and Wrampelmeyer (2018) as well as Ranaldo, Schaffner, and Tsatsaronis (2019) in identifying banks. We 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. Banks trading in the GC 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.[25] Our data contains GC repo trades involving 98 different banks, of which 85 are access banks and 13 are nonaccess banks.[26] 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. At the end of our sample period, access banks had, on average, assets worth 290 million euro compared to 240 million euro for nonaccess banks, the leverage ratios were about 17 for both types of banks, thus highlighting the comparability between access and nonaccess banks.

Moreover, we classify assets as 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.

4. Empirical results

We first analyze the monetary policy pass-through into the GC and special market before looking at their combined effects.

[25]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.

[26]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.

4.1. *Access/nonaccess banks*

We want to understand whether the institutional segmentation associated with access restrictions to central bank facilities leads to a monetary policy disconnect. In particular, we ask whether the segmentation between access and nonaccess banks impedes the monetary policy transmission. Access banks always have the possibility to deposit funds at the deposit facility; our first testing hypothesis is therefore that access banks react less strongly to changes in the monetary policy target rate. This would imply less control of the monetary policy transmission for central banks and indicate pass-through inefficiencies.

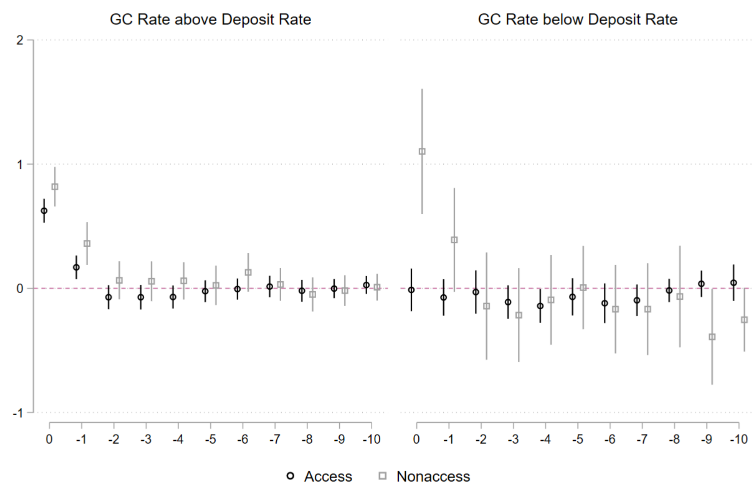


Fig. 8. Impulse response for German trades involving access/nonaccess banks

We provide a first graphical intuition of the analysis in Fig. 8 that illustrates the lower sensitivity of access banks to changes in the monetary policy target rate in the form of impulse response functions. We compute the impulse response function for trades involving access and nonaccess banks separately for periods during which the GC rate is above the deposit rate (left panel) and below the deposit rate (right panel). 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. However, once the GC rate is below the rate on the deposit facility, the sensitivity of access banks is completely muted, while nonaccess banks exhibit an even higher sensitivity. The graphical results point towards a less effective monetary policy transmission once GC rates fall below the rate on the deposit facility associated with access banks reacting less to changes in the monetary policy target rate and a larger dispersion in repo rates of access and nonaccess banks.

For the empirical analysis, we formalize the graphical intuition in a set of panel regressions. Our main regression equations read as follows:

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

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

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

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 $\Delta PolRate_t$ denotes the log-change in the EONIA. Moreover, we employ two dummy variables: $D^{Dep}_{t,n}$, which is equal to one if country n's 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.[27] Additionally, we add basket-month-term fixed effects and employ heteroscedasticity-robust standard errors. Trading in the more liquidity-driven GC repo market is concentrated in the ON and TN term types; we therefore 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.

Although we will provide general validity to our results later, as a first step we restrict our sample to repo transactions collateralized by German government securities. Since German collateral is considered to be safe and liquid, we limit concerns about cross-country differences in sovereign risk

[27] 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, $\Delta PolRate_t$ refers to the log change in the EONIA denoted in percentage points.

Table 2. ECB access

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Germany			Core			All	
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	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
$\Delta PolRate$	0.539***	0.717***	0.675***	0.472***	0.683***	0.643***	0.424***	0.589***	0.560***
	(15.700)	(10.745)	(8.781)	(23.035)	(16.875)	(14.261)	(24.699)	(16.774)	(15.106)
D^{Dep}	−0.046**		−0.047**	−0.032***		−0.032***	0.001		0.002
	(−2.265)		(−2.338)	(−2.940)		(−2.922)	(0.143)		(0.221)
$\Delta PolRate \cdot D^{Dep}$	−0.176**		0.265**	−0.048		0.298***	0.011		0.384***
	(−2.216)		(2.082)	(−0.897)		(3.968)	(0.220)		(5.668)
D^{Access}		−0.001	−0.000		−0.005	−0.004		−0.003	−0.003
		(−0.071)	(−0.035)		(−0.819)	(−0.743)		(−0.755)	(−0.709)
$\Delta PolRate \cdot D^{Access}$		−0.264***	−0.177**		−0.284***	−0.222***		−0.223***	−0.184***
		(−3.549)	(−2.100)		(−6.242)	(−4.423)		(−5.687)	(−4.438)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.719***			−0.561***			−0.595***
			(−4.970)			(−5.885)			(−6.733)
$\Delta repo^{GC}$ lagged	−0.332***	−0.332***	−0.332***	−0.337***	−0.335***	−0.335***	−0.372***	−0.371***	−0.371***
	(−14.230)	(−14.147)	(−14.151)	(−24.685)	(−24.388)	(−24.410)	(−30.291)	(−30.133)	(−30.167)
N	10,001	10,001	10,001	35,082	35,082	35,082	58,183	58,183	58,183
R^2	0.210	0.213	0.220	0.180	0.185	0.187	0.174	0.177	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's GC rate is below the deposit facility. 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 heteroskedastic-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.

and liquidity. Regression (1) relates changes in GC rates to changes in the monetary policy target rate, depending on whether the GC rate is above or below the rate on the deposit facility. The results highlight that GC rates react strongly: A one-percentage-point decrease in the target rate is accompanied by a decrease in GC rates of about 54 basis points. The effect is smaller at 36 basis points when the GC rate is below the rate on the deposit facility. In Regression (2), we analyze the different reactions of access and nonaccess banks. We find that GC trades involving a lender with access to the deposit facility react less strongly. A decrease in the target rate by one percentage point relates to a decrease 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. In this setting, the effect of changes in the monetary policy target rate on GC rates is 68 basis points for nonaccess banks as compared to 50 basis points for access banks. Once GC rates are below the rate on the deposit facility, 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 target rate once GC rates are below the rate on the deposit facility, while lenders without access are very sensitive to it. As is graphically illustrated in Fig. 3.3 in the Appendix, this leads to an increased dispersion in short-term GC rates, a natural indicator for monetary policy pass-through inefficiency. We observe a significant negative autocorrelation in repo rates, which is expected under mean reversion.

We perform a number of additional robustness checks to confirm our main results. First, columns 4–9 expand our analysis by looking at larger samples consisting of core European countries as well as all European countries. Overall, the results remain statistically and economically consistent. This indicates that the market segmentation caused by access to central bank facilities is not only present in the German "safe haven" market but across European countries as well. Second, we report consistent results for each term type and regional classification separately in the Internet Appendix. Finally, the results are also robust for different standard error and fixed effect specifications, these results are also reported in the Internet Appendix.

4.2. Eligible/noneligible assets

We also want to understand whether the eligibility criteria for QE programs impede the monetary policy transmission. In particular, we ask whether the segmentation between eligible and noneligible assets leads to a monetary policy disconnect. Eligible collateral is scarce and in high demand; our second testing hypothesis is therefore that repo rates secured by assets eligible for QE are less aligned to the monetary policy target rate. Similar to the previous analysis, a lower sensitivity implies more difficulties in controlling the monetary policy transmission from the unsecured to the secured funding market. Again, we perform a set of panel analyses. Our main regression equations read as follows:

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

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

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

where $\Delta r^{Special}_{t,i,l}$ denotes the log-change in special repo rates and $\Delta PolRate_t$ denotes the log-change in the EONIA. 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[28] and heteroscedasticity-robust standard errors. 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 in Table 3. 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 monetary policy target

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

Table 3. 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 b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.106***	0.098***	0.109***	0.105***	0.095***	0.103***	0.099***	0.094***	0.101***
	(19.644)	(12.937)	(13.130)	(31.179)	(17.681)	(17.810)	(30.205)	(18.394)	(18.358)
D^{QE}	−0.016		−0.016	−0.008		−0.008	−0.017*		−0.016*
	(−1.462)		(−1.434)	(−1.187)		(−1.158)	(−1.752)		(−1.740)
$\Delta PolRate \cdot D^{QE}$	−0.150***		−0.120***	−0.126***		−0.104***	−0.108***		−0.089***
	(−15.837)		(−8.154)	(−19.814)		(−9.643)	(−17.339)		(−8.198)
$D^{Eligible}$		0.004	0.004		0.005	0.005		0.004	0.004
		(0.454)	(0.440)		(0.972)	(0.969)		(0.669)	(0.649)
$\Delta PolRate \cdot D^{Eligible}$		0.006	−0.005		0.011	0.002		0.004	−0.004
		(0.537)	(−0.463)		(1.592)	(0.295)		(0.562)	(−0.565)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.172***	−0.052***		−0.137***	−0.033**		−0.117***	−0.028**
		(−14.035)	(−2.737)		(−17.552)	(−2.453)		(−15.319)	(−2.119)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.364***	−0.357***	−0.357***	−0.357***	−0.362***	−0.362***	−0.362***
	(−20.719)	(−20.716)	(−20.719)	(−39.267)	(−39.259)	(−39.264)	(−51.918)	(−51.911)	(−51.915)
N	301,608	301,608	301,608	705,633	705,633	705,633	943,349	943,349	943,349
R^2	0.119	0.119	0.119	0.115	0.115	0.115	0.118	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing programs on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy 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 heteroskedastic-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.

rate in the period prior to and after the introduction of the QE program. A more accommodative monetary policy that results in a decrease in the target rate by one percentage point translates into a decrease 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, a new stylized fact emerges as special rates react less strongly to changes in the monetary policy target rate than more liquidity-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 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 collateral asset behave similarly in the period prior to QE. We therefore apply the initial implementation provisions retrospectively. We observe that trades involving hypothetically eligible collateral asset do not exhibit significantly different changes in repo rates prior to QE; eligible and noneligible collateral assets also respond similarly to changes in the monetary policy 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 collateral assets have a 17-basis-point lower sensitivity compared to noneligible collateral assets. This speaks to an effect caused by unconventional monetary policy. Our main Regression (3) captures both effects. The impact of changes in the monetary policy target rate on special repo rates is almost muted during QE, which is in particular driven by trades involving eligible collateral assets. In the period after the introduction of QE, a decrease in the target rate by one percentage point implies a decrease in the rates of noneligible collateral assets by five basis points more relative to eligible collateral assets. While the overall size of this effect seems to be small, it represents a 50% reduction relative to the overall sensitivity of special repo rates to changes in funding conditions. Graphically, the increasing dispersion of repo rates around the monetary policy rate since QE is depicted in the Fig. 3.4 in the Appendix, and indicates monetary policy pass-through inefficiency.

Similar to the previous analyses, we perform a number of additional robustness checks to confirm our main results. First, columns 4–9 extend our analysis to core and all European countries, respectively. Second, we report the results for each term type and regional classification, and the results for different standard error and fixed effect specifications in the Internet Appendix.[29] Overall, the results remain statistically and economically consistent.

To better understand the economic determinants of our results, 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 (since the ECB had more opportunities to purchase those securities). We therefore introduce a new variable "time since eligibility" (TSE) which captures the number of days an asset has been eligible for purchase under the PSPP.[30]

Table 4 reports the regression results focusing on asset scarcity effects. We show two regression specifications: (i) by employing our new TSE variable, 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, interacted with the log-change in the monetary policy rate $\Delta PolRate_t$.

Regression (1) relates changes in special repo rates to changes in the monetary policy target rate under consideration of the TSE variable. We observe that the monetary policy pass-through into repo rates is weaker for those assets that have been eligible for purchase for a longer period. A one-percentage-point change in the target 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

[29]The presented results are also robust to shortening the period of analysis to the time before the changes to the QE program were implemented as well as to the inclusion of differently defined QE dummies (results are available from the authors).

[30]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 4. Asset eligibility: time since eligibility

	Germany		Core		All	
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.106***	0.106***	0.105***	0.105***	0.099***	0.099***
	(19.643)	(19.643)	(31.179)	(31.179)	(30.205)	(30.205)
D^{QE}	−0.015	−0.016	−0.008	−0.008	−0.016*	−0.016*
	(−1.380)	(−1.423)	(−1.102)	(−1.157)	(−1.699)	(−1.736)
$\Delta PolRate \cdot D^{QE}$	−0.094***	−0.120***	−0.080***	−0.103***	−0.070***	−0.082***
	(−9.018)	(−8.469)	(−11.341)	(−9.773)	(−10.103)	(−7.509)
$\Delta PolRate \cdot TSE$	−0.001***		−0.001***		−0.001***	
	(−9.635)		(−9.882)		(−10.592)	
$\Delta PolRate*$						
TSE^1_{Bucket}		−0.008		−0.010		−0.022*
		(−0.486)		(−0.847)		(−1.802)
TSE^2_{Bucket}		−0.279***		−0.086**		−0.036
		(−5.995)		(−2.491)		(−1.344)
TSE^3_{Bucket}		−0.470***		−0.459***		−0.382***
		(−6.521)		(−9.542)		(−11.200)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.357***	−0.357***	−0.362***	−0.362***
	(−20.715)	(−20.716)	(−39.263)	(−39.265)	(−51.913)	(−51.917)
N	301,608	301,608	705,633	705,633	943,349	943,349
R^2	0.119	0.119	0.115	0.115	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through under particular consideration of the number of days an asset is eligible for purchase. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. 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 heteroskedasticity-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.

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 compared to assets which have never been eligible for purchase. However, assets which have been eligible for up to 400 days, have a 28-basis-point lower sensitivity. For assets which have been eligible for more than 400 days, the effect increases to 47-basis-points. The results are consistent for core and all European countries.

Clearly, our results speak to the role of asset scarcity, as assets which have been eligible for purchase by the ECB for a longer period (scarcer assets) are less sensitive to changes in the policy rate. This is in line with an upward movement in the demand curve for eligible assets.

4.3. Joint effects

In addition to the specific impact on repo rates originating from each institutional aspect studied above, bank's access and QE might jointly contribute to the monetary policy disconnect.

In the GC repo market segment, certain baskets contain a higher share of collateral assets that are eligible for asset purchases; thus, market participants might trade in these baskets to source eligible collateral assets. Lenders in a GC transaction might accept a lower interest on those baskets that feature a higher share of eligible assets. This would imply that conditions in the GC market are affected by scarcity effects associated with QE, which would be an additional source of dispersion impeding the monetary policy pass-through. We therefore 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, even in a GC transaction. Our data features a cross-section of 46 GC baskets for which we compute, at each point in time, the share, weighted by issuance volume, of the securities that can be used as collateral that are also (hypothetically) eligible for central bank asset purchases.[31]

For the panel regression, we ask whether baskets with a higher share of eligible securities react less strongly to changes in the monetary policy target rate, even after accounting for the banks'

[31] 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.

access to the ECB's deposit facility as a first form of market segmentation. For the regression, we follow the previously introduced approach for the GC market and newly introduce the dummy variable $D_{t,i}^{Eligible}$ for the GC market, which is equal to one if a basket i at time t has a (hypothetical) eligibility share higher than the median eligibility share across all baskets of that country at time t. As before, we add basket-month-term fixed effects and employ heteroscedasticity-robust standard errors. We show our main results as a pooled regression of the term types ON and TN in Table 5. We report our results for (i) Germany in column 1a, (ii) core European countries in column 3a, and (iii) all countries in column 5a.

Regression (1) confirms the impeded monetary policy pass-through resulting from different access levels to central bank facilities (our main regression), as access banks are less sensitive to changes in the target rate, in particular when the GC rate hovers below the rate on the deposit facility. In addition, we observe that trades involving baskets with high and low eligibility shares respond differently to changes in the monetary policy rate, even after controlling for the banks' access to the deposit facility. Prior to the introduction of QE, baskets with a hypothetically higher share of eligible collateral assets tended to react slightly more. However, since the start of QE, repo trades involving baskets with a higher share of eligible securities are less sensitive to changes in the monetary policy target rate, more than undoing the baseline effect. In the period after the introduction of QE, an accomodative monetary policy with a decrease in the target rate by one percentage point is associated with a seven-basis-point smaller decrease in the rates of baskets with a higher eligibility share relative to baskets with a lower eligibility share. Comparing the economic magnitude, access to central bank facilities remains the more pronounced effect.

In a general collateral repo, certain collateral assets may be more likely to be delivered than others. In particular, it is possible to identify the 'cheapest-to-deliver' collateral asset, which is the asset that commands the highest repo rate in the special market segment and thus features the smallest specialness. As an alternative to our volume-based measure of basket eligibility, we also employ the eligibility of the cheapest-to-deliver bond as a measure of basket eligibility. The results based on this classification are reported for (i) Germany in column 1b, (ii) core European countries in column 3b, and (iii) all countries in column 5b. We find that our results are robust to

Table 5. Joint effects of both forms of 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
$\Delta PolRate$	0.475***	0.599***	0.159***	0.576***	0.606***	0.154***	0.606***	0.653***	0.160***
	(5.030)	(6.026)	(12.959)	(10.521)	(10.483)	(17.617)	(12.420)	(12.430)	(18.668)
D^{Dep}	−0.067**	−0.066**	0.015***	−0.037***	−0.037***	0.005	−0.024**	−0.024**	0.006**
	(−2.456)	(−2.400)	(2.794)	(−2.699)	(−2.733)	(1.575)	(−2.077)	(−2.095)	(2.147)
$\Delta PolRate \cdot D^{Dep}$	0.361***	0.458***	0.012	0.383***	0.389***	0.103***	0.349***	0.362***	0.105***
	(2.692)	(2.814)	(0.416)	(4.260)	(4.343)	(4.510)	(4.165)	(4.358)	(4.686)
D^{Access}	−0.004	−0.003	−0.005***	−0.006	−0.006	−0.005***	−0.005	−0.005	−0.005***
	(−0.265)	(−0.193)	(−2.582)	(−1.018)	(−0.940)	(−4.127)	(−0.908)	(−0.794)	(−4.455)
$\Delta PolRate \cdot D^{Access}$	−0.181**	−0.183*	−0.062***	−0.260***	−0.265***	−0.063***	−0.311***	−0.311***	−0.074***
	(−2.015)	(−1.836)	(−5.181)	(−4.594)	(−4.732)	(−7.875)	(−6.132)	(−6.135)	(−9.305)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.606***	−0.795***	−0.161***	−0.456***	−0.525***	−0.225***	−0.402***	−0.477***	−0.214***
	(−3.775)	(−4.232)	(−5.413)	(−4.341)	(−4.890)	(−9.418)	(−4.035)	(−4.719)	(−8.988)
D^{QE}	−0.113	−0.119	−0.014	−0.047	−0.053	−0.007	−0.056	−0.062	−0.012
	(−1.489)	(−1.519)	(−1.231)	(−1.340)	(−1.503)	(−0.983)	(−1.071)	(−1.191)	(−1.309)
$D^{Eligible}$	−0.017	−0.008	0.003	−0.010**	0.010*	0.005	−0.010**	0.007	0.005
	(−1.509)	(−0.681)	(0.371)	(−2.047)	(1.910)	(0.911)	(−2.180)	(1.603)	(0.908)
$\Delta PolRate \cdot D^{Eligible}$	0.252***	0.045	−0.006	0.141***	0.077*	0.006	0.102**	0.006	0.005
	(3.338)	(0.490)	(−0.541)	(3.255)	(1.782)	(0.816)	(2.576)	(0.138)	(0.643)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.315***	−0.040	−0.097***	−0.429***	−0.301***	−0.104***	−0.349***	−0.220***	−0.110***
	(−2.872)	(−0.261)	(−5.713)	(−6.802)	(−5.256)	(−9.822)	(−5.467)	(−3.633)	(−11.432)
$\Delta repo$ lagged	−0.340***	−0.341***	−0.364***	−0.338***	−0.338***	−0.357***	−0.337***	−0.338***	−0.360***
	(−11.817)	(−11.603)	(−20.711)	(−22.734)	(−22.683)	(−35.249)	(−24.814)	(−24.821)	(−40.685)
N	6,802	6,484	301,475	30,314	29,996	628,208	37,453	37,135	759,772
R^2	0.262	0.255	0.119	0.239	0.237	0.115	0.233	0.231	0.118

The table reports the regression results examining the simultaneous impact of ECB access and asset eligibility on the pass-through of the monetary policy target rate into GC and special repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$ respectively the change in the special rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's GC rate is below the deposit facility. 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. ***, **, 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 heteroskedastic-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.

this alternative specification.

To our knowledge, we are the first to provide empirical evidence on the impact of quantitative easing and central bank asset purchasing programs on the general collateral repo market.

In the special repo market, access banks might also be less sensitive to changes in the monetary policy rate. To measure this effect, we perform a similar set of panel regressions as introduced for the GC market to jointly account for both forms of segmentation. In the regression, $D_{t,i}^{Eligible}$ equals one if *security* i is (hypothetically) eligible for purchase under the PSPP. We add ISIN-month-term fixed effects and employ heteroscedasticity-robust standard errors. The results for the pooled regression for the term types TN and SN 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 monetary policy rate translates into a 16 basis point 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 point lower sensitivity of eligible collateral relative to noneligible collateral during the recent period of unconventional monetary policy. The overall sensitivities of access and nonaccess banks in the special market are smaller than in the GC market, however, the relative magnitude of the effect (as compared to the GC market) is comparable. For a graphical comparison, the impulse response functions of access and nonaccess banks in the two market segments are depicted in Fig. 4.5 in the Appendix.

Columns 3–6 expand our analysis by looking at larger samples. Again, the results remain statistically and economically consistent when we extend our sample to core and all European countries.

The results highlight that in the more funding-related GC market, the pass-through of changes in the monetary policy target rate has been additionally impeded by market segmentation associated with the implementation of QE. The analysis of special rates provides a consistent picture suggesting that in addition to the asset scarcity coming from QE (Arrata et al., 2020), the monetary policy disconnect through special repos depends on the access to central bank's operations.

5. Alternative policy measures

To underline the robustness of our results we experiment with alternative policy rates. Our (i) baseline rate is the EONIA, a weighted average of the interest rates on unsecured overnight lending transactions denominated in euros, as reported by a panel of contributing banks. It is (indirectly) determined by the rates that the ECB sets on its standing facilities. 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. Historical €STR rates date back to the 15th of March 2017. As a (ii) second rate, we therefore consider an EONIA-€STR combination with the €STR rate replacing the EONIA after its publication. As a (iii) third, unsecured reference rate, we consider the overnight euro LIBOR rate. Since monetary policy shapes expectations about future short-term interest rates, 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. As an (vi) additional rate, we consider the one-week OIS rate.[32] Finally, we employ the (vii) rate on the ECB GC Pooling Basket. The GC Pooling Basket is the primary GC funding basket, the basket enables the re-use of received collateral for central bank refinancing operations.

Table 6 reports the results of our baseline specification in the GC market for the seven policy rates described above, while Table 7 reports the results of our baseline specification in the special market. We present the results for German repo transactions. In the GC market, the estimations are statistically and economically consistent across all specifications. Three key results emerge from this analysis: First, GC repo rates are more sensitive to changes in unsecured overnight rates as compared to derivative-based implied overnight rates. This makes sense intuitively since we expect

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

Table 6. ECB access: Germany

	(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
$\Delta PolRate$	0.675***	0.705***	0.480***	0.334***	0.179***	0.329***	0.723***
	(8.781)	(9.274)	(9.220)	(6.013)	(5.055)	(4.349)	(14.246)
D^{Dep}	−0.047**	−0.026**	−0.051**	−0.021	−0.029**	−0.029**	−0.041**
	(−2.338)	(−2.059)	(−2.520)	(−1.564)	(−2.061)	(−2.249)	(-2.108)
$\Delta PolRate \cdot D^{Dep}$	0.265**	0.253**	0.356***	0.268**	0.179**	0.363***	0.277**
	(2.082)	(2.086)	(4.003)	(2.571)	(2.196)	(3.249)	(2.320)
D^{Access}	−0.000	0.002	0.004	0.001	−0.004	0.001	−0.005
	(−0.035)	(0.183)	(0.339)	(0.120)	(−0.361)	(0.090)	(−0.482)
$\Delta PolRate \cdot D^{Access}$	−0.177**	−0.128	−0.117*	−0.165***	−0.072*	−0.046	−0.162***
	(−2.100)	(−1.474)	(−1.743)	(−2.702)	(−1.887)	(−0.516)	(−2.702)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.719***	−0.648***	−0.670***	−0.378***	−0.264***	−0.258*	−0.657***
	(−4.970)	(−4.425)	(−5.607)	(−3.377)	(−3.058)	(−1.740)	(−4.166)
$\Delta repo^{GC}$ lagged	−0.332***	−0.311***	−0.420***	−0.323***	−0.311***	−0.324***	−0.307***
	(−14.151)	(−12.972)	(−15.125)	(−12.711)	(−12.876)	(−12.113)	(−11.913)
N	10,001	10,158	9,952	9,778	9,758	10,078	10,060
R^2	0.220	0.231	0.187	0.124	0.114	0.144	0.297

The table reports the robustness results examining the impact of access to the ECB's deposit facility on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in different policy rates. D^{Dep} equals 1 if a country's GC rate is below the deposit facility. 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 heteroskedastic-robust standard errors. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

Table 7. Asset eligibility: Germany

	(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 b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.109***	0.109***	0.105***	0.054***	0.046***	0.101***	0.117***
	(13.130)	(13.130)	(11.394)	(9.442)	(9.250)	(12.053)	(13.854)
D^{QE}	−0.016	−0.016	−0.040***	−0.028**	−0.031**	−0.039***	0.042***
	(−1.434)	(−1.421)	(−3.105)	(−2.303)	(−2.465)	(−3.456)	(3.461)
$\Delta PolRate \cdot D^{QE}$	−0.120***	−0.116***	−0.109***	−0.025***	−0.019***	−0.039**	0.406***
	(−8.154)	(−7.867)	(−9.346)	(−3.565)	(−2.984)	(−2.427)	(6.250)
$D^{Eligible}$	0.004	0.004	0.003	0.003	0.002	0.002	0.002
	(0.440)	(0.435)	(0.316)	(0.314)	(0.254)	(0.187)	(0.202)
$\Delta PolRate \cdot D^{Eligible}$	−0.005	−0.005	−0.000	0.015**	0.002	−0.022**	0.013
	(−0.463)	(−0.463)	(−0.015)	(1.987)	(0.355)	(−2.059)	(1.172)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.052***	−0.044**	−0.023	−0.031***	−0.017**	−0.023	−0.216***
	(−2.737)	(−2.289)	(−1.491)	(−3.346)	(−2.021)	(−1.086)	(−2.972)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.365***	−0.363***	−0.363***	−0.359***	−0.356***
	(−20.719)	(−20.719)	(−20.277)	(−19.856)	(−19.668)	(−20.195)	(−69.536)
N	301,608	301,608	299,889	290,153	289,058	298,718	303,446
R^2	0.119	0.119	0.120	0.119	0.120	0.116	0.119

The table reports the robustness results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy 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 heteroskedastic-robust standard errors. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

the conditions in the unsecured market to be a key determinant of trades in the secured market. 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 across our baseline specifications. Second, our results hold true if we employ the rate on the ECB GC Pooling Basket as our policy rate, which reinforces our interpretation that the monetary policy disconnect stems from institutional differences within the central bank framework as opposed to a segmentation between different market segments. And third, all regressions arrive at the same conclusion, that is, access banks are less sensitive to changes in monetary policy target rates, in particular, when the GC rate is below the rate on the deposit facility.

In the special market, our results are also consistent if we employ alternative policy measures. Again, special repo rates are more sensitive to changes in unsecured overnight rates as compared to derivative-based implied overnight rates. Overall, the results confirm that eligible securities are less sensitive to changes in monetary policy target rates since the start of the ECB's QE program. This lower sensitivity has not been present in prior periods.

6. Conclusion and outlook

Institutional and political aspects are crucial for the monetary policy transmission. We provide the first empirical study highlighting how two forms of segmentation affecting the main short-term funding market, the repo market, impede the monetary policy pass-through. First, banks with access to the central bank's deposit facility lend at short-term rates that are more misaligned from the monetary policy target rate. Second, secured loans whose collateral assets are the target of Quantitative Easing programs are more disconnected from the monetary policy rate. We provide compelling evidence that these two forms of segmentation disconnecting the monetary policy transmission are statistically and economically relevant.

Our analysis provides new insights into monetary policy and funding liquidity. It calls for reconsidering two common notions in central banking. First, even if central banks exert more control over financial institutions in their jurisdictions, it is not always true that those financial entities are more effective for the monetary policy transmission. Second, under certain circumstances the idea that unconventional policies "safeguard the transmission of our monetary policy," as pointed out by ECB President Christine Lagarde to justify the new Pandemic Emergency Purchase Programme (PEPP), is misplaced (European Central Bank, 2020). QE policies can create some unintended, beneficial effects such as a greater price impact due to the consequent asset scarcity. However, we show that two key features of the central bank framework create rate dispersion and impede the pass-through of monetary policy into the money market, which leaves the central bank with less control over the transmission.

Concerning prudential policy, the European Commission issued some amendments to the Capital Requirements Regulation (CRR) "to facilitate bank lending in the Union amid COVID-19" (European Commission, 2020). At the heart of the CRR amendments, there is the (temporary) exclusion of central bank reserves from the calculation of the leverage ratio needs. While desirable for prudential reasons, this policy could encourage additional amounts to be deposited at the ECB deposit facility creating more segmentation and the opposite effect to its aim. Other institutional frictions than those highlighted in our paper might obstruct the monetary policy transmission and we leave this issue to future research.

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Appendix

A.1. Monetary policy

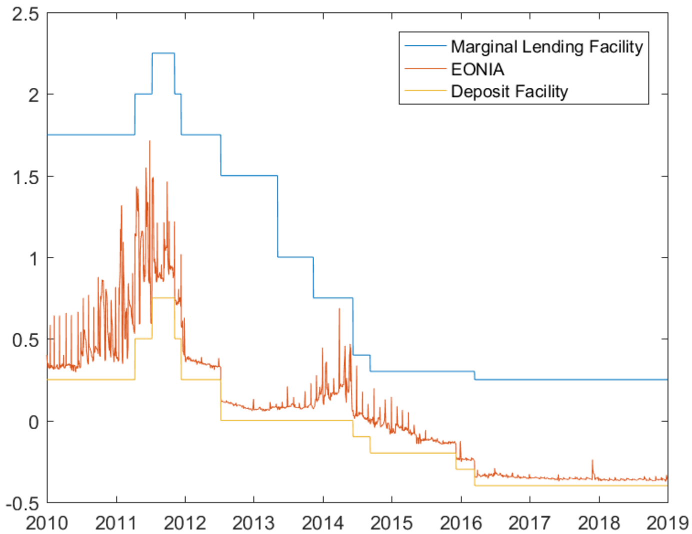
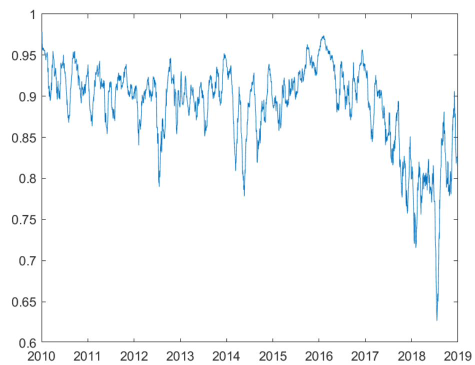


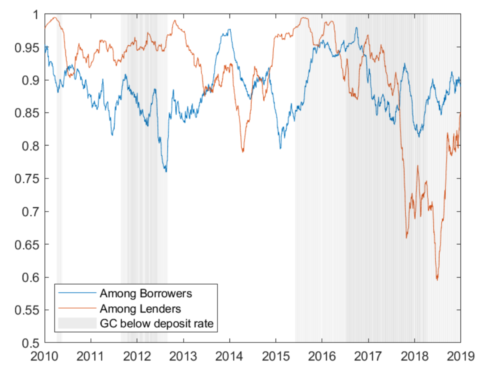
Fig. 1.1. Interest rate corridor

A.2. Trading share of access banks

Since 2015, when repo rates fell below the rate on the deposit facility, general collateral trading volume declined to about a third of its original size. This reduction was mainly driven by banks that had access to the central bank's deposit facility, banks without access to the deposit facility still used the lending side in GC repo transactions to deposit their liquidity. Figure 2.2a depicts the trading share of access banks in general collateral repo transactions collateralized by German government bonds. The share of trading volume by access banks dropped from around 95% in the period prior to QE to around 80% more recently.



(a) Total share by access banks



(b) Share by access borrowers/lenders

Fig. 2.2. Trading volume shares

In section 2.3 we argue that the GC market is characterized by a kinked demand curve from access banks while the demand from nonaccess banks is inelastic. We thus conclude that the increase in trading volume by nonaccess banks as depicted in Figure 2.2a results from fewer lending activities by access banks. This can be observed in the data, as shown in Figure 2.2b. In this graph, we depict the share of access banks among borrowers and among lenders in the GC market. While we observe that the share of access banks among borrowers has been stable over time, we observe that the share of access banks among lenders has dropped in recent years. We thus conclude that the drop in trading by access banks has been caused by a reduction in their lending activity.

A.3. Repo dispersion

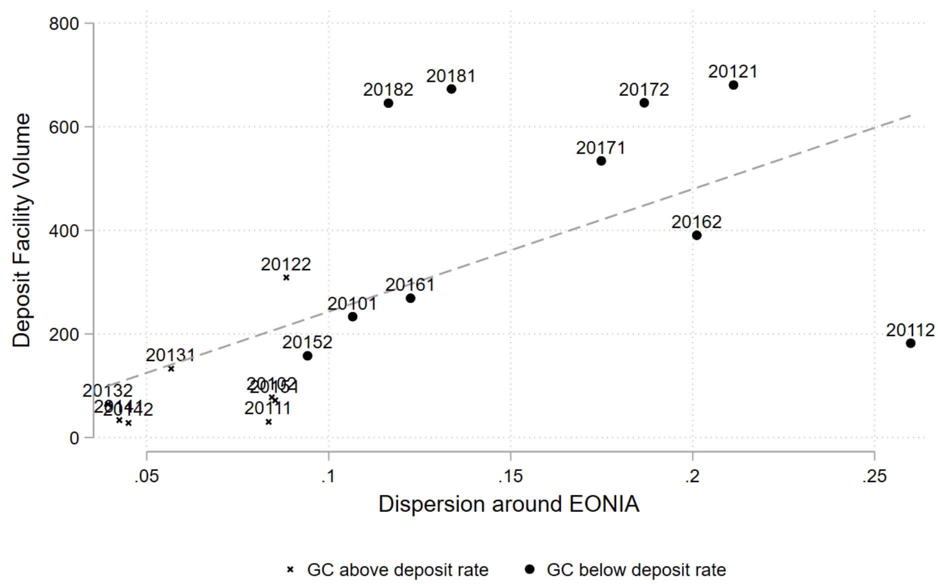


Fig. 3.3. GC market

Inspired by the approach of Duffie and Krishnamurthy (2016), we compute the volume-weighted mean absolute deviation of general collateral rates around the EONIA as our primary monetary policy target rate.

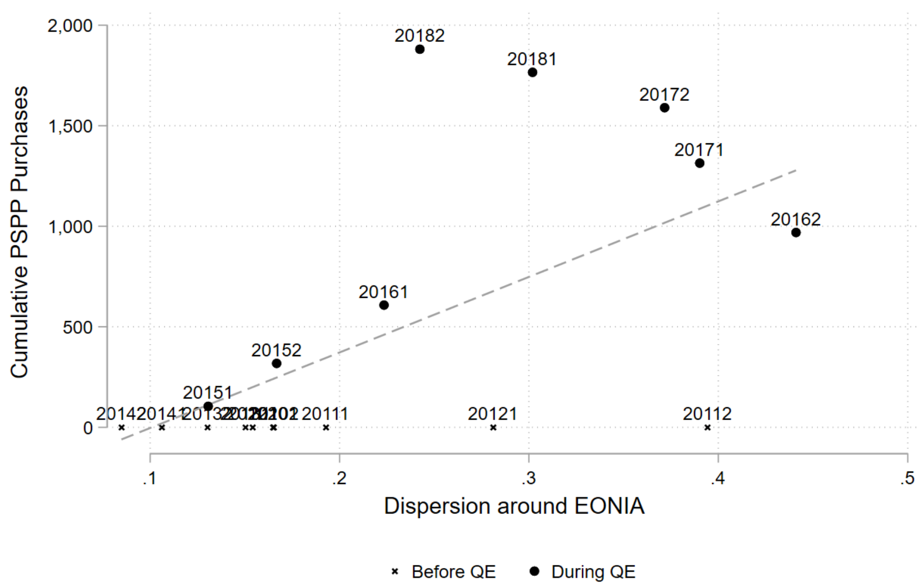


Fig. 3.4. Special market

Inspired by the approach of Duffie and Krishnamurthy (2016), we compute the volume-weighted mean absolute deviation of special repo rates around the EONIA as our primary monetary policy target rate.

A.4. Nonaccess banks in the special market

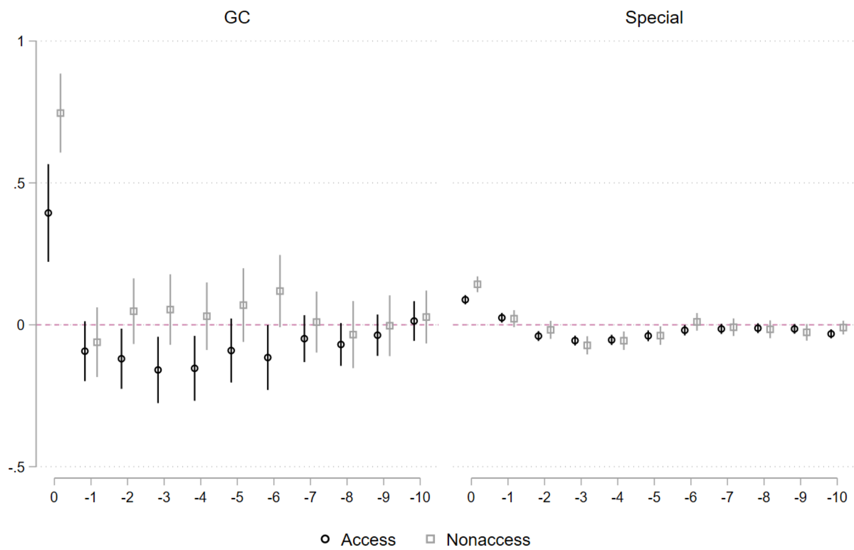


Fig. 4.5. Response of repo rates to (lagged) changes in EONIA