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Money markets, central bank balance sheet and regulation

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Abstract

This paper analyses money market developments since 2005, and examines factors that have affected money market functioning. We consider several metrics of activity in both secured and unsecured euro area money markets, and study interactions with new Basel III regulations and with central bank policies (liquidity provision, asset purchases and the Securities Lending Programme). Using aggregate data, we document that, prior to 2015, heightened financial market volatility coincided with worsening money market conditions, while higher central bank liquidity provision was associated with reduced money market stress. After 2015, the evidence is consistent with central bank asset purchases inducing scarcity effects in some money market segments, and with active securities lending supporting money market functioning. Using transactions-level money market data combined with supervisory data, we further document that the leverage ratio regulation impacts money markets at quarter-ends due to "window-dressing" effects, reducing money market volumes and rates. We also consider the macroeconomic impact of changing money market conditions, finding that the impact depends on whether frictions originate in secured or unsecured markets and on central bank policies in place.

Keywords: Money markets, asset purchases, securities lending, leverage ratio, liquidity coverage ratio

JEL Codes: E44, E58, G12, G20, G28

Non-technical summary

Money markets are an important cornerstone of the financial system. Banks, non-bank financial institutions such as investment funds and money market funds, as well as non-financial corporations rely on money markets for their short-term funding and collateral needs. Money markets are also key for the implementation and transmission of monetary policy. Short-term money market rates often serve as operational targets for central banks and represent the first step in the monetary policy transmission. In addition, money market rates are important for the credit conditions in the economy, as money market rates serve as a benchmark for the pricing of credit, and are therefore an important determinant for the level of lending rates faced by firms and households. To ensure smooth transmission of the monetary policy stance, it is therefore important that money market rates be well-aligned with central bank policy rates.

In the euro area, money markets went through substantial changes and turbulent periods over the past 15 years. First, money markets experienced bouts of volatility during the financial and sovereign debt crises, affecting in particular unsecured money market rates and secured rates collateralised by stressed sovereigns' government bonds. Second, there was a shift away from unsecured money markets and towards the secured money markets. Third, tensions in money markets during the financial and sovereign debt crises led to a large demand by banks for liquidity provided by the central bank. Fourth, new Basel III regulations, in particular the Liquidity Coverage Ratio (LCR) and the leverage ratio (LR), have been phased in since 2015. These regulations may interact with money market functioning in a variety of ways. The LCR requires banks to hold high-quality liquid assets (e.g., reserves and government bonds) and such assets are traded in money markets. The LR is calculated based on the size of banks' balance sheets and money market borrowing has a bearing on bank balance sheet size.

The aim of this Discussion paper is to study the interactions between money markets, new Basel III regulations and central bank policies (liquidity provision, asset purchases and the Securities Lending Programme). We shed light on the changing role of factors affecting money market activity since 2005. We also assess the macroeconomic impact of money market conditions and discuss the implications of money market developments for monetary policy implementation and transmission.

We consider several metrics of activity in both secured and unsecured euro area money markets: volumes, rates and the cross-sectional dispersion of money market rates. Dispersion across money market rates may have repercussions for the conduct of monetary policy, as pointed out by Mr. Cœuré - the former Executive Board member of the European Central Bank - in a 2018 speech: "… the dispersion of short-term rates may affect the transmission of our monetary policy stance. In effect, it could make overall financial conditions looser or tighter than we intend".

Three main take-aways emerge from our analysis. First, at the time of writing (our data end in 2019), conditions in the euro area money markets appeared to be benign. This implies that monetary policy measures were transmitted smoothly across money market rates. Looking back over the past 15 years, our analysis documents that euro area money market conditions tend to worsen if financial stress increases, or if central bank asset purchases induce scarcity effects while the Securities Lending Programme is not sufficiently active.

Second, with regard to the impact of Basel III regulations, we document that the leverage ratio regulation impacts money markets at quarter-ends due to “window-dressing” effects, reducing volumes and rates, and raising money market rate dispersion. Liquidity requirements do not appear to affect money markets significantly at this point. This may be due to the large Eurosystem balance sheet size, which ensures an ample supply of central bank liquidity, facilitating the fulfilment of liquidity requirements.

Third, an analysis of the macroeconomic impact of money market conditions shows that tighter money market conditions may force banks to divert resources into “unproductive” but liquid assets (e.g., central bank reserves) or to de-leverage. As a result, lending capacity of banks may be impaired which triggers a decline in output. Well-functioning secured markets cushion the macroeconomic impact. If secured markets do not function smoothly, however, central bank balance sheet expansion is needed to mitigate output declines.

"In the past, different short-term rates, such as unsecured money market rates or repo rates backed by either general or security-specific collateral, on average moved in tandem and the spread between them was typically very small and rather stable over time. But as excess liquidity increased, these rates started to diverge. ... the divergence between our key policy rates and market rates could become more important in the future once policy rates begin to normalise. … there is a risk that … 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 (2018)

1. Introduction

Money markets are an important cornerstone of the financial system. Banks, non-bank financial institutions such as investment funds and money market funds, as well as non-financial corporations rely on money markets for their short-term funding and collateral needs (with maturity of transactions of up to and including one year). Money markets are also key for the implementation and transmission of monetary policy. Short-term money market rates often serve as operational targets for central banks and represent the first step in the monetary policy transmission. In addition, money market rates are important for the credit conditions in the economy, as money market rates serve as a benchmark for the pricing of credit, and are therefore an important determinant for the level of lending rates faced by firms and households. To ensure smooth transmission of the monetary policy stance, it is therefore important that money market rates be well-aligned with central bank policy rates.

In the euro area, money markets went through substantial changes and turbulent periods over the past 15 years. First, money markets experienced bouts of volatility during the financial and sovereign debt crises, affecting in particular unsecured money market rates and secured rates collateralised by stressed sovereigns' government bonds. Figure 1, Panel A plots private money market rates and three policy rates of the European Central Bank (ECB). The policy rates are depicted as black lines (a corridor formed by the Deposit Facility rate at the bottom, the Marginal Lending Facility rate at the top, and the Main Refinancing Operations rate in-between) while private money market rates are depicted using coloured lines (secured (repo) rates for Germany, France, Italy and Spain, and unsecured rates, the EONIA, the unsecured interbank rate and the €STR, the new unsecured benchmark rate that replaces the EONIA since October 2019). Since late 2015 (Figure 1, Panel B), there has been a divergence between the EONIA, which is firmly anchored at the Deposit Facility (DF) rate, and the secured rates which have mostly moved below the DF rate.[2] Divergence across money market rates may have repercussions for the conduct of monetary policy.

Second, there was a shift away from unsecured money markets and towards the secured (collateralised) money markets. For example, Figure 2 plots cumulative quarterly turnover in the euro

[2] Like the EONIA, the €STR is anchored at the DF rate. Unlike the EONIA, it is slightly below the DF rate due to non-bank and non-euro-area participants in transactions underlying the €STR. These participants do not have access to the Deposit Facility and hence rates on their money market trades are not bounded by the DF rate.

area unsecured and secured interbank money market segments. While the total turnover roughly doubled between 2005 and 2019, the share of the unsecured transactions in total declined from about 40% in 2005 to 5% in 2019.

Third, tensions in money markets during the financial and sovereign debt crises led to a large demand of banks for liquidity provided by the central bank. Figure 3 illustrates the evolution of the ECB/Eurosystem balance sheet. Until 2015, the growth of the balance sheet was driven primarily by the increased demand of banks for central bank liquidity, provided through fixed-rate full-allotment operations and a series of longer-term refinancing operations.

Fourth, the implementation of large-scale asset purchases since 2015[3] – which contributed to a further expansion of the Eurosystem balance sheet (Figure 3) – led to collateral scarcity in some money market segments. This is because the purchases withdraw government bond collateral from the financial system and government bonds are the main type of collateral used in secured money markets (see Figure 4). In this context, we will study the role of the Eurosystem Securities Lending Programme in alleviating collateral scarcity.

Fifth, money market functioning may be affected by new Basel III regulations, namely the Liquidity Coverage Ratio (LCR) and the Leverage Ratio (LR). These regulations started being phased in (in the case of the LCR) or publicly reported (in the case of the LR) as of 2015. They can impact money markets in a variety of ways. For example, the LCR requires banks to hold high-quality liquid assets (e.g., central bank reserves and government bonds) and such assets are traded in money markets. The LR is calculated based on the size of banks' balance sheets and money market borrowing affects bank balance sheet size.

The aim of this Discussion paper is to study the interactions between money markets, central bank policies and new Basel III regulations. We analyse several metrics of activity in both secured and unsecured euro area money markets and shed light on the changing role of factors affecting money market activity since 2005. We also assess the macroeconomic impact of money market conditions and discuss the implications of money market developments for monetary policy implementation and transmission.

Our analysis proceeds as follows. In Section 2, we provide a brief review of the role of money markets in the economy and highlight frictions that may hamper money market functioning.

In Section 3, we describe developments in the euro area money markets (both secured and unsecured) over 2005-2019. We rely on several data sources to measure money market activity. In order to go back in time to prior to the Global Financial Crisis, we use the daily EONIA rates and volumes starting from 2005 and, for secured (repo) markets, we rely on daily aggregated data on transactions executed on the Brokertec and MTS platforms with French, German, Italian and Spanish sovereign securities as collateral. Both Brokertec and MTS cover a significant percentage of the European repo market transactions. To analyse the effects of Basel III regulations on money markets more closely, we rely on transactions-level data in the Money Market Statistical Reporting (MMSR) database, starting from 2016 (which is the beginning of the database). This data covers, on a daily basis, borrowing and lending transactions undertaken by around 52 banks from 10 different euro

[3] For example, the Public Sector Purchase Programme (PSPP) was announced in January 2015.

area countries on the secured and unsecured money markets. We combine this data with supervisory data on bank regulatory capital and liquidity ratios.

Using the above data sources, we analyse money market rates, volumes, as well as the dispersion index of money market rates as proposed by Duffie and Krishnamurthy (2016). Dispersion of money market rates is measured as the weighted mean absolute deviation of the cross-sectional distribution of the rates. There are two channels through which money market rate dispersion may matter for central banks. First, money market rate dispersion can be a sign of market segmentation. A high degree of money market segmentation may lead to an increased demand of banks for central bank liquidity. Second, money market rates determine funding costs of banks. If funding costs increase for some banks, their profitability decreases, which may affect their ability to lend to the real economy and affect the transmission of monetary policy. For example, Altavilla, Carboni, Lenza, and Uhlig (2019) document that the cross-sectional dispersion in unsecured interbank money market rates significantly raises lending rates banks charge to firms, with a peak effect of around 100 basis points during the Global Financial Crisis and the euro area sovereign debt crisis.

In Section 4, we present results of two empirical analyses. First, we analyse co-movements between the aggregated measures of money market activity (volumes, rates and dispersion of money market rates) and several factors that have a bearing on money market functioning. Specifically, we consider general financial market volatility as measured by the VSTOXX index, excess liquidity (proxying changes in the central bank balance sheet size), Securities Lending Programme volumes, as well as month-end, quarter-end, and year-end effects, which aim to capture the effects of liquidity, capital and other regulations that are reported at month-, quarter- and year-ends, respectively.

We document that, prior to 2015, heightened financial market volatility coincided with worsening money market conditions. By contrast, higher central bank liquidity provision (increases in excess liquidity) was associated with lower money market stress. This is consistent with evidence presented in Garcia-de-Andoain, Heider, Hoerova, and Manganelli (2016) who documented that liquidity provision by the Eurosystem stimulated the supply of liquidity in the unsecured money markets, especially to banks located in stressed countries during the European sovereign debt crisis. After 2015, we initially observe an increase in money market dispersion indices, without an accompanying increase in financial market volatility and while excess liquidity levels were at all-time highs. The evidence is suggestive of central bank asset purchases inducing scarcity effects in some money market segments (see Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2019; Brand, Ferrante, and Hubert, 2019). Importantly, money market functioning improved once the Eurosystem Securities Lending Programme became more active as of December 2016. As for regulatory effects, we document significant decreases in volumes and rates as well as increases in money market dispersion indices at quarter-ends, which revert subsequently. Such effects are indicative of capital regulation influencing banks' willingness to trade in money markets at quarter-ends. By contrast, we do not find significant effects on the aggregate money market activity at month-ends, indicating that the effects of liquidity requirements – which are reported at the end of the month - are muted so far.

Using transactions-level money market data combined with supervisory data, we provide further evidence on the effects of capital regulation on money market activity (see Box A in Section 4). Banks that are closer to their regulatory leverage ratio minimum reduce their money market borrowing at quarter-end, by up to 23%. Banks that are further away from their regulatory leverage ratio minimum do not significantly change their money market borrowing. The evidence is consistent with "window-dressing" effects - whereby some banks reduce their balance sheet size at quarter-ends – which have been documented in the previous literature (see, e.g., Munyan, 2017, and Kotidis and Van Horen, 2018). Interestingly, we document that all borrowing banks in our sample experience a reduction in interest rates at quarter-ends, by about 7-8 basis points. All borrowing banks also experience an increase in the dispersion of money market rates, by about 5-6 basis points. This is a relatively large effect as the average dispersion over our sample is 8 basis points. We note that leverage ratios of euro area banks have improved since 2015, and we observe lower quarter-end effects in money market activity towards the end of our sample (2019).

In Section 5, we discuss the impact of money market conditions on the macro-economy and the conduct of monetary policy. Several papers embed money markets in macroeconomic models. For example, Bruche and Suarez (2010) provide a general equilibrium model in which interbank money market can freeze due to a rise in counterparty risk. In turn, this may distort the aggregate allocation of credit and, in the presence of demand externalities, cause large output losses. More recently, Bianchi and Bigio (2017) build a model where banks are exposed to liquidity risk and manage it by borrowing in the unsecured market or by holding a precautionary buffer of reserves. Monetary policy affects lending and the real economy by supplying reserves and thus by changing banks' trade-off between profiting from lending and incurring greater liquidity risk. Arce, Nuno, Thaler and Thomas (2019) develop a model with the same frictions in the interbank market as in Bianchi and Bigio (2017), and show that a policy of large central bank balance sheet that uses interest rate policy to react to shocks delivers more policy space relative to the effective lower bound (ELB) compared to a lean balance sheet policy. At the same time, a lean-balance-sheet policy combined with temporary quantitative easing at the ELB achieves similar stabilization and welfare properties as a large-balance-sheet policy. Piazzesi and Schneider (2018) consider a monetary economy in which trade in both goods and securities relies on money provided by intermediaries. While money is valued for its liquidity, its creation requires costly leverage. Inflation, security prices and the transmission of monetary policy depend on the institutional details of the payment system. The price of a security is higher if it helps back inside money, and lower if more inside money is used to trade it. Vandeweyer (2019) builds an intermediary asset pricing model with heterogeneous banks subject to a liquidity management problem and regulation. In the environment with large excess reserves and stringent capital regulation, traditional banks cease to intermediate liquidity to shadow banks. In this case, the pricing of reserves is disconnected from the pricing of other liquid instruments (like Treasury bills) that shadow banks can hold. The liquidity premium of these assets is then determined by the variations in their supply.

We quantify the macroeconomic impact of money market conditions in the euro area through a lens of a stylised general equilibrium model with secured and unsecured money markets developed in De Fiore, Hoerova and Uhlig (2019). In the model, banks rely on money markets to cover their liquidity needs arising from temporary funding shocks. Tighter money market conditions force banks to either divert resources into "unproductive" but liquid assets (e.g., central bank reserves) to self-insure against liquidity shocks or to de-leverage (shrink their balance sheet to lower exposure to funding shocks). In both cases, lending capacity of banks is impaired which, in turn, triggers a decline in output.

Such negative effects can be mitigated if the central bank expands its balance sheet through bond purchases or through liquidity-providing refinancing operations, as both policies satisfy banks' increased demand for liquid assets and mitigate de-leveraging pressures. Results from a calibrated model suggest that a shift away from the unsecured money market transactions and towards more secured transactions implies a difference in output of about 1%, comparing pre- to post-crisis steady states. Well-functioning secured markets cushion the macroeconomic impact. If secured markets do not function smoothly, however, central bank balance sheet expansion is needed to mitigate output declines.

In Section 6, we offer a brief summary of our results and main take-aways.

2. Money markets: Functions and frictions

This section provides a brief review of the role of money markets in the economy and highlights frictions that may hamper money market functioning.

2.1 Definitions

Money markets include several markets and instruments which share the characteristic of providing short-term funding or collateral, with maturity of transactions of up to and including one year. This includes short-term unsecured loans, secured short-term loans (such as repurchase "repo" agreements), sovereign bills, commercial papers, certificates of deposit, and money market mutual funds. Participants in money markets include banks, non-bank financial institutions such as investment funds and money market funds, as well as non-financial corporations.

In this paper, we focus on short-term unsecured and secured money market transactions. In an unsecured transaction, liquidity (cash) is exchanged for a promise of repayment at a future date (most commonly overnight). In a secured transaction, the trade is collateralised. Secured transactions have been on an increasing path, and this trend has been accentuated by the Global Financial Crisis. The share of the secured transactions in total (secured plus unsecured) turnover increased from around 60% in 2005 to more than 95% in 2019 (Figure 2). Secured loans are often referred to as (reverse) repos. A repo transaction combines two financial transactions legs taking place at different times. It involves the sale of a security at the spot price and a forward agreement to buy back the security at a specified date and price. Repo rates are implied between the two prices. The party that provides the collateral (security) in exchange for liquidity (cash) is entering a repo agreement, while the party that borrows the security while providing cash enters a reverse repo. Secured loans initiated by the cash-providing party are widely thought to be motivated by collateral considerations, e.g., borrowing collateral for a short-sale.

There are two types of repo transactions: special repos and general collateral repos. In special repos, the party delivering the security must deliver a specific asset (with a specific international securities identification number (ISIN) code), while, in general collateral repos (GC repos) she can choose among a basket of possible assets. Special repos imply the payment of a special rate. The special rate can be lower than the general repo rate, reflecting the convenience yield of the asset (how much sought-after the asset is).

A repo may entail buying back the security the next day (overnight repo) or at a later date. The most common maturity for euro area repos is one day.[4] The Euro Money Market Study (ECB, 2019) provides an overview of the activity in the euro area money markets. It reports that transactions with one-day maturity constitute more than 90% of all secured transactions. The Euro Money Market Study further documents that collateral used in secured transaction is mainly coming from six countries: Germany, Italy, France, Spain, Belgium and the Netherlands. Together, they account for more than 80% of the collateral used. The vast majority of the collateral consists of sovereign bonds (80%), followed by bonds issued by financial corporations (13%).

Finally, secured loans may be bilateral or cleared by a Central Counterparty (CCP). A CCP interposes itself between a borrower and a lender, becoming a borrower to the lending counterparty, and a lender to the borrowing counterparty. One important function of a CCP is to insure against counterparty default (see, e.g., Biais, Heider and Hoerova, 2012).[5] According to the Euro Money Market Study, around 70% of trades in 2018 were cleared via CCPs. In bilateral trades, counterparties are typically banks, other financial corporations - such as hedge funds, money market funds or pension funds – or non-financial corporations.

2.2 Role

Money markets are used by a variety of economic agents to manage their short-term funding and collateral needs. In recent years, money markets are increasingly used as a source of collateral. As such, these markets facilitate short-selling and arbitrage (e.g., Adrian, Begalle, Copeland, and Martin, 2013), help security dealers in their intermediation activities (Huh and Infante, 2018) and facilitate circulation and re-use of collateral (e.g., Corradin, Heider, and Hoerova, 2017).

Money markets contribute to informational efficiency and market discipline. In particular, they produce information on bank quality through peer monitoring (Rochet and Tirole, 1996).[6] Collateral provided in secured markets reduces borrowers' moral hazard (Hölmstrom and Tirole, 1997). Collateral can also reduce the asymmetry of information between borrowers and lenders (see Bester, 1985, 1987). Furthermore, money markets allow the pooling of the idiosyncratic liquidity risk faced by market participants (Bhattacharya and Gale, 1987).

Money markets are also key for the implementation and transmission of monetary policy. Short-term money market rates often serve as target rates for central banks and represent the first step in the monetary policy transmission (Bindseil, 2004). In addition, money market rates are important for the pricing of credit to the real economy, as money market rates are used as reference rates.

[4] There are three types of transactions: overnight, when the repo settles on the trade date T and the bond is repurchased the next business day T+1; tomorrow next, when the repo settles at the trade date plus one business day T+1 and the bond is repurchased the following business day T+2; and spot next when the repo settles at T+2 and the bond is repurchased at T+3.
[5] In centrally cleared transactions, CCPs require both parties to post margins with the aim of providing the CCPs with sufficient resources to mitigate potential risks such as counterparty risk.
[6] See also Furfine (2001) and King (2008) for empirical evidence of peer monitoring.

2.3 Frictions

Information asymmetry – whereby one counterparty to a transaction has more or better information than the other - can plague money market functioning. It can lead money markets to breakdown and banks to hoard liquidity (Heider, Hoerova, and Holthausen, 2015).[7] A large information asymmetry might lead to rationing in interbank money markets (e.g., Freixas and Jorge, 2008; Hoerova and Monnet, 2016), exclude some banks from the unsecured market and lead them to borrow in the secured market (Di Filippo, Ranaldo, and Wrampelmeyer, 2018), or limit the scope for international interbank market integration with unsecured lending (Freixas and Holthausen, 2004). Credit rationing resulting from information asymmetry can impair monetary policy transmission (Freixas and Jorge, 2008).

Collateral requirements can mitigate frictions associated with information asymmetries, and reduce moral hazard and credit rationing. However, collateral requirements come with their own set of potential frictions. For example, lenders in collateralised transactions often use the so-called "haircuts" - the difference between the initial market value of an asset and the purchase price paid for that asset at the start of a repo - to protect themselves against changes in the market price of collateral. Haircuts tend to be pro-cyclical, increasing in times of market stress. In addition, prices for assets with high haircuts may drop significantly. Therefore, rising haircuts make raising liquidity in secured markets harder and can exacerbate liquidity and market stress.[8]

Money markets may malfunction when a counterparty has a large bargaining power, or when counterparties compete imperfectly. Bilateral money markets are over-the-counter markets in which counterparties search for trading partners and bargain over the terms of the transaction (Ashcraft and Duffie, 2007). Banks with liquidity surpluses can generate market power, leading to a rationing of liquidity (Acharya, Gromb, Yorulmazer, 2012). Bargaining power in money markets matters for monetary policy as it influences the relationship between policy rates and money market rates (Afonso and Lagos, 2015).

Equilibrium multiplicity and the associated coordination failures may plague money market functioning. Short-term liquidity needs are fundamentally inelastic which translates into an inelastic demand for and supply of funds in money markets. This may lead to a multiplicity of equilibria in interbank money markets associated with different pairs of interbank market rates for "good" and "crisis" times (Freixas, Martin and Skeie, 2011). Coordination failures may lead to panic-induced runs in repo markets (Martin, Skeie, and Von Thadden, 2014), and may expose money markets to systemic risk (Freixas, Parigi, and Rochet, 2000). Central bank policies can select the "good" equilibrium by acting as a coordination device for market participants. For example, in Freixas, Martin and Skeie (2011), the central bank should lower the interbank rate when confronted with a crisis that causes a disparity in the liquidity held among banks.[9]

More generally, central banks have an important role to play when money markets malfunction. Central banks act as a lender of last resort and provide liquidity when solvent banks become illiquid

[7] See Acharya and Merrouche (2013) for evidence of liquidity hoarding.

[8] See Brunnermeier and Pedersen (2009) for a model of feedback loops between funding liquidity and market liquidity.

[9] Diamond and Rajan (2012) argue that central banks should lower rates in bad times to deal with episodes of illiquidity but raise them in normal times to offset distortions from reducing rates in adverse times.

(Bagehot, 1873; Rochet and Vives, 2004; Garcia-de-Andoain, Heider, Hoerova, and Manganelli, 2016). They provide liquidity and improve market functioning when markets malfunction due to uncertainty about aggregate liquidity demand (e.g., Goodfriend and King, 1988; Allen, Carletti, and Gale, 2009).[10] The type of collateral central banks accept in their operations and the haircuts central banks set can influence the ability of the banking system to deliver maturity transformation and can affect monetary policy conduct (e.g., Ashcraft, Gârleanu, and Pedersen, 2011; Bindseil, 2013). When high-quality collateral is scarce, the central bank can remedy the situation by providing liquid collateral in exchange for less liquid collateral (Heider and Hoerova, 2009), as well as by lending against potentially illiquid assets (Corradin and Sundaresan, 2019).

Money market functioning affects central bank policies but there is also an interaction in the opposite direction. In particular, large-scale asset purchases conducted by central banks around the world in the wake of the Great Financial Crisis had a significant impact on money markets. The aim of our paper is to analyse these two-way interactions between money markets and central bank policies, and additionally shed light on the effects of the recent Basel III regulations on money market functioning.

3. Developments in the euro area money markets over 2005-2019

In this Section, we describe developments in the euro area money markets (both secured and unsecured) over the period from January 2005 to June 2019, and consider factors that may interact with money market activity.

3.1 Money market activity

To measure money market activity, we analyse money market rates, volumes, as well as the dispersion index of money market rates as proposed by Duffie and Krishnamurthy (2016).

Money market volumes and rates. We focus on transactions with 1-day maturity as this is the most common maturity (see Section 2). For the secured money market segment, we use data on special and general collateral (GC henceforth) repos traded on the BrokerTec and MTS platforms with French, German, Italian and Spanish sovereign securities as collateral. Both platforms cover a significant percentage of the European market transactions and the large majority of these transactions is central counterparty clearing (CCP) cleared. For the unsecured segment, we use EONIA rate and volume data. EONIA is a daily reference rate that expresses the weighted average of unsecured overnight interbank lending in the euro area.

Dispersion of money market rates. Duffie and Krishnamurthy (2016) have proposed a dispersion index of money market rates, whereby higher dispersion corresponds to lower pass-through efficiency of monetary policy. This measure - the volume-weighted average absolute deviation from the volume-weighted average rate - captures how much each market rate deviates from the average rate across markets. To calculate the index, each rate's influence is weighted by its outstanding amount. This index is designed to equal to zero in financial markets without any frictions and/or

[10] In the presence of aggregate uncertainty about liquidity needs, there is a role for a government to issue claims that provide a store of liquidity (Holmström and Tirole, 1998).

collateral risk premia, where all rates yield the same return, and to be constant in financial markets with a perfect pass-through, where all rates move in lockstep. We use this methodology to compute a dispersion index for the main euro area money markets rate at 1-day maturity. We aim to understand the impact of monetary policy actions and recent Basel III regulations on pass-through efficiency.

Euro area money market rates were well-anchored to the ECB main policy rate (the MRO rate) prior to the Great Financial crisis. However, signs of dispersion across rates emerged during the financial (2007-2009) and sovereign debt (2010-2013) crises as well as with the activation of Public Sector Purchase Program (PSPP) in 2015. Figure 1, Panel A shows the evolution of the short-term secured rates for Germany, France, Italy and Spain, the unsecured EONIA rate and the ECB policy rates over the period from January 2005 to June 2019.[11] Our sample includes periods of rising and falling interest rates. Until the fall of 2008, rates increase in line with the ECB's interest rate policy, followed by a fast decline in repo and EONIA rates in the summer of 2009. In this period, repo and EONIA rates remained close to each other and were in general above the ECB deposit facility rate. In the period following the two 3-year longer term refinancing operations (LTROs) (in December 2011 and February 2012), Figure 1 shows some evidence of dispersion across the rates pointing to increasing risk premia during the sovereign debt crisis. Towards the end of our sample (Figure 1, Panel B), money market rates dropped to historically low levels and traded below zero but also below the deposit facility in some countries. Money market rates diverged once again. The dispersion coincided with the start of the large-scale purchases of sovereign bonds by the Eurosystem which started in March 2015 and with the introduction of the new Basel II requirements for bank liquidity and leverage.

The resulting dispersion of money market rates may reduce the monetary policy pass-through to short term rates. In an idealized money market, any change in the main monetary policy rate should pass through perfectly to all money market rates. In reality, a number of factors may impede pass-through. Dispersion across money market interest rates can be rising due to a general increase in financial risk or due to increasing risk premia of the underlying bonds used as collateral for repo transactions. Additional factors that can contribute to rising dispersion include scarcity effects associated with the implementation of unconventional monetary policies or frictions associated with the implementation of bank regulations.

Prior to 2015, there were significant interactions between money market conditions and measures of financial stress. Figure 5 shows the variation of the dispersion index over the sample period. Dispersion increases in the run-up to the crisis, peaking in late 2008. Such developments in the financial markets are measured by the evolution of the VSTOXX index, the euro area stock market option-based implied volatility as a proxy of a crisis severity. Dispersion decreased after the Global Financial Crisis but it increased again at the start of the euro area sovereign debt crisis in April 2010 and increased further at the peak of that crisis in December 2011. Dispersion across money market interest rates decreased following the large liquidity injection through the two 3-year LTROs.

After 2015, we observe an increase in money market dispersion indices, without an accompanying increase in financial market stress and while excess liquidity levels were at all-time highs. We also

[11] We volume-weigh the special and GC repo rates at country level on a daily basis.

uncover significant increases in money market dispersion indices at quarter-ends, which we will link to the effects of the new Basel III capital (leverage) requirements.

3.2 Central bank policies

Central bank operations can alter the mix of assets available for use in money markets. In response to the Global Financial Crisis, central banks have implemented several unconventional monetary policy measures to provide liquidity to the financial system. A central bank can provide liquidity to the financial system via refinancing operations (lending central bank reserves against collateral) or via outright asset purchases.

Excess liquidity. Excess liquidity is defined as the amount of liquidity provided by the Eurosystem in excess of bank reserves requirements. It corresponds to the funds held by banks as excess reserves, either on their current account or on their deposit facility account. Since the Great Financial Crisis, a number of unconventional policies were introduced by the Eurosystem and the amount of excess liquidity in the financial system increased dramatically. Figure 3 shows the evolution of the Eurosystem balance sheet size as well as the split between the drivers of the balance sheet growth – refinancing operations and asset purchases - over the period from January 2005 to September 2019.

Refinancing operations. During the period marked by the Global Financial Crisis and euro area sovereign debt crisis, the increase in the balance sheet size was mainly the result of the sharp increase in banks' demand for refinancing. The extension of the maturity of refinancing operations up to three years in 2011 also contributed to increasing the balance sheet size, which reached almost EUR 1 trillion in 2012. The recent targeted long-term refinancing operations (TLTROs), with a maturity of 4 years, also led to an increase in the balance sheet size. Refinancing operations are characterized by several features that may affect the functioning of private money markets. Central bank eligibility policy, defining the range of securities that can be posted as collateral, and haircuts charged by the central bank might affect asset prices (e.g., Ashcraft, Gârleanu, and Pedersen, 2011, Crosignani, Faria-e-Castro, and Fonseca, 2020, and Corradin and Moreno, 2016) or induce market participants to issue own assets for the sole purpose of being retained and pledged as collateral (Carpinelli and Crosignani, 2016). Since central bank operations are effectively asset swaps, the impact of these swaps depends on their size and maturity term. The maturity term determines how long the collateral will remain encumbered at the central bank, potentially inducing collateral scarcity in private markets.

Asset purchases. Assets started to accumulate as of March 2015 with the launch of the PSPP, while liquidity provided via refinancing operations declined sharply after 2012, in line with easing of financial market conditions. Outright purchases can also have side effects on the collateral use of assets due to the effective decrease in the supply of collateral for a given stock of assets. Corradin and Maddaloni (2020) document that the Securities Market Program (SMP) purchases increased specialness - the scarcity premium of procuring a bond in the repo market - of specific Italian government bonds in the second half of 2011. The increase in the premium to be paid to procure a specific bond is related to the amount purchased in every transaction but also to the holdings already in the Eurosystem's portfolio. These effects are amplified when the SMP purchases involve bonds already in high demand in the repo market due to short-selling activity. Arrata, Nguyen, Rahmouni-

Rousseau, and Vari (2019) document that most short-term repo interest rates in the Euro area are below the European Central Bank deposit facility rate after the activation of the PSPP by the Eurosystem. They assess the scarcity channel of the PSPP and its impact on repo rates, estimating that purchasing 1 percent of a bond outstanding is associated with a decline of its repo rate of 0.78 basis points (bps).

Securities Lending Programme. Central banks can offset scarcity premia by introducing a security lending facility making their collateral available for reuse. D'Amico, Fan and Kistul (2018) find an economically substantial scarcity premium due to specialness in U.S. Treasury securities that were targeted by the Fed during their quantitative easing (QE) programme. However, their results suggest that the Fed lending facility (reverse repos providing collateral to the market) as a supplementary policy tool was effective in alleviating shortage of high-quality collateral due to the change of the net supply of Treasury collateral. In the euro area, bonds purchased in the PSPP are made available to the market through a securities lending facility to mitigate impairments in the price mechanism. Aggarwal, Bai and Laeven (2018) find that the possibility to borrow German sovereign bonds from the Eurosystem reduces the demand to borrow these bonds in the private repo and security lending market.

4. Empirical analysis of money market activity

In this Section, we analyse co-movements between the three metrics of money market activity we introduced in the previous section (volumes, rates and dispersion across money market interest rates) and factors that may affect money market functioning. Specifically, we consider financial market volatility as measured by the VSTOXX index, central bank excess liquidity, securities lending balances, as well as month-end, quarter-end, and year-end effects.

We investigate the co-movements by estimating the following time-series regression using daily data: [12]

$$y_t = \alpha + \beta_1 VSTOXX_t + \beta_2 \Delta ExcessLiquidity_t + \beta_3 D_t^{eom} + \beta_4 D_t^{eoq} + \beta_5 D_t^{eoy} + \varepsilon_t \quad (1)$$

where y_t is either the dispersion index, the interest rate spread (the difference between volume-weighted money market rates and the policy rate), or the logarithm of the total (secured and unsecured) money market volumes on day t. On the right-hand side, $VSTOXX_t$ is the VSTOXX index (index of stock market volatility based on the STOXX50 options), the $\Delta ExcessLiquidity_t$ is the change in excess liquidity between day t and t-1, D_t^{eoy} is an end-of-year dummy to account for the decrease in money market activity when banks close their books at the end of the year. D_t^{eoq} is a series of five dummies capturing the change in dispersion, rate spreads and volumes up to four business days before the end-of-quarter day. The fifth dummy picks up the change of the first business day after the end-of-quarter. Table 1 provides details on all data sources used in our analysis. Following our previous discussion, we split our sample into two sub-periods which we analyse separately: 1) before 2015; and 2) after 2015.

[12] The regression specification in (1) does not attempt to identify causal effects and our results should be interpreted only as correlations. Where possible, we discuss how our simple analysis links to results from other research papers, obtained using different methodologies.

4.1 Money market activity before 2015

Financial market volatility (VSTOXX). Dispersion across money market interest rates tends to be high during crisis periods and is positively related to VSTOXX. An increase of 1% of VSTOXX has an impact of 0.285 bps in the dispersion index. Volumes decrease with higher financial stress, pointing to an overall decrease in money market activity (see Table 2). An increase of 1% of VSTOXX results in a decrease of volumes of around EUR 500 million. Thus, our findings support recent literature that suggests that market risk negatively affects money market activity. Empirically, run on repo (Gorton and Metrick, 2010) and credit crunch hypotheses (Krishnamurthy, Nagel, and Orlov, 2013) imply larger haircuts, lower volumes, and higher repo rates when financial risk increases. Similarly, credit rationing and liquidity hoarding in times of crisis due to informational frictions (Allen, Carletti and Gale, 2009, Heider, Hoerova and Holthausen, 2015) could be so strong that financial institutions do not only stop lending in the unsecured market but also retreat from secured markets which increases repo rates.[13]

Excess liquidity. Dispersion across money market interest rates is negatively related to the Eurosystem liquidity provision.[14] This result suggests that central bank liquidity is associated with lower money market tensions. As for the interplay between money market rates and volumes as such and central bank liquidity, we do not find a significant relationship in our setting. However, Garcia-de-Andoain, Heider, Hoerova, and Manganelli (2016), focusing on the interbank unsecured market between 2008 and 2014, document that liquidity provision by the Eurosystem supported market functioning in two ways. During the Global Financial Crisis, when the unsecured interbank market came under stress, the Eurosystem "took over" the liquidity provision role of the private market as banks turned to the central bank to obtain liquidity. During the sovereign debt crisis in the euro area, banks once again increased their demand for central bank liquidity. In that period, the provision of central bank liquidity also stimulated the supply of liquidity in the private market, especially to banks located in stressed countries (Greece, Spain and Italy).

4.2 Money market activity since 2015

The second sub-period starting in January 2015 is characterised by the start of the PSPP and the introduction of the Securities Lending Facility as well as new Basel III regulations. In the regression specification we now also include the amount of the securities lent by the Eurosystem via its lending facility (see Table 3).

Financial market volatility (VSTOXX). Financial market volatility no longer positively co-moves with the dispersion index. We find, in fact, a (surprisingly) negative relation between dispersion in money market interest rates and VSTOXX. Such negative relation is also evident in Figure 5, in particular in the last part of the sample.

[13] Alternatively, other literature argues that financial institutions might reduce lending in the unsecured market and instead lend in the secured market if particular if repo transactions are cleared by CCPs (Mancini, Ranaldo and Wrampelmeyer, 2016, Boissel, Derrien, Ors and Thesmar, 2017).

[14] Using data for the 2004-2006 period, Linzert and Schmidt (2011) found that the spread between the EONIA rate and the ECB's MRO rate is linked to a trending liquidity deficit, with tight liquidity conditions exerting a significant upward pressure on the EONIA spread.

Excess liquidity. During 2015-2016, increasing excess liquidity, driven primarily by the asset purchases under the PSPP (see Figure 5), is associated with increasing money market dispersion. As for the repo rates, we observe that they declined below the ECB deposit rate facility from the second half of 2016 onwards (see Figure 1, Panel B). The deposit facility rate should in principle constitute a floor for all money market rates in the euro area because no financial institution should be willing to lend liquidity below that rate. One reason for this phenomenon in the environment of large excess liquidity is the segmentation between banks - who have access to the ECB deposit facility - and non-bank and non-euro area entities, who do not have access.[15] This segmentation between banks and non-banks implies that banks can take on liquidity from non-banks and pay a rate lower than what they earn by depositing this liquidity at the central bank, thus earning a spread. This phenomenon is also reflected in the €STR rate which is slightly below the DF rate (see Figure 1, Panel B), again owing to non-bank and non-euro-area participants in transactions underlying the €STR.

We also observe that repo rates (both GC and special) have been diverging since 2016. GC rates in Italy and Spain seem to remain effectively bounded by the deposit facility rate. In Germany and France, GC repo rates trade at significantly lower levels, suggesting that excess liquidity affects euro area countries differently. Finally, dispersion across special repo rates increased because more bonds became special and some of them traded sometimes 100 basis points below the country GC rate (Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2019). A plausible explanation is that some bonds became increasingly scarce in the repo market (i.e., there was an increase in specialness) because the Eurosystem was progressively buying these bonds without lending back them to the market via the Security Lending Facility.

Securities lending. If collateral scarcity is an important factor driving repo market activity after 2015, one might expect that more active securities lending programme may improve market functioning by increasing collateral availability. To investigate this channel, we exploit easing in the terms of the Securities Lending Facility in December 2016. Specifically, the Eurosystem adopted the so-called "cash-collateral" option whereby cash was now accepted as collateral in securities lending operations. Previously, other government bonds were needed as collateral to borrow under the Securities Lending Programme, implying that transactions occurred on a "cash neutral" basis and did not increase the supply of bonds in circulation. Figure 5 shows that the amount of government bonds in circulation dramatically increased after December 2016. The figure also suggests a change in the dispersion index trend pointing to a lower pressure on repo rates.

To capture this change, we split the sample before/after the December 2016 easing and investigate how it affected the regression coefficients. The results are reported in Table 4. We find that the coefficient associated with the Securities Lending Facility changes sign before and after easing. Before easing, the coefficient for the dispersion index is positive and statistically significant confirming that the security lending volumes did not help reducing dispersion across rates. Consistently, the coefficient for the rate spreads is negative, pointing to pressure on repo rates. After easing, the sign flips, suggesting that when Securities Lending is more active, dispersion across rates tends to decline. Quantitatively, an increase of EUR 1 billion of securities lent results in almost 0.13

[15] It should be noted that a large share of the liquidity injected by the Eurosystem through the PSPP went to the non-bank and non-euro area entities (as sellers of securities). These entities cannot hold central bank reserves with the central bank. Instead, they need to store this liquidity on an account held with a euro area bank.

bps of lower dispersion. These results suggest that the impact of easing the terms of the Securities Lending Facility was economically significant, given that the total amount of securities lent reached almost EUR 68 billion and that the average dispersion was 7.7 bps before the easing. Our results are also in line with Jank and Moench (2018) who document that the Eurosystem Securities Lending Programme was an effective way of counteracting the effects of scarcity on the repo market.[16]

End-of-month and end-of-quarter effects. Money market activity often exhibits special patterns at month and quarter ends. In our sample, we find larger and statistically significant coefficients for the quarter-end dummies. Moreover, when we compare these estimates with the pre-2015 period estimates (see Tables 2 and 3), we observe that the magnitude of quarter-end coefficients is larger and more quarter-end dummies are statistically significant. At quarter-ends, the money market rate dispersion increases by almost 25 bps, while the pre-2015 estimates point to an average increase of 5bps. Spreads decrease by 22 bps on average while volumes decline at quarter-ends.

A potential explanation for the end-of-quarter effects is the recent introduction of leverage regulation (see, e.g., Munyan, 2017, Kotidis and Van Horen, 2018, and Box A below). European banks have to report the leverage ratio at the end of the quarter inducing them to reduce their balance sheet exactly at this point in time.[17] The leverage ratio is an important part of the Basel III regulatory framework. Basel III proposed to limit the overall leverage of financial institutions. The ratio is defined as Tier 1 capital divided by a non-risk-weighted measure of a bank's on- and off balance sheet items. The minimum Basel III leverage ratio is 3 %. Additionally, there is a bank-specific add-on for the globally systemically important banks (G-SIBs). Since 2015, European banks have been obliged to publicly disclose their leverage ratio and its components. While the 3% leverage ratio will only become binding in the EU in June 2021, it's seen as de facto binding for banks given the public disclosure and given the fact that it will be binding in the near future.

As for month-ends, we do not find statistically significant effects. This would suggest that liquidity requirements – which are reported by banks at the end of the month – do not currently have a significant effect on money markets in the euro area. This may be due to the large Eurosystem balance sheet size, which ensures an ample supply of central bank reserves. Reserves held by banks count as high-quality liquid assets and help them satisfy their liquidity requirements.

Focusing on US money markets, Klee, Senyuz, Yoldas (2019) examine the effects of changing monetary and regulatory policy on key U.S. dollar funding rates. Interestingly, they also document that the new Basel III regulations affected rate dynamics on reporting days primarily through increased balance sheet costs of financial intermediaries at quarter-ends.

In the next subsection, we zoom in on the role of liquidity and leverage requirements in more detail.

[16] Other factors may have contributed to alleviating collateral scarcity post-2017, including an expansion of the set of securities eligible for the PSPP purchases in January 2017 and, according to anecdotal evidence, more active private securities lending towards the end of our sample period.

[17] Capital Requirements Regulation (CRR, Regulation (EU) No 575/2013), supplemented by a Delegated Regulation (Delegated Regulation (EU) 2015/62).

4.3 Impact of regulatory requirements

Liquidity requirements. In our time-series analysis in the previous section, we did not uncover significant month-end effects in money markets, suggesting that liquidity requirements – which are reported by banks at the end of the month – do not have a significant effect on money markets in our sample.

Prior literature examined the impact of the Liquidity Coverage Ratio (LCR) on bank behavior and the financial system more broadly. For example, using UK data, Banerjee and Mio (2018) estimated the causal effect of liquidity regulation on bank balance sheets, taking advantage of the heterogeneous implementation of tighter liquidity regulation by the Financial Services Authority in 2010. They find that banks adjusted the composition of both assets and liabilities, increasing the share of high quality liquid assets and non-financial deposits while reducing intra-financial loans and short-term wholesale funding. For the US, Roberts, Shachar, and Sarkar (2018) find that banks subject to the LCR create less liquidity per dollar of assets in the post-LCR period than banks not subject to the LCR, in part because LCR banks make fewer loans. However, they also find that LCR banks are more resilient, as they contribute less to fire-sale risk relative to non-LCR banks. Rezende, Styczynski and Vojtech (2020) estimate the effects of the LCR on bank demand for central bank reserves, namely on the tenders that banks submit in Term Deposit Facility operations. Banks subject to the LCR submit tenders more often and submit larger tenders than exempt banks when term deposits qualify for the LCR. Their results suggest that liquidity regulation affects bank demand in monetary policy operations.

In the euro area context, Hoerova, Mendicino, Nikolov, Schepens and Van den Heuvel (2018) examine costs and benefits of liquidity regulation. They provide empirical evidence on the benefits – stemming from smaller reliance on central bank liquidity in crisis times – as well as quantitative evaluation of the costs based on two state-of-the-art macro models with financial frictions. Kedan and Ventula Veghazy (2019) analyse the impact of the LCR on the demand for central bank reserves in the euro area. They exploit the cross-country heterogeneity in the regulatory treatment of reserves for LCR purposes prior to the announcement of a harmonised euro area standard as a quasi-natural experiment, finding evidence of LCR-induced demand for central bank reserves. Schmidt (2019) examines the effects of LCR introduction on collateral pledging behavior of euro area banks in their operations with the Eurosystem. The LCR recognizes only a subset of assets eligible as central bank collateral as liquid which offers banks an opportunity to improve their LCR by pledging less liquid collateral – ineligible for the LCR fulfilment - with the Eurosystem while obtaining central bank reserves which are recognized as highest-quality liquid assets for LCR purposes. Using the existence of national liquidity requirements to proxy for banks' incentives to exploit this differential treatment, she finds that banks without a preceding national liquidity requirement pledge more and lower quality collateral compared to banks with a preceding national liquidity requirement after the LCR introduction.

Leverage requirements. The leverage ratio (LR) is calculated based on the size of banks' balance sheets and money market borrowing affects bank balance sheet size. Specifically, both unsecured and secured borrowing expands a bank's balance sheet. For unsecured borrowing, this is straightforward: it adds a cash liability on the liabilities side and the same amount of cash on the asset side of the balance sheet. For secured borrowing, it's slightly more complicated due to the presence of collateral. When entering a repo agreement, the collateral that is posted by the borrower stays on the borrower's balance sheet, while the balance sheet is expanded with the amount borrowed. Note that, for the cash lender, nothing changes in terms of balance sheet size. The cash that was on its asset side is simply replaced by a cash receivable item.

As the bulk of money market transactions happen in the overnight (one-day maturity) market, this is the ideal place for a bank to adjust its balance sheet for a short period of time (i.e., at reporting days). To lower its leverage ratio requirement, a bank would have to reduce its borrowing in money markets, thus reducing its balance sheet size.

Our analysis in the previous subsection documents that at quarter-ends, interest rates decrease. This pattern would be consistent with reduced borrowing in money markets, whereby banks' demand for cash goes down. In addition, dispersion across money market rates increases at quarter-ends. Box A presents more detailed evidence on this mechanism, by combining supervisory data on bank leverage with detailed, trade level, money market data for 52 large euro area banks.

Box A – Impact of the leverage ratio on money market functioning: evidence from the Money Market Statistical Reporting data

This box summarizes the analysis in Hoerova and Schepens (2019), which provides evidence on the relation between leverage regulation and banks' behaviour in money markets. The paper combines supervisory balance sheet data from the Single Supervisory Mechanism (SSM) with trade-level money market data that is collected within the Money Market Statistical Reporting (MMSR) framework.

Data: The MMSR data set is a confidential proprietary data set available at the European Central Bank (ECB). It covers all daily borrowing and lending transactions undertaken by around 52 banks from 10 different euro area countries on the secured and unsecured segments of the money market. The banks in the MMSR report to their national central bank or the ECB the list of repo transactions, with information on the amount and the rate (fixed or floating) at which they borrow, the amount of collateral and the haircut applied to it, as well as ISIN-level information on the asset backing each individual transaction, such as the type of collateral and the country and location of the issuer, and information on the counterparty from which they borrow, such as the legal entity identifier (LEI) code in case it is a banking institutions, the sector and country of residence in case of other types of counterparties. All data is collected from 2016-Q3 onwards. Our sample stops in 2019-Q2.

The reporting banks in our sample mainly borrow and lend in the secured market: secured borrowing volumes represent 74% of total borrowing, while secured lending represents 96% of total lending.

We combine this detailed dataset with quarterly supervisory information on banks' leverage ratios, as reported in the COREP templates collected by the Single Supervisory Mechanism (SSM). We end up with a sample of 48 banks.

Empirical setup: Combing these datasets, we investigate the impact of leverage ratio regulation on bank borrowing in in money markets. As explained in the main text, banks might have an incentive to improve their leverage ratio at reporting dates (end of quarter) by reducing their borrowing in money markets. Especially banks that are closer to the regulatory threshold should be interested in doing so.[18]

Given that the leverage ratio has to be reported on a quarterly basis, we only take into account overnight trades[19] and trades with a maturity of up to one month. Reducing trade volumes for trades with longer maturities would imply long-term planning before the end-of-quarter. Additionally, the vast majority of trading in money markets is happening overnight. Overnight borrowing trade volumes constitute 81% of total borrowing in our sample. Trades up to one month cover an additional 12.9%.

Our main hypothesis is the following:

Hypothesis 1 Banks closer to the regulatory threshold reduce their overnight borrowing volumes more than others during the last days of a quarter.

We test this hypothesis by running the following regression:

$$Log(vol)_{b,t} = \alpha_{b,q} + \beta_1 D_t^{eoq} + \beta_2 D_t^{eoq} Dist_{b,q} + \beta_3 D_t^{eoy} + \beta_4 D_t^{eoy} Dist_{b,q} + \varepsilon_{b,t} \quad (1)$$

Where $Log(vol)_{b,t}$ is the logarithm of the volume borrowed by bank *b* at day *t* in the money market. Throughout the analysis below, we will be looking either at the total stock (all outstanding borrowing with a maturity below 1 month) or at total amount of overnight borrowing. D_t^{eoq} (D_t^{eoy}) is an end-of-quarter (end-of-year) dummy, which is equal to one at the last trading day of a quarter (year). $Dist_{b,q}$ is the difference between the leverage ratio of bank *b* in quarter *q* and the regulatory minimum. For example, if the leverage ratio of a bank is 4.5 %, and its regulatory minimum is 3%, then $Dist_{b,q}$ is equal to 1.5. $\alpha_{b,q}$ is a bank-quarter fixed effect.

We are mainly interested in the coefficient for the end-of-quarter dummy (β_1) and the coefficient for the interaction term between the end-of-quarter dummy and the distance measure (β_2). β_1 measures the change in volume borrowed at the end of the quarter for banks that have a leverage ratio exactly equal to the regulatory minimum ($Dist_{b,q}$ =0). The sum of β_1 and β_2 will give us the end-of-quarter change for a bank that is 1 percentage point away from the regulatory threshold.

Additionally, we also analyse the impact of this drop in overnight volumes during reporting days on rates and dispersion in money markets. Our dispersion measure is based on Duffie and Krishnamurthy (2016), described in the main text (see Section 3.1).

The observed drop in borrowing by low-leverage banks could suppress rates in the whole market, as it represents a drop in demand for cash borrowing. Similarly, these fluctuations at quarter-end could increase dispersion. We postulate the following 2 hypotheses:

[18] The regulatory minimum is 3% for non G-SIB banks, and 3% plus an extra buffer ranging between 0.5 and 1% for G-SIBs.

[19] An overnight trade for day T is defined as all O/N (overnight), S/N (spot-next) and T/N (tomorrow-next trades) with settlement date T. We choose to focus on settlement dates as these are the days that the trade enters the balance sheet. O/N, T/N and S/N are all overnight trades, but they differ in terms of distance between agreement and settlement date: O/N trades are agreed on business day T and the cash is made available at business day T. T/N trades are agreed on business day T and the cash is made available at business day T+1. T/N trades are agreed on business day T and the cash is made available at business day T+2.

Hypothesis 2 Money market rates will drop at the end of a quarter, due to the reduced cash demand by low-leverage banks.

Hypothesis 3 Dispersion will increase at the end of a quarter.

To test these hypotheses, we re-run specification (1), but now with either a daily, bank-level, volume-weighted borrowing rate or with a daily, bank-level dispersion index as dependent variable.

Empirical analysis: Table A.1 show the results of specification (1). In the first column, the dependent variable is the (log of) the total volume of outstanding secured and unsecured borrowing (up to 1 month) at the bank-day level. The negative coefficient of -0.137 for the end-of-quarter dummy implies that borrowing by a bank at the regulatory threshold is around 14% lower at the end of the quarter compared to the average daily borrowing by that same bank during that quarter. The positive coefficient of 0.047 for β_2 means that the impact of the end-of-quarter effect becomes less strong if the distance to the regulatory minimum increases (i.e. if banks are better capitalized).

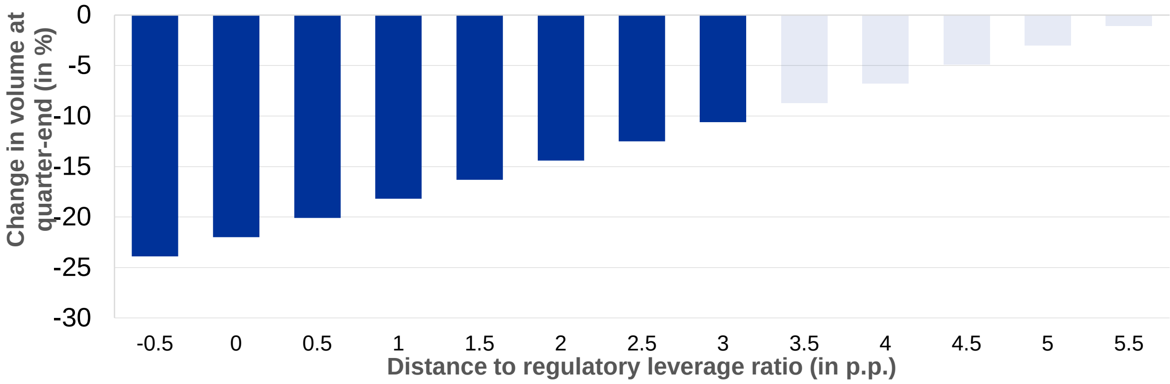
Table A1: Leverage regulation and bank borrowing in money markets - volumes

	Log(volume)			
	Secured + unsecured		Secured	Unsecured
	Up to 1 month	Overnight	Overnight	Overnight
VARIABLES	(1)	(2)	(3)	(4)
End of quarter	-0.137**	-0.222***	-0.243***	-0.068
	(0.055)	(0.072)	(0.081)	(0.068)
End of quarter x Distance LEV	0.047**	0.038*	0.067**	-0.025
	(0.020)	(0.023)	(0.030)	(0.026)
End of year	-0.303	-0.275	-0.338	-0.506**
	(0.241)	(0.186)	(0.215)	(0.222)
End of year x Distance LEV	-0.129	0.027	-0.063	0.165*
	(0.125)	(0.076)	(0.099)	(0.092)
Observations	34,000	31,078	26,630	25,886
Bank-quarter FE	Y	Y	Y	Y
Nr. of banks	48	48	45	46

Note: All regression are run at the bank-day level for the period 2016Q3 until 2019Q2. We focus on borrowing trades by banks in the money market. All types of counterparties are taken into account. In column 1, the dependent variable is the logarithm of the total of secured and unsecured borrowing volume with up to 1 month maturity that a bank has outstanding on its balance sheet. In columns 2, 3, and 4 the dependent variable is the logarithm of the total volume that is borrowed overnight, respectively in the secured+unsecured market, the secured market or the unsecured market. End of Quarter (End of Year) is a dummy equal to one at the last day of a quarter (year). Distance LEV is the difference between a bank's leverage ratio and the regulatory required minimum ratio. This is measured on a quarterly basis. All regressions include bank-quarter fixed effects. Robust standard errors (clustered at the bank-quarter level) are in parentheses. Bank money market data is taken from the MMSR database, bank leverage ratios are taken from bank's regulatory reports (COREP).

Column 2 of Table A.1 show the results for the subsample of secured and unsecured overnight trades, as overnight is by far the most popular maturity for money market trades. Results are similar to the results in Column 1: banks closer to the regulatory minimum reduce overnight borrowing at the end of the quarter, and this effect is dependent on the distance to the minimum: better capitalized banks reduce their borrowing volume less than others. Figure A.1 show the impact over a range of values for the distance to the regulatory minimum (x-axis). A bank that is 0.5 percentage points below its regulatory minimum reduces its end-of-quarter overnight borrowing by 24%. On the other hand, the impact is statistically not different from 0 for banks that are 2.5 percentage points or more above the regulatory minimum.

Figure A.1: Change in overnight money market borrowing (volumes) at reporting dates



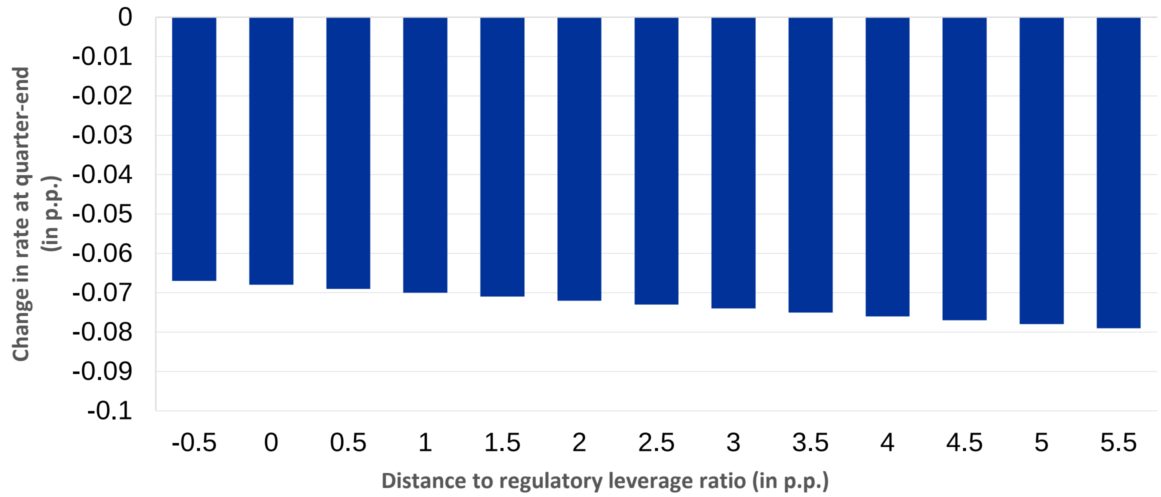
Notes: The x-axis shows the distance to the regulatory required leverage ratio. The y-axis shows the expected change (in percent) in overnight borrowing (secured + unsecured) at the end of the quarter. Estimates are based on the following regressions specification: $Log(vol)_{b,t} = \alpha_{b,q} + \boldsymbol{\beta_1} D_t^{eoq} + \boldsymbol{\beta_2} D_t^{eoq} \boldsymbol{Dist_{b,q}} + \beta_3 D_t^{eoy} + \beta_4 D_t^{eoy} Dist_{b,q} + \varepsilon_{b,t.}$ *where* D_t^{eoq} *(*D_t^{eoy}*) is an end-of-quarter (end-of-year) dummy, which is equal to one at the last trading day of a quarter (year).* $Dist_{b,q}$ *is the difference between the leverage ratio of bank b in quarter q and the regulatory minimum.* $\alpha_{b,q}$ *is a bank-quarter fixed effect. Log(vol) is the log of the total amount of outstanding unsecured and secured borrowing up to 1month, measured at the bank-day level. The sample period is 2016Q3-2019Q2. Each bar is calculated as* $\boldsymbol{\beta_1} + \boldsymbol{\beta_2}$ **** Dist.*** *A Blue bar implies that the coefficients are significant at the 5% level. Gray bars are insignificant at 5% level. Standard errors are calculated as follows:* $\sqrt{var(\beta_1) + Dist^2 * var(\beta_2) + 2 * Dist * cov(\beta_1, \beta_2)}$ *. Own calculations based on MMSR and COREP data for 48 banks.*

Columns 3 and 4 of Table A.1 separately look at the secured and the unsecured market. The results in these columns indicate that it's the overnight secured trades that are driving the previous findings, as we don't find any significant effect in overnight unsecured markets. Given that the vast majority of money market trading is done in overnight secured markets, it is not surprising that this market segment is driving the overall results.

Next, we analyze the impact of this drop in overnight volumes during reporting days on rates and dispersion in money markets. The observed drop in borrowing by low-leverage banks could suppress rates in the whole market, as it represents a drop in demand for cash borrowing. Similarly, these fluctuations at quarter-end could increase dispersion.

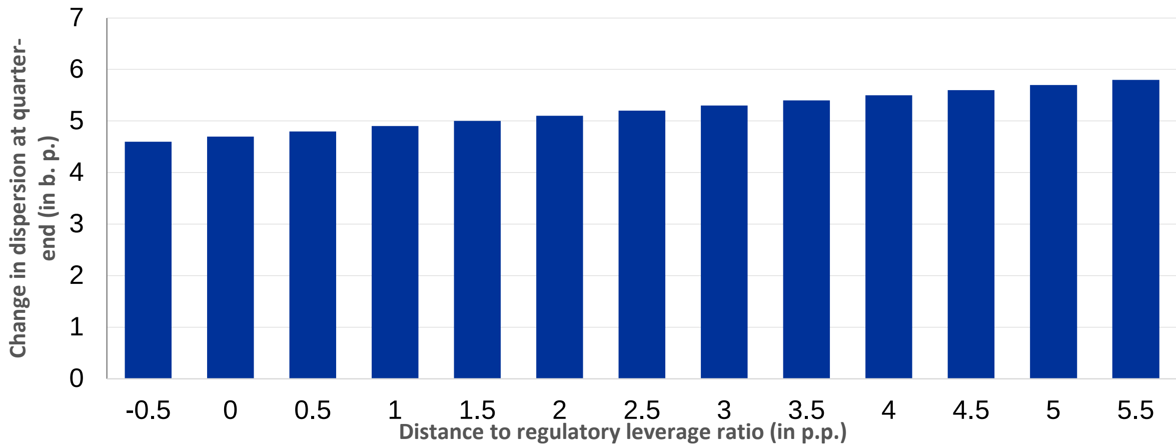
The results for rates and dispersion in the overnight market are depicted in Figures A.2 and A.3. Figure A.2 shows that there is a statistically significant (at the 5% level) reduction in rates at the end of the quarter of about 6.5 basis points. Importantly, this drop in rates market-wide. In other words, all banks experience lower borrowing costs at the end of a quarter. Similarly, Figure A.3 shows that dispersion goes up for all banks at the end of a quarter. Further analysis confirms that these effects in overnight markets are again driven by overnight secured trades.

Figure A.2 Change in overnight rates at reporting days



Notes: Own calculations based on MMSR and COREP data for 48 banks. The x-axis shows the distance to the regulatory required leverage ratio. The y-axis shows the expected change (in percentage points) in average (volume-weighted) overnight money market borrowing rates at the end of the quarter. Estimates are based on the following regressions specification: $Rate_{b,t} = \alpha_{b,q} + \boldsymbol{\beta_1} D_t^{eoq} + \boldsymbol{\beta_2} D_t^{eoq} \boldsymbol{Dist_{b,q}} + \beta_3 D_t^{eoy} + \beta_4 D_t^{eoy} Dist_{b,q} + \varepsilon_{b,t.}$ *where* D_t^{eoq} (D_t^{eoy}) *is an end-of-quarter (end-of-year) dummy, which is equal to one at the last trading day of a quarter (year).* $Dist_{b,q}$ *is the difference between the leverage ratio of bank b in quarter q and the regulatory minimum.* $\alpha_{b,q}$ *is a bank-quarter fixed effect. Rate is the volume-weighted interest rate paid on overnight borrowing trades (secured + unsecured), measured at the bank-day level. The sample period is 2016Q3-2019Q2. Each bar is calculated as* $\boldsymbol{\beta_1}$+$\boldsymbol{\beta_2}$**** Dist.*** *All results depicted are statistically significant at the 5% level. Standard errors are calculated as follows:* $\sqrt{var(\beta_1) + Dist^2 * var(\beta_2) + 2 * Dist * cov(\beta_1, \beta_2)}$

Figure A.3 Change in dispersion at reporting days



Notes: Own calculations based on MMSR and COREP data for 48 banks. The x-axis shows the distance to the regulatory required leverage ratio. The y-axis shows the expected change (in basis points) in dispersion of overnight money market borrowing rates at the end of the quarter. Estimates are based on the following regressions specification: $Dispersion_{b,t} = \alpha_{b,q} + \boldsymbol{\beta_1} D_t^{eoq} + \boldsymbol{\beta_2} D_t^{eoq} \boldsymbol{Dist_{b,q}} + \beta_3 D_t^{eoy} + \beta_4 D_t^{eoy} Dist_{b,q} + \varepsilon_{b,t.}$ *where* D_t^{eoq} (D_t^{eoy}) *is an end-of-quarter (end-of-year) dummy, which is equal to one at the last trading day of a quarter (year).* $Dist_{b,q}$ *is the difference between the leverage ratio of bank b in quarter q and the regulatory minimum.* $\alpha_{b,q}$ *is a bank-quarter fixed effect. Dispersion is the dispersion index for a bank's overnight borrowing (secured+unsecured), measured at the bank-day level. The sample period is 2016Q3-2019Q2. Each bar is calculated as* $\boldsymbol{\beta_1}$+$\boldsymbol{\beta_2}$**** Dist.*** *All results depicted are statistically significant at the 5% level. Standard errors are calculated as follows:* $\sqrt{var(\beta_1) + Dist^2 * var(\beta_2) + 2 * Dist * cov(\beta_1, \beta_2)}$.

Summary

This box shows that banks are likely window dressing their balance sheets at the end of the quarter by reducing repo borrowing. This reduction in cash demand leads to a market-wide lower cost of cash borrowing or, looking at it from the other side of the trade, a higher cost of obtaining collateral. Dispersion rates also increase market-wide.

These findings are particularly interesting in light of the upcoming regulatory switch to daily average reporting of the leverage ratio. Until now, European banks reported an end-of-quarter snapshot of the leverage ratio. From 2022 onwards, they will have to report an average over the quarter. This should mitigate the incentive to window-dress at the end of the quarter, but could at the same time reduce repo trading volumes throughout the quarter. Bassi, Behn, Constantini, and Grill (2019) show that, if banks were to maintain current leverage ratio levels, the switch would result in a median daily drop in outstanding repo volumes of around 15%. However, maintaining the same amount of outstanding repos would require accepting only a moderate reduction in leverage ratio levels (about 2-3 basis points) for the median bank. In other words, the ultimate impact on money market trading will depend on how flexible banks' leverage ratio targets are.

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5. The macroeconomic impact of money market conditions

In our analysis so far, we documented changes in money market conditions in the euro area since 2005. In what follows, we assess the macroeconomic impact of changing money market conditions, using a stylised general equilibrium model with secured and unsecured money markets, and a central bank, calibrated using euro area data.

We focus on two developments in particular. The first development is a declining importance of the unsecured money market (see Figure 2). The second development is changing value of banks' collateral assets. During the euro area sovereign debt crisis, haircuts on the government debt of some countries increased substantially, reaching 80% or more for some peripheral countries. The haircuts applied by the ECB on the same collateral were much lower and remained largely stable (see Table 5).

To analyse the macroeconomic impact of higher haircuts in the secured market and of declining activity in the unsecured market, we use a model developed in De Fiore, Hoerova and Uhlig (2019). The model features secured and unsecured money markets, which banks use to manage their liquidity needs, as well as a central bank (CB). A central feature of the model is that banks financing themselves through deposits face the risk of temporary deposit outflows, for instance, when depositors transfer their funds to other banks while paying for goods and services using their checking accounts (similar to Bianchi and Bigio (2017)). Moreover, some banks face a liquidity constraint: they cannot manage their deposit outflows by borrowing in the unsecured money market but, instead, they must resort to collateralised borrowing in the secured market or from the central bank, and/or hold precautionary buffers of reserves. We call banks without access to the unsecured money market "Unconnected", while the other banks are "Connected" and not subject to these liquidity constraints. In addition to these constraints, all banks face a leverage constraint (similar to

Gertler and Kiyotaki (2011)) that limits how much they can borrow. This constraint arises because depositors recognise that excessive leverage provides incentives for bankers to misbehave.

We calibrate the model to the pre-2008 euro area data and compare macroeconomic outcomes under three alternative central bank balance sheet policies: 1) maintaining a constant balance sheet; 2) standing ready to provide credit to banks at a fixed rate, against collateral in the form of government bonds, so that the size of the balance sheet is determined by banks' demand for central bank funding (akin to a fixed-rate full-allotment policy); and 3) conducting outright purchases of government bonds, with the central bank buying bonds at market price to achieve a certain inflation goal (akin to quantitative easing).

The interactions between bank leverage and liquidity constraints turn out to be key for determining macroeconomic outcomes as money market conditions change. In particular, tighter money market conditions force banks to either de-leverage (shrink their balance sheet to lower exposure to funding shocks) or to divert resources into unproductive but liquid assets (e.g., reserves) to self-insure against funding shocks. In both cases, lending capacity of banks is impaired which, in turn, triggers a decline in output.[20] The severity of the macroeconomic impact depends on whether it is the secured or the unsecured market that is under stress. We first examine in more detail an increase in secured market haircuts. We then assess the impact of reduced activity in the unsecured market.

5.1 What is the macroeconomic impact of an increase in secured market haircuts?

If haircuts in the private market increase, banks face tighter liquidity constraints. Unless the central bank intervenes, banks may have to de-leverage by reducing both their deposits and their lending, in turn triggering a fall in output. The left panel of Figure 7 compares the output effects (as % deviations from the calibrated pre-crisis steady state) of an increase in the secured market haircuts (from 0.03, or 3%, to 0.70, or 70%) under the three central bank balance sheet policies outlined above. Under the constant balance sheet policy, as haircuts increase, the collateral value of bonds in the secured market decreases. Reserves become increasingly scarce as Unconnected banks increase their demand but the central bank keeps its balance sheet constant. Unconnected banks become so severely liquidity-constrained that they de-leverage sharply, both by accepting fewer deposits and by reducing their lending to firms. Output declines significantly (for haircut levels above 25%). Under our benchmark calibration, steady-state output is 7% lower under 70% haircuts than it is under 3% haircuts.

The key to mitigating the reduction in lending and output is to expand the central bank balance sheet to prevent de-leveraging. This can be achieved both through collateralised refinancing operations, which allow Unconnected banks to top up their deposit funding with central bank funding, and through outright bond purchases, which replace bonds with low collateral value in the private market with reserves so that banks can self-insure against deposit outflows. Both policies reduce output

[20] We should note that, in our analysis, changes in money market conditions (like the increase in haircuts or the reduction in unsecured lending) are treated as exogenous parameters. This is not to deny that there likely were endogenous reasons for these developments, such as sovereign default fears or a general weakening of bank balance sheets. Our analysis is therefore silent on the optimality of various central bank policies and instead focuses on understanding the quantitative response of the banking system and the economy to these policies.

losses. The difference in output between a steady-state with 3% haircuts and one with 70% haircuts is just 0.6% under a policy of refinancing operations, and even lower – a mere 0.06% – under outright purchases. The reason why refinancing operations are somewhat less effective than outright purchases at mitigating output losses is that, under the former, banks must hold collateral to obtain central bank funding and this crowds out their lending to firms, though only marginally so.

5.2. What is the macroeconomic impact of reduced activity in the unsecured market?

Now consider a situation in which the secured market functions smoothly but fewer banks can borrow in the unsecured market. In this case, banks anticipate that they will need to rely on collateralised money market transactions and they increase their demand for liquid assets accordingly. As banks shift the composition of their assets away from lending, there is a decline in output.

How much does central bank balance sheet policy matter? The right panel of Figure 7 compares the output effects (as % deviations from the calibrated pre-crisis steady state) of an increase in the share of Unconnected banks in the economy under the three balance sheet policies outlined above. Outright purchases expand the central bank balance sheet and mitigate the scarcity of reserves. By contrast, the central bank balance sheet remains constant under both the constant balance sheet policy and under the refinancing operations, as there is no advantage in borrowing from the central bank as long as the secured market functions smoothly. The difference in output between a steady-state in which 0.58 of banks are Unconnected and one in which 0.95 of banks are Unconnected (average pre-2008 versus 2017 share of secured market turnover in total turnover) is around 1.5% under the constant balance sheet/refinancing operations and about 1% under outright purchases.

6. Conclusions

This Discussion Paper highlighted how the euro area money markets, both secured and unsecured, changed over the past years. It analysed the interactions between money market activity – measured by volumes, rates and the cross-sectional dispersion of rates – and other factors, in particular the central bank balance sheet size, the Securities Lending Programme, and the new Basel III regulations. It provided an assessment of how money market conditions affect the macro-economy through the lens of a general equilibrium model with secured and unsecured money markets, and a central bank providing collateralised funding to banks and purchasing assets outright.

Several take-aways emerge from our analysis. First, at the time of writing (our data end in 2019), frictions in the euro area money markets appeared to be at a low level. This implies that monetary policy measures were transmitted smoothly across money market rates. Looking back over the past 15 years, our analysis documented that money market conditions tend to worsen if financial stress increases, or if central bank asset purchases induce scarcity effects while the Securities Lending Programme is not sufficiently active. Going forward, money market developments should be monitored, as factors interacting with money market conditions may change. One factor in particular deserves attention: non-banks becoming important participants in money markets. Unlike banks, these participants may not have access to operations with the central bank. This has a bearing on the formation of some money market rates, like the €STR. Were the transmission across money market rates to worsen, with potentially widening dispersion driven by non-banks, a question may arise whether non-banks should have access to central bank operations.

Second, with regard to the impact of Basel III regulations, we documented that the leverage ratio regulation impacts money markets since 2015 at quarter-ends due to “window-dressing” effects, reducing volumes and rates, and raising money market rate dispersion. Liquidity requirements do not appear to affect money markets significantly, possibly due to the large Eurosystem balance sheet size, which ensures an ample supply of central bank liquidity, facilitating the fulfilment of liquidity ratios.

Third, an analysis of the macroeconomic impact of money market conditions shows that tighter money market conditions may force banks to divert resources into “unproductive” but liquid assets (e.g., central bank reserves) or to de-leverage. As a result, lending capacity of banks is impaired which triggers a decline in output. Results from a calibrated model suggest that a shift away from the unsecured money market transactions and towards more secured transactions implies a difference in output of about 1%, comparing pre- to post-crisis steady states. Well-functioning secured markets cushion the macroeconomic impact. If secured markets do not function smoothly, however, central bank balance sheet expansion is needed to mitigate output declines.

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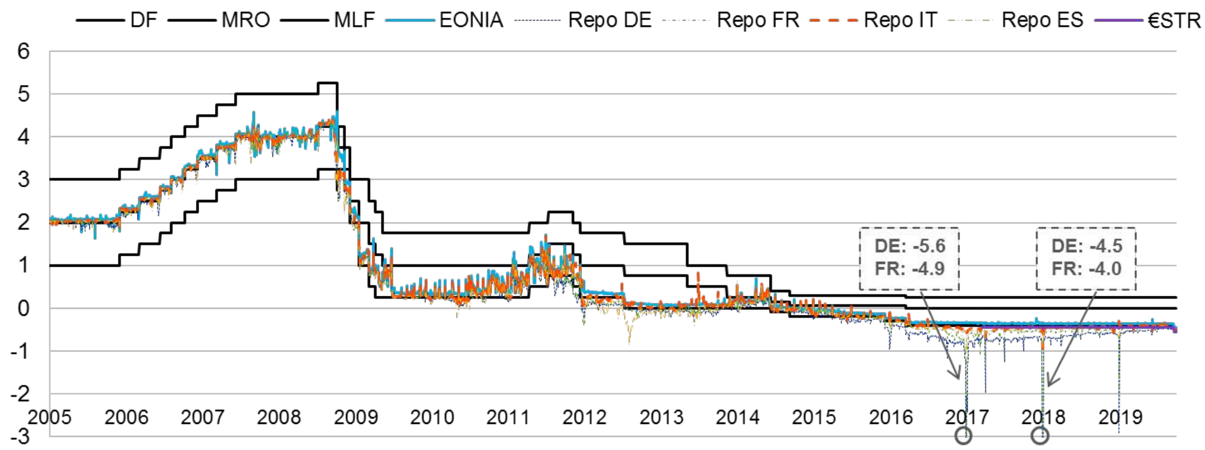
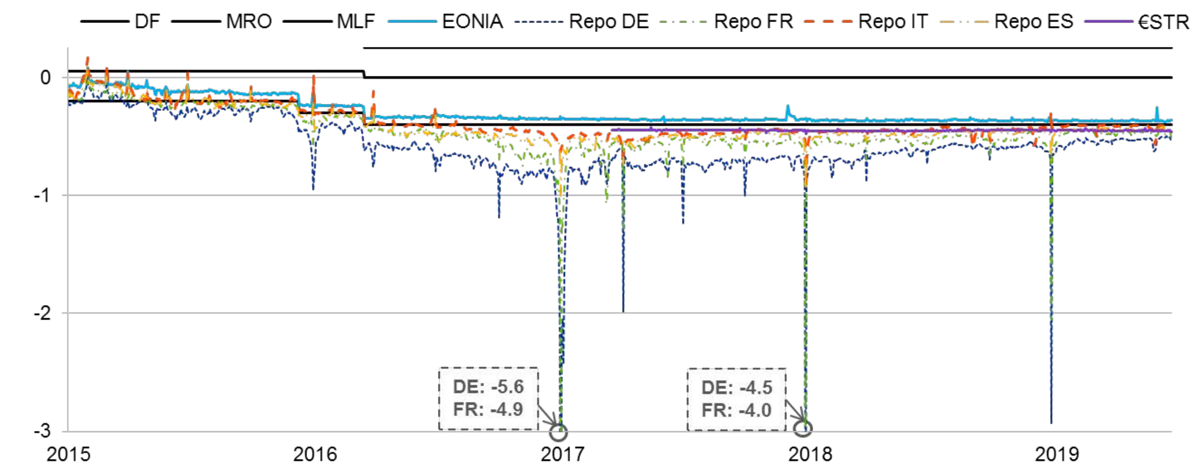
Figures

Figure 1, Panel A: Euro area money market rates and ECB policy rates, 2005-2019



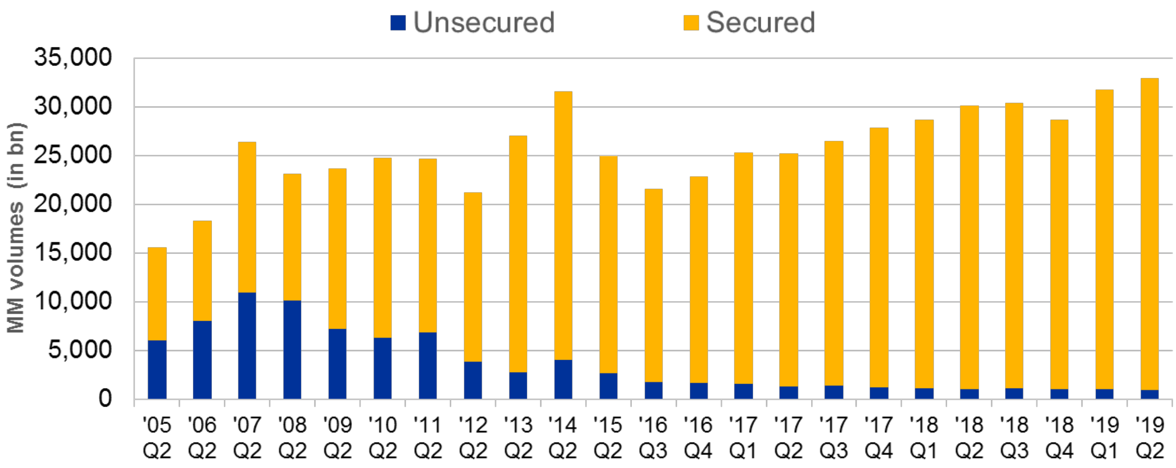
Note: Money market rates (unsecured rates, EONIA and €STR, and country-specific repo rates); ECB policy rates (DF, MRO, MLF), in percent, 2005-2019. Repo data include both general collateral and suitable specific collateral repo trades (the composite repo rate is volume-weighted). Source: SDW, BrokerTec and MTS.

Figure 1, Panel B: Euro area money market rates and ECB policy rates, zoom in on 2015-2019



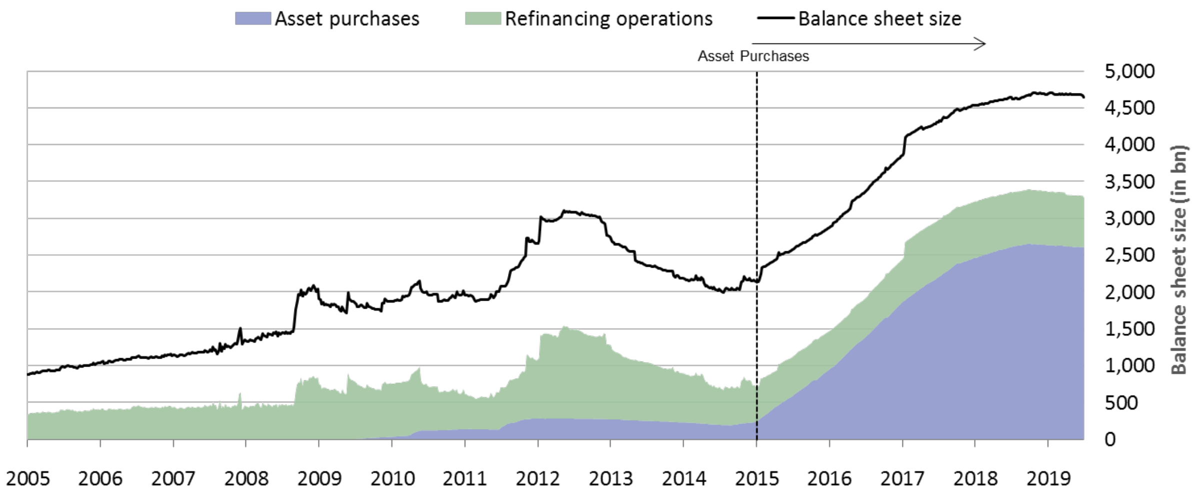
Note: Money market rates (unsecured rates, EONIA and €STR, and country-specific repo rates); ECB policy rates (DF, MRO, MLF), in percent, zoom in on 2015-2019. Repo data include both general collateral and suitable specific collateral repo trades (the composite repo rate is volume-weighted). Source: SDW, BrokerTec and MTS.

Figure 2: Turnover in unsecured and secured euro area interbank money markets



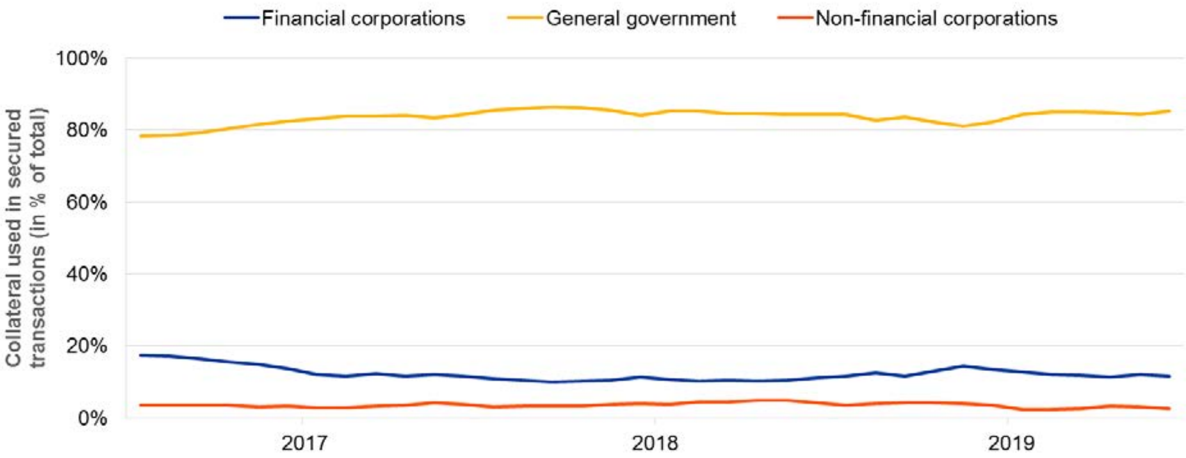
Notes: Cumulative quarterly turnover in the euro area unsecured and secured money market segments, in EUR billions. Source: Euro Area Money Market Survey (MMS) until Q2 2015, Money Market Statistical Reporting (MMSR) data thereafter (based on data for 38 banks that participated in both data collections; only transactions with deposit-taking institutions and CCPs are considered). Both borrowing and lending transaction of the reporting banks are included; and all collateral types and maturities are considered.

Figure 3: Eurosystem balance sheet



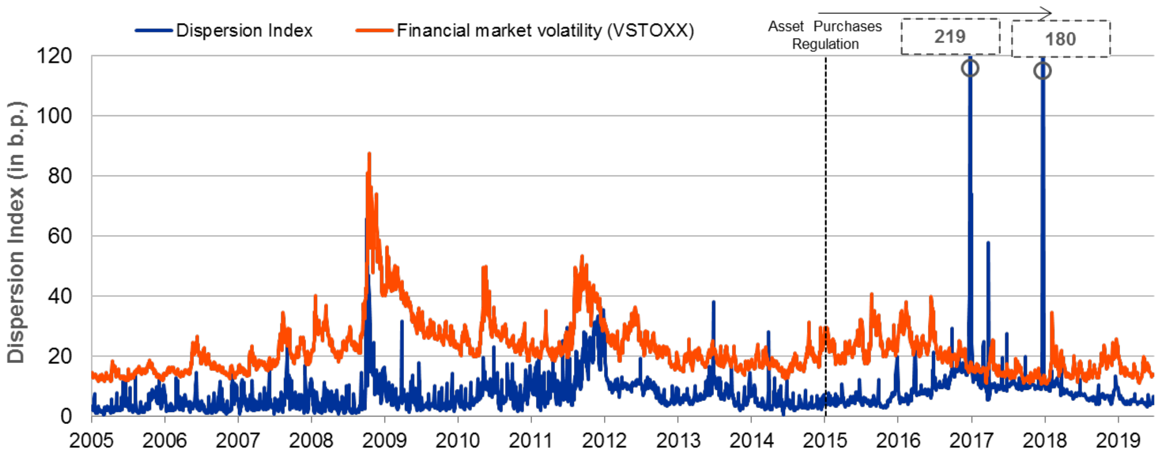
Note: Eurosystem balance sheet size, asset purchases and refinancing operations, in EUR billions, from January 2005 until September 2019. The vertical line indicates that the Public Sector Purchase Programme (PSPP) was introduced in 2015 (announced in January 2015 and launched in March 2015). Source: ECB.

Figure 4: Collateral used in secured transactions by issuer sector



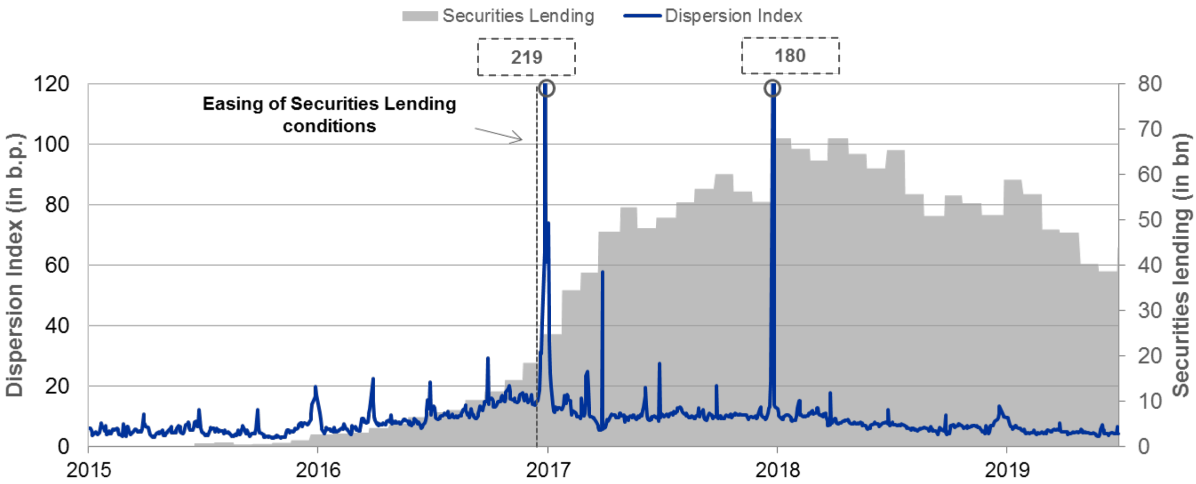
Note: Based on volumes of transactions in the Eurozone area. Source: The Euro Money Market Study (ECB, 2019).

Figure 5: Dispersion index for the euro area money market rates and VSTOXX



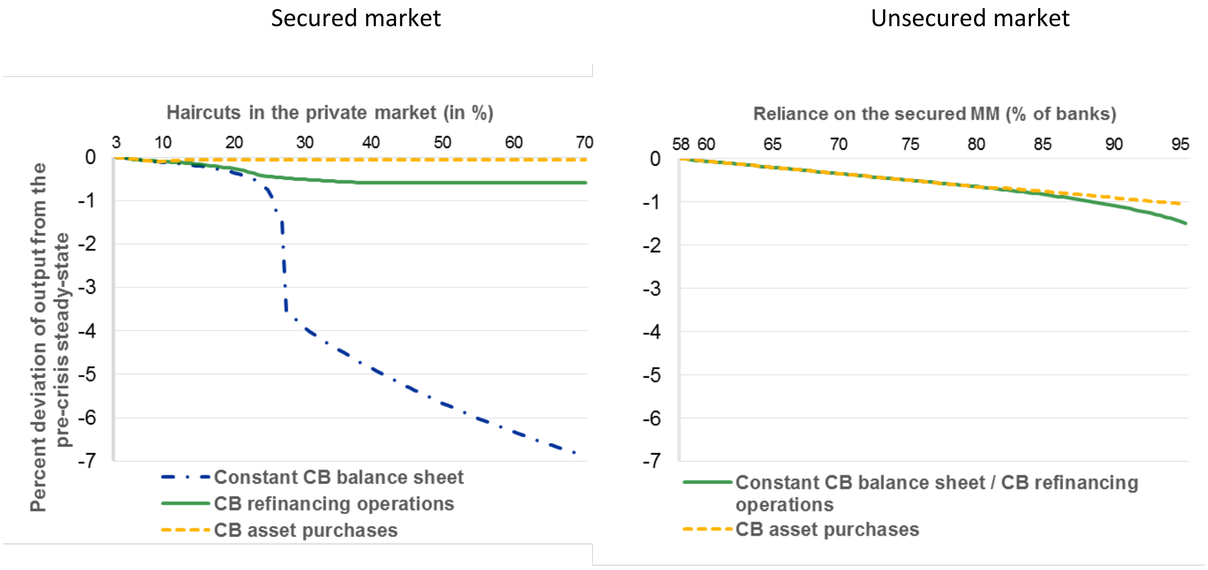
Note: Authors' calculations following Duffie and Krishnamurthy (2016). Index constructed using EONIA, DE, FR, IT, ES GC and special repo rates, volume-weighted.

Figure 6: Dispersion index for the euro area money market rates and Securities Lending



Note: Authors' calculations following Duffie and Krishnamurthy (2016). Index constructed using EONIA, DE, FR, IT, ES GC and special repo rates, volume-weighted.

Figure 7: Impact of changing money market conditions on output



Notes: Based on the calibrated model from De Fiore, Hoerova and Uhlig (2019).

Tables

Table 1: Data sources

Variable	Source	Unit	Description
Repo rates	BrokerTec/MTS	basis points	Volume-weighted rate for repo transactions
Repo volumes	BrokerTec/MTS	EUR billions	Traded volume
Dispersion Index	BrokerTec/MTS	basis points	Volume-weighted absolute deviation from mean rate
VSTOXX index	www.stoxx.com	percentage points	Volatility index
Excess liquidity	ECB	EUR billions	Current account and deposit facility holdings in excess of minimum requirements
Securities lending	ECB	EUR billions	Average book value of securities stock
DF rate	ECB	basis points	DF rate
MRO rate	ECB	basis points	MRO rate
Rate spread	BrokerTec/MTS and ECB	basis points	Repo rate spread from relevant policy rate
EONIA rate	ECB	basis points	Overnight unsecured bank-to-bank rate
EONIA volume	ECB	EUR billions	Overnight unsecured bank-to-bank volume

Table 2: Time-series regressions, Jan. 2005 – Dec. 2014 sample.

		Models, 2005-2014 sample	
Model	Dispersion Index	Rate spread	Log(volume)
VSTOXX	0.285***	-0.015	-0.001*
	(29.549)	(-0.468)	(-2.107)
Excess liquidity	-0.005*	-0.014	-0.000
	(-2.022)	(-1.637)	(-0.182)
D.Quarter end	5.026***	3.580	-0.015
	(5.377)	(1.126)	(-0.606)
D.Quarter end, t-1	0.591	-0.717	0.024
	(0.763)	(-0.272)	(1.153)
D.Quarter end, t-2	0.189	-0.359	0.032
	(0.244)	(-0.136)	(1.541)
D.Quarter end, t-3	-0.076	0.548	0.044*
	(-0.098)	(0.208)	(2.165)
D.Quarter end, t-4	0.380	0.178	-0.002
	(0.501)	(0.069)	(-0.083)
D.Quarter end, t+1	0.761	-1.166	0.044*
	(0.974)	(-0.439)	(2.151)
D.Month end	0.808	3.707*	-0.023
	(1.493)	(2.015)	(-1.586)
Constant	-0.203	6.719***	12.241***
	(-0.811)	(7.910)	(1852.362)
N	2544	2544	2544
R squared	0.280	0.013	0.086
D.Year-end	YES	YES	YES

Note: The table reports the results of a time-series regression of dispersion index, rate spread and volumes in log on the VSTOXX, Excess liquidity (in first-difference), end-of-year dummy, a series of quarter-end dummies and month-end dummy. The series of quarter-end dummies captures the change in dispersion, rate spreads and volumes up to four business days before the end-of-quarter day. The last dummy picks up the change of the first business day after the end-of-quarter.

Table 3: Time-series regressions, Jan. 2015 – Jun. 2019 sample

	Models, 2015-2019 sample		
Model	Dispersion Index	Rate spread	Log(volume)
VSTOXX	-0.257***	0.342***	-0.001
	(-3.815)	(4.564)	(-1.253)
Excess liquidity	0.006	-0.017	-0.001***
	(0.301)	(-0.832)	(-3.418)
Securities Lending	-0.029	-0.077***	0.004***
	(-1.809)	(-4.293)	(27.722)
D.Quarter end	25.808***	-22.629***	-0.058*
	(9.865)	(-7.781)	(-2.307)
D.Quarter end, t-1	-0.858	1.899	-0.028
	(-0.405)	(0.807)	(-1.381)
D.Quarter end, t-2	-3.380	4.606	-0.004
	(-1.587)	(1.945)	(-0.192)
D.Quarter end, t-3	-4.096	5.255*	-0.008
	(-1.937)	(2.235)	(-0.418)
D.Quarter end, t-4	1.522	-0.669	-0.033
	(0.733)	(-0.290)	(-1.679)
D.Quarter end, t+1	-1.393	0.982	0.011
	(-0.612)	(0.389)	(0.524)
D.Month end	0.680	0.513	0.012
	(0.435)	(0.295)	(0.791)
Constant	14.239***	-14.592***	12.260***
	(8.127)	(-7.491)	(733.441)
N	1037	1037	1037
R squared	0.308	0.327	0.665
D.Year-end	YES	YES	YES

Note: The table reports the results of a time-series regression of dispersion index, rate spread and volumes in log on the VSTOXX, Excess liquidity (in first-difference), Eurosystem Securities Lending, end-of-year dummy, a series of quarter-end dummies and month-end dummy. The series of quarter-end dummies captures the change in dispersion, rate spreads and volumes up to four business days before the end-of-quarter day. The last dummy picks up the change of the first business day after the end-of-quarter.

Table 4: Time-series regressions, sample split Jan. 2015 – Dec. 8, 2016 and Dec. 9, 2016 – Jun. 2019

					Models, 2015-2019 sample, before and after easing	
Model	Dispersion Index	Dispersion Index	Rate spread	Rate spread	Log(volume)	Log(volume)
Sample	before easing	after easing	before easing	after easing	before easing	after easing
VSTOXX	-0.049**	-0.136	0.077**	0.092	0.001	0.000
	(-2.625)	(-1.049)	(3.204)	(0.667)	(1.705)	(0.286)
Excess liquidity	-0.004	0.025	0.017	-0.051	-0.000	-0.001**
	(-0.581)	(0.974)	(1.780)	(-1.899)	(-1.514)	(-3.285)
Securities Lending	0.619***	-0.173***	-0.952***	0.130**	0.001	0.002***
	(38.305)	(-4.393)	(-45.636)	(3.080)	(0.998)	(5.268)
D.Quarter end	9.997***	35.130***	-0.705	-35.851***	-0.030	-0.080*
	(12.105)	(9.259)	(-0.661)	(-8.848)	(-0.939)	(-2.458)
D.Quarter end, t-1	3.272***	-2.741	-0.296	2.190	-0.007	-0.044
	(4.717)	(-0.906)	(-0.331)	(0.678)	(-0.251)	(-1.692)
D.Quarter end, t-2	2.736***	-6.641*	0.090	6.663*	-0.005	-0.004
	(3.957)	(-2.192)	(0.101)	(2.059)	(-0.176)	(-0.167)
D.Quarter end, t-3	1.803**	-7.121*	0.774	7.228*	-0.029	0.002
	(2.643)	(-2.363)	(0.880)	(2.246)	(-1.091)	(0.079)
D.Quarter end, t-4	1.878**	1.836	0.034	-1.922	-0.025	-0.044
	(2.765)	(0.622)	(0.039)	(-0.610)	(-0.959)	(-1.737)
D.Quarter end, t+1	3.684***	-5.410	-2.263*	4.206	0.005	0.018
	(5.299)	(-1.613)	(-2.522)	(1.174)	(0.171)	(0.613)
D.Month end	1.211*	0.260	1.298*	0.116	-0.011	0.027
	(2.479)	(0.114)	(2.059)	(0.047)	(-0.580)	(1.399)
Constant	5.511***	19.830***	-3.395***	-21.376***	12.219***	12.383***
	(10.780)	(6.800)	(-5.146)	(-6.864)	(621.841)	(497.318)
N	392	645	392	645	392	645
R squared	0.855	0.400	0.878	0.375	0.089	0.296
D.Year-end	YES	YES	YES	YES	YES	YES

Note: The table reports the results of a time-series regression of dispersion index, rate spread and volumes in log on the VSTOXX, Excess liquidity (in first-difference), Eurosystem Securities Lending, end-of-year dummy, a series of quarter-end dummies and month-end dummy. The series of quarter-end dummies captures the change in dispersion, rate spreads and volumes up to four business days before the end-of-quarter day. The last dummy picks up the change of the first business day after the end-of-quarter.

Table 5: ECB vs private haircuts on government bonds (in %)

	ECB		Private	
	CQS1-2	CQS3	Germany/France/NL	Portugal
2010	2.8	7.8	2.8	7.9
2013	2.7	8.2	3.4	80.0
2017	2.2	9.4	2.8	28.4

Notes: ECB haircuts: CQS1-2 refers to sovereign bonds with credit quality 1 and 2, corresponding to a rating from AAA to A-; CQS3 refers to bonds with credit quality 3, corresponding to a rating from BBB+ to BBB-. Private haircuts: the column "Germany/France/NL" refers to an average haircut on bonds from Germany, France, and the Netherlands. Sources: ECB and LCH Clearnet.

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