The Euro Interbank Repo Market*

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ABSTRACT

The search for a market design that ensures stable bank funding is at the top of regulators' policy agenda. This paper empirically shows that an important part of the European money market features this quality, namely the central counterparty (CCP)-based euro interbank repo market. Using a unique and comprehensive data set, we provide the first systematic study of this market and show that it functions well, even during crisis episodes. CCP-based repos secured with high-quality collateral even act as a shock absorber, in the sense that repo lending increases with risk, while spreads, maturities, and haircuts remain stable.

Keywords: Repurchase agreements, repo market, central counterparty, short-term debt, liquidity hoarding, financial crisis, unconventional monetary policy

JEL Codes: E43, E58, G01, G12, G21, G28

1. Introduction

Banks heavily rely on short-term funding. This exposes them to runs, rollover risk, and wider financial contagion, which can cause financial crises and/or necessitate the controversial support of governments and central banks. In the aftermath of the recent financial crisis, policy makers and regulators worldwide have initiated enormous efforts to reform financial markets, including the search for a market design that ensures stable bank funding. Is there a market for short-term funding that ensures that banks can satisfy their liquidity needs, even during severe crisis periods like the 2007–2009 financial crisis or the European sovereign debt crisis? If yes, what are the characteristics of this market? Can a well designed market encourage lending even when aggregate risk is large and overall funding conditions tighten?

This paper empirically shows that such a funding market exists, namely the central counterparty (CCP)-based euro interbank repo[1] market. Using a unique and comprehensive data set, we provide the first systematic study of this important funding market and show that it functions well, even during crisis episodes. When the CCP-based infrastructure is combined with high-quality collateral, the market even acts as a *shock absorber*, in the sense that repo lending *increases* with risk, while spreads, maturities, and haircuts remain stable. Our results indicate that banks trust the CCP-based repo market to be a safe venue to hoard liquidity.

Analyzing the euro interbank repo market is of first-order relevance for a number of reasons. First, the infrastructure of the euro interbank market is unique, unexplored, and largely different from U.S. repo markets. The majority of euro repo transactions are conducted in the interbank market. Thus, in contrast to the United States, most repo transactions are not part of the shadow banking system. Moreover, almost 60% of interbank repo transactions in the euro area are conducted anonymously via CCP-based electronic trading.[2] On the one hand, trading via a CCP may increase efficiency and reduce direct counterparty risk exposure to other banks. On the other hand, CCPs involve a larger concentration of credit and operational risks, moral hazard, incentive

[1]A repo is a collateralized loan based on a simultaneous sale and forward agreement to repurchase securities at the maturity date. There are two main types of repo transactions: bilateral and triparty. A bilateral repo is an agreement between two institutions, whereas a triparty repo involves a third party, usually a custodian bank, that acts as an agent for both the collateral taker and the collateral provider.

[2]Information about the relative importance of repos in the interbank vs. shadow banking market is based on Bakk-Simon et al. (2012). The shares for the different types of interbank repos are taken from the ECB money market studies (European Central Bank, 2012)

problems, and adverse selection due to asymmetric information. Consequently, it is a priori unclear how the euro interbank repo market reacts during crisis periods, given that the market structure can play a crucial role for the fragility of funding markets (Martin, Skeie, and von Thadden, 2014).

Second, a better understanding of repo activity and the factors contributing to market fragility is crucial for financial institutions' risk management and for repo market reform, which is at the top of regulators' policy agenda (Financial Stability Board, 2012). Our paper provides valuable insights for banks and regulators, not only in Europe but also in the United States, where total repo activity experienced a substantial decline during the recent financial crisis (Gorton and Metrick, 2012; Krishnamurthy, Nagel, and Orlov, 2014). Lehman Brothers' triparty repo funding with all types of collateral decreased dramatically in the days prior to its bankruptcy, accelerating its demise (Copeland, Martin, and Walker, 2014). While there has already been progress in reforming triparty repos, the risk of fire sales remains an open issue (Begalle et al., 2013). The European repo market infrastructure incorporates features that are currently proposed in the ongoing effort to reform the U.S. repo market (see, e.g., Federal Reserve Bank of New York, 2010; Payments Risk Committee, 2012) and thus our results can help assess the efficacy of different market designs.

Third, the behavior of repo markets during sovereign crises has not been investigated in the previous literature. Krishnamurthy, Nagel, and Orlov (2014) show that the reduction in U.S. repo funding during the financial crisis was mostly caused by a decrease in repos with private securities as collateral, whereas repos with U.S. Treasuries as collateral were relatively stable. During the European debt crisis, the risk of government bonds issued by a number of European countries (Greece, Ireland, Italy, Portugal, and Spain (GIIPS)) increased significantly compared with bonds of safer core countries (e.g., Germany), undermining their collateral properties. This increased risk and market segmentation may significantly impact repo markets, given that the majority of euro repos is collateralized by government bonds. More generally, repos may have been affected by the worsened funding conditions of European banks that were subject to sovereign-to-bank contagion, the threat of a euro zone-breakup, the corresponding redenomination risk, and uncertainty about the regulatory and institutional framework, e.g., related to the proposed European banking union.

Fourth, the euro repo market constitutes banks' main source of money market funding in Europe (European Central Bank, 2012). With an estimated outstanding volume of more than EUR 5.6 trillion (International Capital Market Association, 2012), the size of the European repo market is of similar magnitude compared with estimates for the United States that range from

USD 5.5 trillion (Copeland et al., 2012a) to USD 10 trillion (Gorton and Metrick, 2012). The interbank segment is crucial for an efficient allocation of liquidity and collateral among banks and broker-dealers, facilitating price discovery for funding liquidity.

Our data cover the vast majority of CCP-based repo market activity. We investigate general collateral (GC) repo transactions[3] performed on all three major anonymous electronic trading platforms, namely Eurex Repo, BrokerTec, and MTS. The data include repos collateralized with securities of varying degrees of riskiness, allowing us to assess how repo market activity depends on collateral quality. By investigating repo spreads, volumes, maturities, and haircuts, we cover all main channels of risk mitigation that banks may use. A funding market is resilient if none of these measures of market activity is adversely affected during crisis periods. If, in addition, repo volume actually increases in times of risk, the market acts as a shock absorber. Our sample period from January 2006 to February 2013 covers both a normal regime and crisis periods and thus allows us to analyze how repo market activity responded to financial stress, increased sovereign risk, and institutional as well as monetary policy changes. Thus, we are in a unique position to conduct a clean and in-depth analysis of the euro interbank repo market.

Overall, our results indicate that the CCP-based euro interbank repo market is resilient. In contrast to non-CCP-based parts of the euro repo market and repo markets in the United States, the aggregate volume of CCP-based repos did not decline during crisis periods, but it actually increased during our sample period. For instance, from 2008 to 2010, CCP-based euro repo volume increased by 14%, whereas the total volume of U.S. triparty repos and repos from money market mutual funds as well as security lenders declined by 40% (Copeland, Martin, and Walker, 2014) and 34% (Krishnamurthy, Nagel, and Orlov, 2014), respectively. Moreover, we do not find evidence for significant increases in risk premiums or a shortening of the average repo term during the recent financial crisis or the European debt crisis. Also the haircuts, which are set by the CCP in the European institutional setting, remained relatively stable during 2006 to 2013.

While we find evidence that the whole CCP-based repo market was resilient, there are also cross-sectional differences. On the one hand, repos with relatively riskier collateral, such as Italian government securities, exhibit weaker resilience. On the other hand, volume for repos secured by

[3]Repo transactions are typically used for financing purposes via GC repos or to obtain specific securities via special repos (specials). Thus, GC repos are mainly cash driven and the collateral can be any security from a predefined basket of securities, whereas special repos are security driven, that is, collateral is restricted to a single security. Specials are analyzed in Duffie (1996), Jordan and Jordan (1997), and Buraschi and Menini (2002), among others.

the safest securities (e.g., German government bonds) increases with risk, leaving repo rates and maturity essentially unaffected. In addition, we show that repo volume is negatively related to volume in the unsecured money market. These findings are consistent with various theoretical models, predicting that risk disincentivizes unsecured lending and prompts liquidity hoarding.

Our analysis shows that the key distinguishing characteristics that make CCP-based euro interbank repos *resilient* are the market design, including anonymous electronic trading through a CCP, and the reliance on fairly safe collateral. While it is a priori unclear whether a market with these characteristics is resilient, our findings are consistent with market participants perceiving the CCP-based euro interbank repo market as a safe and effective venue to hoard liquidity in times of stress. Trading via a CCP effectively reduces direct counterparty risk exposure to other banks and the exclusive use of fairly safe collateral protects the CCP. Importantly, we show that the repo market even acts as a *shock absorber* when the CCP-based infrastructure is combined with high-quality collateral.

Our paper contributes to at least four streams of the literature. First, we contribute to the growing body of empirical literature on repo market activity. Whereas most existing studies analyze U.S. repos and the U.S. subprime crisis (Gorton and Metrick, 2012; Krishnamurthy, Nagel, and Orlov, 2014; Copeland, Martin, and Walker, 2014), we conduct an in-depth analysis of the European market from 2006 to 2013, including the financial crisis as well as the European sovereign debt crisis.[4] We extend the previous literature on repo markets by analyzing all dimensions of repo market activity jointly and by conducting regression analysis to identify the main determinants of interbank repo rates, trading volume, and maturity. Given the link between the repo market and the central bank, we control for ECB policy and investigate its effects on the euro interbank repo market. No previous study has a comparable research design.

Second, we extend the literature on the recent financial crisis by showing that repo markets act as a shock absorber if they feature anonymous trading via a CCP, as well as high-quality collateral. By highlighting the crucial role of the repo market infrastructure, we provide empirical evidence for the theory of Martin, Skeie, and von Thadden (2014) who argue that the repo market structure can impact the vulnerability of borrowers to runs. Because CCPs have mostly been studied theoretically so far (see, e.g., Duffie and Zhu, 2011), we contribute to the debate about benefits

[4]European repos are also studied in Dunne, Fleming, and Zholos (2011); however, they conduct a microstructure analysis of repos traded on BrokerTec, focusing mainly on specials and on bidding behaviors at ECB auctions.

and drawbacks of CCPs by providing empirical evidence that a CCP-based market performed well during the recent financial crises.

Third, we provide empirical support to the theoretical literature on money markets and funding activity. We show that banks substitute unsecured lending with secured lending and rely on euro interbank repos as a means for liquidity hoarding in periods of financial stress and flight-to-quality. Our findings are consistent with the theoretical predictions that informational and inventory frictions (e.g., Stiglitz and Weiss, 1981; Poole, 1968), increases in aggregate risk, Knightian uncertainty and funding risk (Allen, Carletti, and Gale (2009), Caballero and Krishnamurthy (2008), Acharya and Skeie (2011)), and the anticipation of fire sales (Diamond and Rajan, 2011) prompt liquidity hoarding and a reduction in unsecured lending.

Fourth, we contribute to the literature analyzing the effect of (unconventional) central bank policy (e.g., European Central Bank, 2010; Freixas, Martin, and Skeie, 2011; Giannone et al., 2012) by highlighting the effects on the secured funding market. Our results show that repo rates decrease with ECB liquidity provision up to a saturation threshold of EUR 300 billion of excess liquidity,[5] which approximately corresponds to the total single-counted volume of secured and unsecured lending in the euro area (European Central Bank, 2012). Once central bank liquidity reaches this threshold, repo rates hit the bottom of the ECB's interest rate corridor and do no longer respond to additional liquidity provision, evoking a sort of "liquidity trap." Moreover, we find that central bank liquidity provision can be detrimental to secured interbank lending, in the sense that repo volume decreases with excess liquidity. This substitution effect between "private" and "public" liquidity suggests that accomodative central bank liquidity provision can reduce the demand for private funding, providing empirical support to the models by Bolton, Santos, and Scheinkman (2009) and Jurek and Stafford (2012).

2. The euro repo market

2.1. Institutional background

This section introduces the institutional setting of the euro interbank repo market. Figure 1 shows a schematic description of the euro repo market, including the different market segments as defined

[5]Consistent with the ECB definition (European Central Bank, 2002, 2010), we define excess liquidity as credit institutions' current account holdings at the ECB plus funds in the ECB deposit facility minus reserve requirements.

by the Financial Stability Board (2012). Our focus is the interbank segment of the repo market, that is, the part excluding all repos outside the banking sector, or with customers or intragroup trades. The majority of euro repo transactions are conducted in this segment (Bakk-Simon et al., 2012).

The euro repo market structure is different than that in the United States.[6] Contrary to the United States, where the dealers dominate the repo market, the euro interbank repo market is populated by a rich array of banks, including commercial, retail, and investment banks, as well as more specialized institutions (e.g., public banks, cooperatives, saving institutions, and national central banks).[7] All participants have access to the ECB's refinancing facilities, whereas U.S. dealers may not have access to such a liquidity backstop in times of crisis.

As shown in Figure 1, the euro interbank repo market can be divided into three parts: bilateral repo CCP-based, bilateral repo non-CCP-based, and triparty repo with market shares of 58%, 32%, and 10%, respectively (European Central Bank, 2012). In Europe, triparty repos are typically only used to manage non-government bonds and equity. Bilateral repos have a market share of 90% and therefore play an even larger role compared with the United States, where estimates for the corresponding number range from between 29% and 54% (Copeland et al., 2012a) to 72% (Gorton and Metrick, 2012).[8]

The most important difference to the U.S. repo market is that the majority of euro interbank repos are conducted via a CCP. Non-CCP-based repos typically involve less standard securities as collateral and more customized contract terms, whereas repos with government bonds and other relatively safe securities as collateral are predominantly CCP-based. The main advantage of trading via a CCP is that it essentially protects banks from losses in case of default of a counterparty. The triparty repo service providers, on the other hand, do not take responsibility for collateral

[6]Adrian et al. (2013) and Copeland et al. (2012b) provide a detailed explanation of the institutional setting of the U.S. repo market.

[7]Another important difference is that in Europe, repo transfers a legal title to collateral from the seller to the buyer by means of an outright sale. Under New York law (that predominantly applies for U.S. repos), transferring a title to collateral is more difficult. However, repo collateral securities (as derivatives) are exempt from automatic stay (i.e., there is no obligation of a temporary hold when a firm files for bankruptcy by U.S. Bankruptcy Code).

[8]Although less concentrated than in the United States, where only the Bank of New York Mellon and JP Morgan act as triparty agent, the main triparty agents in Europe are Clearstream, Euroclear, Bank of New York Mellon, JP Morgan, and SIS, which together perform around 75% of the repo business (European Central Bank, 2012).

liquidation.[9]

[Include Figure 1 about here]

Figure 2 shows the double-counted borrowing volume of euro interbank repos according to the ECB money market studies. Since 2002, total interbank repo volume exhibits an increasing trend and declined only in 2008 and 2012, corresponding to the peaks of the financial crisis and the European sovereign debt crisis. These declines in volume are mostly due to decreases in non-CCP-based bilateral repos. This is consistent with the run hypothesis of Gorton and Metrick (2012) and the credit crunch hypothesis of Krishnamurthy, Nagel, and Orlov (2014) for bilateral repos with risky, non-standard collateral in the United States. The volume of euro triparty repos also declined by more than 15% in 2008 and 2012.

CCP-based repos exhibit the strongest increase in volume over time. The ECB money market study only distinguishes CCP-based and non-CCP-based bilateral repos since 2009. However, we can reconstruct the CCP-based repo volume since 2006 by summing the volume in our data sets (sum of trading volume on the Eurex Repo platform and volume of repos with German, French, and Italian government securities traded on BrokerTec and MTS[10]). CCP-based repo volume is actually flat in 2008, whereas the total volume of bilateral repos contracted. In 2012, the decrease of non-CCP-based bilateral repos is much stronger than for the CCP-based counterpart.

Note that the average daily trading volume in our data is larger than the CCP-based volume reported by the 172 banks, participating in the ECB's money market survey. Thus, our data allow us to comprehensively investigate the CCP-based repo market. The next subsection provides more information about the CCP-based trading platforms.

[9]For instance, at Eurex, the market is structured in a way that a bank does not learn about the default of a counterparty. A participant can only be affected by the default if the CCP has to draw on the clearing fund. This occurs after position closeout of the participant in default, liquidation of collateral of the participant in default, exhaustion of the clearing fund contribution of the participant in default, and after Eurex Clearing runs out of reserves. The CCP's layers of protection against the default of a counterparty are discussed in detail on the website of Eurex Clearing: `www.eurexclearing.com/clearing-en/risk-management/lines-of-defense/`. LCH.Clearnet has a similar water fall procedure in case of default of a clearing member. Other benefits offered by CCPs include the reduction of risk exposure, multilateral netting, rigorous and harmonized risk management, operational efficiencies from the netting of payments and deliveries, and the potential for enhancing market transparency. Moreover, CCPs facilitate balance sheet netting, which reduces banks' risk-weighted assets.

[10]BrokerTec and MTS publish three daily euro repo indexes comprising RFR Germany, RFR France, and RFR Italy that are calculated from trades executed on either of the two electronic platforms. The value-weighted interest rate and the total trading volume for each index can be downloaded from `www.repofundsrate.com`. Similar indexes have been introduced for Eurex Repo in April 2013. However, we actually have access to all trades executed on Eurex Repo and thus we use the raw data rather than the STOXX GC Pooling indexes. We discuss our data sets in more detail in Section 3.

[Include Figure 2 about here]

2.2. CCP-based interbank repo market

There are three main electronic trading platforms constituting the CCP-based euro interbank repo market, namely Eurex Repo, BrokerTec, and MTS. Established in 2001, Eurex Repo GmbH is the leading electronic trading platform for euro GC repos. It runs a transparent electronic order book with binding quotes that are displayed per term/collateral combination, including volume. More than 115 international participants from 12 countries trade anonymously relying on Eurex Clearing AG as CCP for each repo transaction and on Clearstream as settlement organization.[11] All participants and the CCP are regulated, and there are various safeguards in place to protect the market in times of stress.[12]

We study the GCP ECB basket and the GCP ECB EXTended basket, which are the most traded forms of GC repos, reaching an average daily trading volume of 30 billion in 2012 without double counting of lending and borrowing. Thus, GC Pooling repos constitute the vast majority of repo volume (more than 85%) traded on the Eurex platform. The GCP ECB basket consists of those securities admitted for collateralization of open market operations by the ECB that have been rated as at least upper medium grade (i.e., A−/A3), subject to a number of further restrictions. Thus, Eurex repo eligibility requirements are more stringent than those of the ECB, reducing the maximum number of eligible securities from almost 45,000 to less than 10,000 for the ECB basket. For instance, Italian and Spanish government bonds are currently excluded.[13] Repos collateralized by the broad and safe GCP ECB basket are regarded as a benchmark in the euro repo market and thus also serve as a benchmark for our analysis.

[11] Once two banks agree to trade on Eurex Repo platform, Eurex Repo transmits trading data to Eurex Clearing (who becomes the counterparty), and it sends a confirmation to Eurex Repo and clearing reports to involved banks. Eurex Clearing transmits settlement information to Clearstream that runs an eligibility check, evaluation, and allocation of securities in its Collateral Management System. Finally, securities are settled in the respective settlement accounts.

[12] Participants have to meet a number of criteria to be eligible for clearing membership. For instance, participants need to be subject to a financial market supervisory authority in their country of domicile, meet minimum capital requirements, contribute to the clearing fund, and fulfill regular stress tests. The CCP is regulated by the German Federal Financial Supervisory Authority (BaFin) and fully complies with the recommendations from the Committee on Payment and Settlement Systems (CPSS) and the Technical Committee of the International Organization of Securities Organization (IOSCO). It is owned by Deutsche Boerse Group, which is a publicly traded company.

[13] More precisely, the location of the bond issuance is restricted to Austria, Belgium, France, Germany, Slovenia, the Netherlands, and international Eurobonds (XS ISINs), whereas the bond issuer must be established in the European Economic Area (EEA) or in one of the non-EEA G10 countries (i.e., the United States, Canada, Japan, or Switzerland). Thus, issuers resident in Spain, Greece, Ireland, Italy, and Portugal are not eligible.

Introduced after the extension of the Eurosystem's collateral framework in the fall of 2008, the GCP ECB EXTended basket refers to a set of eligible assets closer to the ECB definition (i.e., less strict than that of the GCP ECB basket). For instance, Italian and Spanish government bonds are eligible, but those of Greece and Portugal are not.[14] This translates into broader coverage of around 25,000 ECB-eligible securities.

For the GCP ECB basket, Eurex Repo enables the reuse of received collateral for refinancing within the framework of ECB/Bundesbank open market operations and for further transactions in the Eurex Repo GCP system, whereas the ECB EXTended basket can only be reused for the latter. A unique feature of GCP is the pooling of transactions, i.e., collateral can be used in further trades without actually opening new positions. Only at settlement, which occurs three times a day, is it determined whether a participant is net borrower or net lender and cash or collateral is delivered. The lender can reuse collateral for further transactions, but the securities must remain in the GCP system, and the borrower has the right to substitute a security with another security included in the GCP basket at any time.

BrokerTec is an electronic trading platform for various fixed income products operated by ICAP plc. Similar to Eurex Repo, BrokerTec is an anonymous electronic trading platform and clients need to be member of the CCP (LCH.Clearnet) to trade repos. MTS Repo is an anonymous electronic repo trading platform, which is part of MTS Group and majority owned by the London Stock Exchange. Repos traded on MTS predominantly rely on Italian government securities as collateral. In contrast to Eurex Repo, the majority of trading volume on BrokerTec and MTS is in repos with specific collateral (about 80%). We study repos with German, French, and Italian government securities as collateral, which constitute more than 80% of the trading volume on the platforms operated by BrokerTec and MTS.

The repo infrastructure most similar to the CCP-based euro interbank repo market in the United States is the GCF repo market, which is an anonymous brokered interdealer market for Fedwire-eligible securities run by the Fixed Income Clearing Corporation (FICC) that nets the settlement obligations. There are some important differences though. GCF trades rely on the intermediation of several dealers and brokers who settle GCF trades on their own books. This means that the GCF is framed within a triparty repo scheme, whereas in Europe the CCPs

[14] Compared with the GCP ECB, the location of issuance is extended to Finland, Ireland, Italy, Luxembourg, Malta, and Spain. However, ineligibility still holds for securities for which the location of issuance or issuers' residence is Greece and Portugal.

operate on the basis of a bilateral contract design. More precisely, the CCP, e.g., Eurex Clearing for repos traded on the Eurex Repo platform, performs intradaily delivery management and risk assessment of all positions held by a participant. At the time of settlement, Eurex Clearing sends the settlement instructions to Clearstream that, in turn, provides reports on the settled cash and collateral. Thus, the contract design applied by the CCP virtually insulates euro repos from several (possibly systemic) threats inherent to the U.S. triparty repo mechanism, including the collapse of clearing agent banks, the adverse consequences for repo sellers if the clearing bank exercises its right to withdraw the intraday credit extensions, and the lack of orderly distribution of losses when the repo borrower defaults and collateral value is insufficient (e.g., Eichner, 2012).[15] Another important difference between CCP-based repos and GCF is that in the latter, the reuse of collateral is not possible by design. In the following section we investigate how CCP-based euro interbank repo activity evolved from 2006 to 2013.

3. Empirical analysis

3.1. The data

To conduct a comprehensive study of the euro interbank repo market, we collect data on all main risk mitigation channels a lender may use. To this end, we investigate repo volume, maturity, haircuts, and rates for different collateral baskets.

Our main data set includes all GCP transactions that were executed on the Eurex Repo trading platform between January 2006 and February 2013. This allows us to accurately analyze CCP-based repos, which due to data limitations has so far not been possible. Overall, we have 109,473 trades, with a total cumulative volume of more than EUR 33 trillion. For each trade, the data include the time of the trade, the purchase and repurchase dates, the collateral basket, the trade volume, and the repo rate. Using these raw intraday data, we construct weekly time series with average daily trading volume and volume-weighted repo rates for the two GCP baskets. As is common in the literature (see, e.g., Thornton, 2006), we exclude repos that mature on days at the

[15] In overnight U.S. triparty repo transactions, an unwind of the trade occurs every morning, when the triparty clearing bank accounts for a repurchase of the financial securities by the initial repo seller and the provision of the sales proceeds to the initial repo buyer (or lender). Until the repo agreement is rewound in the afternoon, the triparty clearing bank is lending to the repo seller between this 8:00–8:30 a.m. unwind and the rewind after 3:30 p.m.

end of maintenance period or at the end of the quarter.[16]

Our main focus are short-term repos (o/n, t/n, and s/n) for the ECB basket, because more than 80% of GCP repos have a term of one day,[17] and the ECB basket existed during the whole sample, whereas the GCP EXTended basket was introduced only in November 2008. The short-term segment of the repo market is by far the most active, as it represents an immediate source of liquidity for banks. Consequently, it is important for the functioning of the overall secured interbank market and for monetary policy operations.

We also collect data from the two other main CCP-based electronic trading platforms for euro interbank repos, BrokerTec and MTS. We rely on data from RepoFunds Rate (RFR), that publishes indexes with repo rates and volumes from trades executed on these platforms. There exist three indexes, RFR Germany, RFR France, and RFR Italy, which are based on repo trades collateralized by government bonds issued by the respective country. While Eurex GCP repos are unambiguously used for funding purposes, the trades underlying the RFR indexes also contain specials and may thus be driven by the demand for specific securities rather than the demand for funding. Moreover, because the RFR data only contain daily index values, it is not possible to control for end-of-maintenance period effects. Lastly, information about the haircuts and average maturity of repos on the BrokerTec and the MTS platforms is not available, so we focus our analysis of RFR repos on volume and spreads.

For the sake of brevity, the remaining part of this section focuses on the results based on Eurex Repo data. Repo rates and volumes for BrokerTec and MTS repos, which we report in the Internet Appendix, exhibit overall similar patterns. We use the RFR data to compare repos collateralized with securities of varying degrees of riskiness in Section 4.3.

3.2. Repo rates and volume

Figures 3 and 4 show the evolution of short-term GCP ECB basket repo rates and total GCP volume over time. Our sample includes periods of rising and falling interest rates (tight and easy monetary stances). Until the fall of 2008, repo rates increase in line with the ECB's interest rate

[16]In Europe, compliance with reserve requirements is a hard constraint as reserve requirements cannot be rolled over into the next maintenance period. Thus, liquidity shortages can lead to sharp temporary interest rate peaks on those days. Using weekly instead of daily data reduces noise because of possible day of the week effects.

[17]In a repo contract, the main standard terms are Overnight (o/n), TomorrowNext (t/n), and SpotNext (s/n). Less frequently, the repo maturity extends from one week up to 12 months (1W, 2W, 3W, 1M, 2M, 3M, 6M, 9M, and 12M). A repo contract with flexible terms is when the dates for the front and term legs are determined freely.

policy, followed by a fast decline in repo rates to 0.25% in the summer of 2009. Most interesting is the position of repo rates in relation to the interest rate corridor,[18] as it compares repo rates to ECB rates. We refer to the corridor position as the relative repo spread or simply as the repo spread,

$$S_t^{1d} = \frac{r_t^{GCP,1d} - r_t^{ECB,deposit}}{r_t^{ECB,lending} - r_t^{ECB,deposit}},$$

where $r_t^{GCP,1d}$ is the short-term GCP repo rate. A repo spread of zero indicates that repo rates are equal to the ECB deposit rate ($r_t^{ECB,deposit}$), whereas a repo spread of one occurs if repo rates equal the rate for borrowing from the ECB lending facility ($r_t^{ECB,lending}$). If the repo rate is equal to the main refinancing operations (MRO) rate, the repo spread is 0.5.

The repo spread is shown in Panel B of Figure 3; Table 1 provides descriptive statistics. Prior to the shift from variable-rate auctions (VRA) to fixed-rate full allotment (FRFA) in the ECB refinancing operations on October 15, 2008, repo rates remained close to the middle of the corridor and were in general slightly larger than the MRO rate.[19] This pattern changed dramatically after the ECB moved to the FRFA regime and repo rates dropped toward the floor of the corridor. In the period following the 3-year longer-term refinancing operations (LTROs), repo rates hovered near the ECB deposit rate.[20] When the ECB lowered the deposit rate from 25 bps to zero in July 2012, the repo rate immediately declined in lockstep. To the extent that repo spreads proxy for risk premiums, Figure 3 does not show evidence for increasing risk premiums during crisis episodes.

Repo volume in Figure 4 exhibits a positive trend over our sample period. Average daily trading volume increased from less than EUR 10 billion in 2006 to more than EUR 45 billion in mid-August 2011. This increase arises both from internal growth, that is, larger volume per active bank, and from external growth, that is, more participating banks. The volume growth is remarkable given that banks experienced severe problems with obtaining funding during the financial crisis, both in the unsecured market (see, e.g., Hördahl and King, 2008; Brunetti, di Filippo, and Harris, 2011) and in the U.S. repo market. After the 3-year LTRO in December 2011, euro repo volume declined

[18] The interest rate corridor is determined by the rate at which banks can borrow overnight from the Eurosystem using the ECB's lending facility (the top of the corridor) and the rate at which banks can deposit liquidity overnight using the ECB's deposit facility (the bottom of the corridor). The interest rate on the main refinancing operations of the ECB, that provides the bulk of liquidity to the banking system, is typically at the center of the corridor.

[19] The slightly positive gap between the repo rate and the MRO rate is essentially due to the prevalence of the ECB tightening stance from 2006 to mid-October 2008. Moreover, ECB auction rates are typically set above the MRO rate in the VRA mechanism.

[20] The ECB introduced LTROs to extend the standard (bi)weekly maturity of its MROs up to three, six, 12, and 36 months.

again to approximately EUR 25 billion. The majority of transactions relies on securities from the ECB basket as collateral, with the ECB EXTended basket gaining a share of up to 40% of the daily transaction volume in 2012. We denote the total o/n, t/n, and s/n repo trading volume by VOL_t^{1d} and $VOL_t^{ext,1d}$ for the GCP ECB basket and for the ECB EXTended basket at time t, respectively.

[Include Figures 3 and 4 and Table 1 about here]

3.3. Maturity and term spread

The repos traded on the Eurex repo platform are not exclusively short-term repos, but the maturity actually extends up to one year. Figure 5 shows the volume-weighted average term. After the introduction of FRFA refinancing operations, the average term increases from 2.8 to 4.3 days. This increase is in contrast to the shortening of maturity in the United States (Gorton, Metrick, and Xei, 2012). The fraction of traded repo volume in o/n, t/n, and s/n tenors slightly decreased from 86.6% between 2007 and October 2008 to 81.7% after the introduction of FRFA operations. Overall, we neither observe a reduction of the average term during the financial crisis nor during the European debt crisis, suggesting that repo traders did not reduce risk via this channel.

[Include Figure 5 about here]

To further corroborate this result, we analyze the risk premium for longer term repos. Figure 6 shows the repo term spreads between long-term (one month or one year, $r_t^{GCP,LT}$) and short-term repo rates,

$$TS_t = r_t^{GCP,LT} - r_t^{GCP,1d}.$$

We compute the one-month term spread using the one-month repo rate, which is the volume-weighted average of all GCP repos with a maturity longer than one week and up to one month.[21] The one-year term spread is constructed similarly. The term spread appears to track the ECB monetary policy path closely. It becomes small or even negative in response to the ECB's accommodative monetary policy from October 2008 on, suggesting that repo traders did not increase term premiums significantly during the crisis.

[21] Because such longer-term repos are not traded during a few weeks, particularly in the beginning of our sample, we fill missing values with fitted values from a regression of one-month GCP rates on one-month Eurepo rates from the European Banking Federation that we obtained from Datastream.

[Include Figure 6 about here]

3.4. Haircuts and composition of collateral baskets

The fourth component to understand the repo market is the haircut applied to the collateral in the repo transactions. In the Eurex GC Pooling market, the haircut rules applied by the CCP are derived from those used by the ECB for its refinancing operations, that is, if a security is accepted in a GCP basket, it receives the same haircut as the one the ECB applies to its refinancing operations. Thus, haircuts in the CCP-based euro interbank repo market are not subject to negotiation. They are exogenous to repo traders and the lender cannot increase haircuts as a means of risk mitigation.

To construct a measure for the haircuts applied by the CCP, we obtained the list of eligible securities from the ECB website[22] and used this list as the basis for our haircut calculations. The only difference between haircuts at the ECB and at Eurex is that fewer securities are eligible for the latter, because Eurex excludes certain riskier securities from its GCP baskets. For instance, asset-backed securities were never eligible as collateral within the GCP baskets. For each week in our sample, we apply Eurex eligibility rules[23] and determine the number of accepted securities that is shown in Panel A of Figure 7. The number of accepted securities is largest at the ECB, reaching almost 45,000 securities in 2010. A subset of less than 10,000 securities — out of those eligible at the ECB — is part of the GCP ECB basket. The ECB EXTended basket lies in between the two.

The equally weighted average haircut for each basket is shown in Panel B of Figure 7, highlighting that the GCP ECB basket consists of the safest securities from the full ECB portfolio. The average haircut for the GCP ECB basket is only around 4%, whereas all assets eligible at the ECB have an average haircut of up to 9%.

[Include Figure 7 about here]

Next, we compute representative haircuts at the ECB and at Eurex from the point of view of a bank that holds a large portfolio of assets and uses them as collateral for its funding needs. To this end, we first reconstruct the universe of outstanding assets for each week, including all

[22] The list of assets eligible for ECB refinancing operations is available on a daily basis since April 8, 2010, from the ECB website `www.ecb.europa.eu/paym/coll/assets/html/list.en.html`.

[23] Because the ECB's list of eligible assets does not include the ratings of individual securities, we use the Fitch sovereign rating corresponding to the issuer's country of residence when applying Eurex eligibility rules.

asset categories that were eligible at the ECB at least during part of our sample period. Then, for each week, we apply the ECB's haircut rules that were prevailing at that time to all securities in the asset universe. A security that is not accepted as collateral receives a haircut of 100%. We weight the haircuts of each security by the total outstanding volume of the corresponding security type[24] to obtain weekly time series of volume-weighted average haircuts for the ECB refinancing operations. We repeat this procedure for the GCP ECB basket and for the GCP ECB EXTended basket. See the Internet Appendix for a more detailed description on how we construct our haircut measures.

Figure 8 shows the volume-weighted average haircuts over time. Only four main movements are discernible. First, in October 2008 haircuts decreased, because the ECB largely expanded the list of eligible securities for refinancing at the ECB to alleviate funding strains during the crisis. Second, in the beginning of 2011, some of these crisis measures expired, reducing the list of eligible securities at the ECB and thus increasing haircuts. For instance, debt instruments denominated in currencies other than the euro and subordinated debt instruments were no longer eligible as collateral. Third, at the beginning of 2012, the ECB responded to the escalation of the European debt crisis by expanding the list of eligible assets again, loosening the requirements for debt instruments issued by credit institutions and lowering the rating threshold for certain asset-backed securities. Fourth, in January 2012 haircuts for the GCP ECB basket increased because Italian securities became ineligible (the haircuts for the GCP ECB Extended basket and at the ECB were not affected).

Overall, haircuts remain relatively stable. However, the differences in collateral requirements at Eurex GCP and at the ECB may influence repo market activity. We investigate the potential role of this difference as a state variable in Section 4.1.

[Include Figure 8 about here]

3.5. Volatility and illiquidty

In addition to the risk mitigation channels discussed above, the financial crisis may have affected the quality of the repo market; that is, volatility and illiquidity as proxies for market quality

[24]We consider the following security types: central government securities, regional government securities, uncovered bank bonds, covered bank bonds, corporate bonds, asset-backed securities, and other marketable assets. The data on outstanding eligible assets for each of these types are available on the ECB website: `www.ecb.europa.eu/paym/coll/html/index.en.html`.

(O'Hara and Ye, 2011) might have increased. The realized volatility of repo rates and the bid-ask spread implied by Roll's (1984) measure are shown in Figure 9 for each week in our sample.[25] Both volatility and illiquidity tend to be higher in distressed market conditions, but fluctuate within a fairly narrow range, suggesting that market quality for the CCP-based euro interbank repo market was not impaired. The market appears to be very liquid and exhibits low volatility even when compared with notoriously liquid markets. For instance, Mancini, Ranaldo, and Wrampelmeyer (2013) document that volatility of EUR/USD spot exchange rate returns was on average 8.91% on an annual basis during 2007–2009. Even for classic safe haven assets, such as U.S. Treasuries, the average daily volatility was 10.2% over our sample period.[26]

[Include Figure 9 about here]

4. What drives repo market activity?

In the CCP-based repo market, repo traders choose rates, volume, and term for different types of collateral. To address the question of what drives these variables, we first introduce the state variables for repo market activity, and perform a comprehensive regression analysis for Eurex GCP ECB basket repos. Then, we extend our regression analysis to other collateral baskets, i.e., the GCP ECB EXTended basket and repos traded on BrokertTec and MTS with German, French, and Italian government securities as collateral. Lastly, we provide various extensions and robustness checks.

4.1. Determinants of repo market activity

Although no comprehensive model for repo market activity exists, some potential determinants of repo spreads, volume, and maturity can be derived from previous research. We group these state variables into three categories, namely, risk, conditions in secured money markets, and central bank policy. We discuss each in turn.

[25] We obtain similar results when using the intraday range instead of realized volatility as a measure of price dispersion and the illiquidity measures of Amihud (2002) and Corwin and Schultz (2012) instead of Roll (1984). These results are collected in the Internet Appendix.

[26] We compute Treasury volatility based on a 20-day rolling window of nominal rates for constant maturity 10-year Treasuries that we downloaded from the FED website (`www.federalreserve.gov/releases/h15/data.htm`).

4.1.1 Risk

The literature suggests various mechanisms that relate risk to money market rates, volume, and maturity, but it is a priori unclear how the interbank repo market is affected. Depending on market participants' confidence in the functioning of the repo market in times of crises, three scenarios are possible: repo market activity is negatively affected by risk, unaffected by risk, or positively impacted by risk. Credit rationing and liquidity hoarding in times of crises may arise due to informational frictions (e.g., Stiglitz and Weiss, 1981), inventory risk (e.g., Poole, 1968), aggregate risk (i.e., a decrease of total interbank liquidity as in Allen, Carletti, and Gale (2009)), Knightian uncertainty (Caballero and Krishnamurthy, 2008), roll-over risk (e.g., Acharya and Skeie, 2011), and liquidity hoarding to profit from potential fire sales (Diamond and Rajan, 2011). Although the mechanisms behind these theoretical models differ, they all predict that liquidity hoarding is so strong that banks do not only stop lending in the unsecured market (Heider, Hoerova, and Holthausen, 2009) but also retreat from secured lending or increase repo rates. Empirical evidence that repo markets can be vulnerable to risk is presented in Gorton and Metrick (2012). They document a "run on repo" in the United States, i.e., larger haircuts and higher repo rates when risk in the financial system is high.

In the second scenario, that is, repo market activity is unaffected by risk, the repo market is resilient. A weaker form of liquidity hoarding implies that banks reduce lending in the unsecured market, but continue to lend in the secured market, which is safer. Under this resilience hypothesis, risk is neither positively related to the repo spread, nor is there a negative relation to repo volume and repo maturity.

In the third scenario, that is, repo lending increases with risk, the market actually acts as a shock absorber. This can happen if repo lending represents a form of liquidity hoarding and replaces riskier funding sources in times of risk. Thus, risk positively impacts repo volume and a decrease in unsecured trading volume is associated with an increase in repo volume, while repo spreads and maturity are unaffected.

To analyze how the CCP-based repo market reacted in times of crisis, we relate the repo spread, volume, and maturity to broad measures of risk in financial markets. More precisely, we use the composite indicator of systemic stress (CISS) (Hollo, Kremer, and Lo Duca, 2012) as the main proxy for stress in the financial system. This risk indicator, that we denote by $CISS$ and plot in

Panel A of Figure 10, aggregates 15 individual financial stress measures for the European market and thus summarizes the level of market frictions and strains into a single statistic. We show in Section 4.4.1 that our results are robust to the choice of risk measure.

To investigate how the volume in the unsecured market and in the interbank repo market interact, we include Eonia volume (called VOL^{Eonia} and plotted in Panel B of Figure 10) as a state variable for repo volume. The euro overnight index average (Eonia) is the reference rate for unsecured overnight lending in the euro area. We downloaded the total volume of unsecured overnight lending transactions from the ECB website. Panel B of Figure 10 shows that overnight unsecured lending declined significantly from 2008 to 2013. According to the ECB's money market studies, the drop in longer-term unsecured lending during the same period was even larger because of the additional counterparty risk.

[Include Figure 10 about here]

4.1.2 Conditions in secured money markets

The relative riskiness of collateral accepted in the private and public markets can affect repo market activity. In a FRFA regime, the ECB supplies unlimited funding and banks can freely choose between private and public funding sources based on their relative attractiveness, in particular given that the favorable terms and broad usage of the ECB refinancing operations (800 banks participated in the second 3-year LTRO) have probably diminished stigma effects associated with borrowing from the central bank. If the number of securities accepted at the ECB is increased relative to that in the private market, traders have a larger incentive to use the former as funding source; that is, a reduction of haircuts promoted by the "lender of last resort" can disincentivize private secured lending (Bolton, Santos, and Scheinkman, 2009; Jurek and Stafford, 2012). Similarly, if Eurex excludes the riskiest securities from its basket, this is likely to reduce spreads and volume, simply because less securities can be used as collateral, but the remaining basket is safer.

Using the haircut measure explained above, we compute the relative riskiness of eligible collateral by the ratio of volume-weighted average haircuts applied at the ECB for its refinancing operations and at Eurex for the GCP ECB basket:

$$HCR = \frac{\text{Avg. HC at ECB}}{\text{Avg. HC at Eurex}}.$$

Because Eurex accepts fewer securities than does the ECB, HCR is always between zero and one, with one indicating that the haircuts at the ECB and at Eurex are identical. A low value of the haircut ratio implies that fewer securities are accepted at Eurex (i.e., excluded risky securities receive a haircut of 100%), making the collateral safer relative to the ECB's collateral portfolio. HCR is plotted in Panel C of Figure 10. Descriptive statistics for all state variables are provided in Table 1.

4.1.3 Central bank policy

Central bank policy is a main driver of interest rates in general and repo market activity in particular (see, e.g., Ellingsen and Söderström, 2001). The two main ways in which ECB policy can affect repo spreads, volumes, and maturities are the steering of expectations about future target rates and the liquidity policy. Monetary policy expectations affect short-term repos mostly indirectly, for example, via banks' rebalancing of their funding structures. The ECB announces interest rate changes in advance, so the benchmark policy rate is known for o/n, t/n, and s/n repos. However, a change in policy rate is likely to affect the term spread, potentially triggering changes in the average maturity and the volume of short-term repos.

During the crisis, the ECB applied various measures that extended its role in providing bank financing, all of which potentially impact interbank lending (e.g., Giannone et al., 2012). In particular, the amount of central bank liquidity in the financial system can affect money market functioning. For instance, a large supply of central bank liquidity is likely to lower interest rates and alleviate funding strains in money markets.

In line with, for instance, Gürkaynak, Sack, and Swanson (2007), we use futures prices on short-term interest rates as market-based measures of monetary policy expectations. We compute the difference between one-month futures contracts on Eonia minus the current Eonia. This variable, which we call EMC and plot in Panel D of Figure 10, measures the difference between the market's expected policy rate and the current rate and thus captures the predictable path of the repo spread due to monetary policy expectations.[27]

Consistent with the European Central Bank (2002, 2010), we define excess liquidity (denoted

[27] Our results remain unchanged if we instead use the difference between the Eonia rate one month in the future and today's Eonia rate, which captures the hypothetical case in which traders could forecast interest rates perfectly. The results with these "perfectly correct expectations" are reported in the Internet Appendix.

by EL) as credit institutions' current account holdings at the ECB plus funds in the ECB deposit facility minus reserve requirements.[28] Panel E of Figure 10 shows how EL changed over time. When this variable is above zero, the liquidity supplied by the ECB via its refinancing operations is larger than the reserve requirement, indicating a liquidity surplus in the financial system. To understand which levels of EL can be considered as high, Figure 11 shows scatter plots of EL and the repo spread as well as the repo volume. Panel A indicates that if EL is larger than EUR 300 billion, repo rates are very close to the ECB deposit rate, whereas there is a larger spread between the repo rate and the ECB deposit rate as well as more variability if excess liquidity is smaller than this empirical threshold. Similarly, detrended GCP volume appears to be smaller when EL is above the threshold of EUR 300 billion, whereas no pattern is visible below this level. Thus, to indicate high levels of excess liquidity, we define a dummy variable that equals one if EL is larger than EUR 300 billion. In the regression analysis in Section 4.2, the dummy variable interacts with excess liquidity and repo volumes, and it is called $DUM^{EL>300}$. Note that the empirical threshold of EUR 300 billion approximately corresponds to the total single-counted volume of secured and unsecured lending in the euro area according to the ECB's latest money market study (European Central Bank, 2012). Thus, we deem EL to be high if it exceeds private money market funding.

[Include Figure 11 about here]

4.2. Regression analysis for the GCP ECB basket

In this section, we identify the main drivers of repo market activity by running least-squares regressions with heteroskedasticity and autocorrelation-consistent (HAC) standard errors. As discussed above, the switch from VRA to a FRFA format for the ECB refinancing operations has potentially strong effects on the repo market. The switch to FRFA operations on October 15, 2008, qualifies as a regime shift for the euro banking system from a traditional liquidity deficit to a liquidity surplus. To account for this structural change, we perform all our analyses over two separate periods.

The discussion in Section 4.1 implies relations in levels between repo market activity and the state variables. For instance, the shock absorber hypothesis implies that higher levels of risk are associated with larger repo volume, and essentially unchanged repo spreads and maturities. Similarly, a high level of excess liquidity can disincentivize repo activity. Thus, we focus our

[28]We downloaded data on daily liquidity conditions from the ECB website `www.ecb.int/stats/monetary/res/html/index.en.html`.

analyses on the levels of repo market activity and the state variables. In the Internet Appendix, we show that our conclusions remain intact if we work with first differences.

We regress repo spreads, volumes, and average terms on past values of the state variables introduced above. The advantage of this procedure is that we eliminate endogeneity issues, because values of the state variables at any point in time are not influenced by future repo market variables that have not been yet realized.[29]

Equations (1) to (3) show our regression specifications for short-term repo spreads, repo volume, and average term, respectively. For each dependent variable, we include potential state variables in line with economic arguments as discussed in Section 4.1. In addition to the state variables, all equations contain lagged spreads, volumes, and average terms as additional controls and to account for interactions among the dependent variables. We include a time trend in the volume equation to allow for linear growth of repo trading volume.[30]

$$\begin{aligned} S_t^{1d} &= \beta_0 + \beta_1 S_{t-1}^{1d} + \beta_2 VOL_{t-1}^{1d} + \beta_3 AVGTERM_{t-1} \\ &\quad + \beta_4 CISS_{t-1} + \beta_5 HCR_{t-1} + \beta_6 VOL_{t-1}^{1d} DUM_{t-1}^{EL>300} \\ &\quad + \beta_7 EL_{t-1} + \beta_8 EL_{t-1} DUM_{t-1}^{EL>300} + \beta_9 EMC_{t-1} + \varepsilon_t \end{aligned} \tag{1}$$

$$\begin{aligned} VOL_t^{1d} &= \gamma_0 + \gamma_1 t + \gamma_2 VOL_{t-1}^{1d} + \gamma_3 S_{t-1}^{1d} + \gamma_4 AVGTERM_{t-1} \\ &\quad + \gamma_5 CISS_{t-1} + \gamma_6 VOL_{t-1}^{Eonia} + \gamma_7 HCR_{t-1} \\ &\quad + \gamma_8 EL_{t-1} + \gamma_9 EL_{t-1} DUM_{t-1}^{EL>300} + \gamma_{10} EMC_{t-1} + \nu_t \end{aligned} \tag{2}$$

$$\begin{aligned} AVGTERM_t &= \delta_0 + \delta_1 AVGTERM_{t-1} + \delta_2 S_{t-1}^{1d} + \delta_3 VOL_{t-1}^{1d} \\ &\quad + \delta_4 CISS_{t-1} + \delta_5 HCR_{t-1} \\ &\quad + \delta_6 EL_{t-1} + \delta_7 EL_{t-1} DUM_{t-1}^{EL>300} + \delta_8 EMC_{t-1} + \eta_t \end{aligned} \tag{3}$$

Not all variables in Equations (1) to (3) are available in both subsamples. In particular, the interaction terms measuring the effect of volume and EL for large values of EL do not apply in the first subsample, because EL is always smaller than the EUR 300 billion threshold prior to the

[29]The disadvantage of this procedure is that past values of the state variables may have a lesser impact on the current repo spread, volume, and average term than contemporaneous values. Thus, if anything, regression results below could be considered to be conservative.

[30]Additional results in the Internet Appendix show that our conclusions do not change when we estimate a vector autoregressive model including the repo spread, repo volume, and the average term as endogenous variables and the full set of lagged state variables as exogenous explanatory variables. Similarly, the additional inclusion of a quadratic trend to allow for nonlinear trends does not alter our conclusions.

ECB's switch to FRFA refinancing operations. Moreover, HCR is essentially constant prior to October 15, 2008, so we include it only in the regressions for the second subsample.

Standard tests confirm the stationarity of the regression residuals ε_t, ν_t, and η_t. This suggests that the structural break on October 15, 2008, is well captured by the three regression models in levels, estimated separately for the two subsamples. Estimation results are presented in Table 2. Columns 2 to 4 show the results for the period prior to the ECB's introduction of FRFA operations, whereas columns 5 to 7 show results for the sample after mid-October 2008.

In line with the shock absorber hypothesis, risk is positively related to repo volume, while there is no significant positive effect of risk on repo spreads or a negative effect on the average term. Magnitudes are economically important. An increase in the CISS by 0.176, that is, a one-standard deviation increase in systemic risk, induces an increase in daily repo trading volume of EUR 1.25 billion in the FRFA period. The negative impact of Eonia volume on repo volume is consistent with a migration from unsecured to the secured interbank lending market. In the FRFA regime a decrease of Eonia volume by 10 billion is followed by an increase of short-term repo volume by almost one billion. This is the substitution effect from overnight unsecured lending alone and thus constitutes a lower bound for the possible substitution effect. The magnitude is likely to be even larger for longer-term unsecured lending, because of the higher levels of counterparty risk involved. Overall, our empirical results suggest that Eurex GCP repos are immune to risk and even behave as a shock absorber, facilitating liquidity hoarding and interbank lending during financial crises.

We find some evidence that the ratio of average haircuts at the ECB and for the GCP ECB basket, HCR, is positively related to repo spreads. This suggests that the haircut policies of the central bank and of the CCP are relevant for repo pricing. For instance, if the CCP excludes relatively riskier securities from the set of eligible securities (imposing a 100% haircut) as it did in the case of Italian bonds in January 2012, then the haircut ratio decreases and the collateral basket at Eurex becomes safer compared with the one at the ECB. As a consequence, risk premiums decrease, thus pushing repo rates down.

In the FRFA period, a lower repo spread (S^{1d}_{t-1}) is associated with a longer average term, which is consistent with a search for yield and stronger incentives for lenders to trade longer-term repos in times of low repo rates. Past repo volumes (VOL^{1d}_{t-1}) have virtually no impact on the repo spread, suggesting that cash takers and cash providers have roughly balanced market power. However, when EL exceeds the threshold of EUR 300 billion identified in Section 4.1, any volume increase tends to decrease the repo spread. This suggests that when excess liquidity is high, cash providers outweigh cash takers and push the repo spread down.

Central bank policy has a significant impact on repo market activity, namely, via the liquidity channel. In times of moderate EL, higher levels of EL are followed by lower repo spreads, reflecting the classic demand and supply mechanism in the money market. This suggests that the ECB liquidity provisions were effective in lowering interest rates. This finding echoes the theoretical arguments in Freixas, Martin, and Skeie (2011) and Diamond and Rajan (2012) that the central bank should lower the interbank rate when liquidity in the interbank market is impaired. This is also in line with the empirical finding of Afonso, Kovner, and Schoar (2011) that government and central bank interventions after the bankruptcy of Lehman Brother sharply reduced borrowing rates in the federal funds market.

However, the effect of central bank liquidity on the repo market is not linear. When the level of excess liquidity is already above EUR 300 billion, the repo rate is close to the floor of the corridor (i.e., the repo spread almost narrows to zero). Under these circumstances, the impact of further liquidity injections by the ECB on repo rates almost vanishes. On average, a further increase of EUR 100 billion in excess liquidity above the EUR 300 billion threshold induces a statistically insignificant decrease in the repo spread of −0.006, compared with a significant −0.030 decline when excess liquidity is below that threshold. We experimented with other excess liquidity thresholds, such as EUR 250 or EUR 350 billion, and regression results are virtually unchanged.

ECB liquidity provisions reduce repo volume. An increase by EUR 100 billion translates into a decrease of repo volumes by EUR 757 million. This provides empirical evidence for a substitution effect between public liquidity and liquidity in this segment of the repo market, when the ECB is offering unlimited liquidity at favorable terms. This is in line with the results of Giannone et al. (2012), who find that the positive impact of the ECB's non-standard measures on interbank lending appears to diminish after the first quarter of 2009 and may have deterred private intermediation. Moreover, the results support the theoretical model of Bolton, Santos, and Scheinkman (2009), who argue that public liquidity provision through collateralized lending can produce "crowding out" effects; that is, central bank liquidity provisions with favorable terms can reduce repo volume.

According to Figure 11, the EUR 300 billion threshold is closely related to the introduction of the two 3-year LTROs in December 2011 and February 2012. We repeated the analysis, including outstanding LTRO volume and the EL net of LTRO volume as separate explanatory variables.

The results of this analysis, which we report in the Internet Appendix, confirm the presence of a substitution effect between private and public liquidity, which is strongest following the 3-year LTROs. This is intuitive, given that the terms of the LTROs were particularly favorable for banks; that is banks could obtain cheap funding (interest rate of 1%) for a 3-year period in exchange for various types of collateral from the ECB without significant stigma and with the option for early repayment at any time after the initial year.

[Include Table 2 about here]

4.3. Comparison of collateral baskets

In this subsection, we extend the regression analysis to other collateral baskets to identify the effect of the riskiness of collateral on repo market activity. To that end, we investigate Eurex GCP repos with the ECB EXTended basket as collateral and repos traded on BrokerTec and MTS with German, French, and Italian government securities as collateral.

4.3.1 GCP ECB EXTended basket

The GCP ECB EXTended basket repo differs from the GCP ECB basket for two reasons. First, the ECB EXTended basket is riskier than the ECB basket, as the latter only includes higher-quality securities as collateral. Second, because of infrastructure constraints, banks cannot reuse the ECB EXTended basket for ECB refinancing operations. Hence, we expect that repos collateralized by the ECB EXTended basket are less resilient and exhibit a weaker substitution effect between private and public liquidity, if any.

Table 3 reports regression results for repo rates and volumes of the ECB EXTended basket, after the introduction of FRFA operations. Overall, the empirical findings exhibit similar patterns as those for the ECB basket presented above. Increases in risk are followed by larger repo volume, both for the ECB EXTended and the ECB basket, but the increase is less than half for the riskier ECB EXTended basket. Moreover, there is some evidence that the spread increases with risk for the ECB EXTended basket, whereas the average term shortens. The coefficient of Eonia volume is not significantly different from zero, suggesting that the substitution effect between the unsecured market and the repo market is restricted to the safer ECB basket. Larger excess liquidity tends to reduce the repo spreads of both baskets until the threshold of EUR 300 billion, but the reduction is slightly stronger for the riskier ECB EXTended basket. The substitution effect between private and public funding is almost absent in the repo volumes of the ECB EXTended basket.

All in all, our empirical findings indicate that the combination of riskier collateral and constraints on the reuse of collateral for the ECB EXTended basket appears to weaken resilience.

[Include Table 3 about here]

4.3.2 Repos on other CCP-based electronic trading platforms: BrokerTec and MTS

This subsection analyzes data from the two other CCP-based electronic trading platforms for euro interbank repos, BrokerTec and MTS. The RFR indexes allow us to compare repos collateralized with securities of varying degrees of riskiness. A stronger (weaker) increase of repo volume with risk when repo trades are collateralized by German (Italian) bonds would corroborate the hypothesis that the safety of collateral is crucial for the behavior of the repo market.

Table 4 shows the results of regressing the repo rate and trading volume for the RFR indexes on the state variables. Similar to the results for the GCP ECB basket, RFR Germany repos, which are the safest among the three indexes, act as a shock absorber. An increase in risk has no impact on spreads and a positive effect on volume. In contrast, the spreads for the riskier RFR France and RFR Italy indexes are positively impacted by risk. However, the volume of RFR France increases with risk, whereas a substitution effect occurs between unsecured volume and RFR Italy volume. Moreover, liquidity provisions reduce RFR repo spreads until excess liquidity reaches the EUR 300 billion threshold.

All in all, we find that the CCP-based euro interbank market is resilient during crisis episodes. While repos with the safest collateral even act as shock absorber, the weaker resilience for repos with French and Italian collateral can be explained by higher risk of the underlying securities.

[Include Table 4 about here]

4.4. Robustness checks

4.4.1 Different measures of risk

The analyses above document that activity in the CCP-based euro repo market is not adversely affected in times of high risk. In this section we investigate the robustness of this result with respect to the choice of risk measure. Table 5 reports the estimated coefficients of risk when running regressions as in Table 2, but using different risk measures. Namely, we replace the CISS by the 3-month euro Libor-OIS spread ($LIBOIS$), the iTraxx Europe Senior Financials CDS index, the VSTOXX index of option implied volatility, the yield spreads between 10-year bonds of Italy and Spain and those of Germany, and TARGET2 balances[31] of Germany and countries most affected by the European debt crisis (Greece, Ireland, Italy, Portugal, and Spain, abbreviated as GIIPS). These variables capture a variety of different risks, more specifically counterparty risk in unsecured money market, credit default risk of the European financial sector, stock market volatility, sovereign risk premia, and segmentation in the Euro area.

No matter which risk variable we use in the regression, we obtain a positive effect of risk on repo volumes in the FRFA period. This effect is statistically significant for all variables, except the yield spread between Italy and Germany, at least at the 10% level. Prior to FRFA operations, we find a significant positive effect when using the CISS, iTraxx Europe Senior Financials CDS index, VSTOXX, and the TARGET2 balance of Germany. Moreover, we do not find any significant positive effect on repo spreads for any of the variables in both subsamples, implying that repo spreads do not increase with risk. Similarly, no risk variable has a significant negative effect on the average repo term, meaning that traders do not reduce the maturity of GCP repos in response to high risk. The estimated coefficients of the other explanatory variables in Equations (1) to (3) remain qualitatively unchanged in general. Thus, the finding that the CCP-based euro interbank repo market is resilient and may even act as a shock absorber is robust to the choice of risk measure.

[Include Table 5 about here]

4.4.2 Repo rates for maturities longer than one day

So far we have focused the analysis on repo spreads of short-term repos (o/n, t/n, and s/n). In this section we investigate longer-term repos traded on the Eurex Repo platform by using the term spread as dependent variable (c.f. Figure 6). If the term spread increased with risk, this would indicate that risk premiums for longer-term repos go up in times of stress. Similarly, central bank liquidity may have affected longer-term repos differently.

[31] The Trans-European Automated Real-time Gross settlement Express Transfer system (TARGET2) is owned and operated by the Eurosystem. The TARGET2 balances measure current account surpluses/deficits and/or cross-border payment flows. See Cecchetti, McCauley, and McGuire (2012) for more information. We obtained data on TARGET2 balances from `www.eurocrisismonitor.com/`.

Table 6 presents the results of regressing the one-year term spread on the state variables. We find a negative relation between the CISS and the term spread, suggesting that it becomes relatively cheaper to obtain longer-term financing via GCP repos when risk increases. Expected policy rate changes (EMC) are positively related to the term spread; that is, an expected increase in the policy rate makes long-term repo borrowing more expensive. Finally, we find a negative impact of excess liquidity on the term spread. This effect prevails even in times of high excess liquidity or when we include LTRO volume as separate explanatory variable. Thus, although we find evidence for a "liquidity trap" when short-term repo rates reach the ECB deposit rate, further liquidity provisions by the ECB above the EUR 300 billion threshold were still able to lower longer-term repo rates.

[Include Table 6 about here]

4.4.3 Term-adjusted trading volume

Our previous analyses document a decrease in trading volume for short-term repos and an increase in repo maturity toward the end of our sample. Thus, the decrease in trading volume after the LTRO may be partly compensated by an increase of volume in longer maturities. For instance, if a bank rolls over its funding on a weekly, instead of daily, basis, trading volume declines, but the use of secured funding remains constant. To control for such effects, this subsection analyzes term-adjusted trading volume. To that end, we multiply trading volume for each repo transaction by the repo maturity in days to give more weight to longer-term repos. We then repeat the regression analysis from Section 4.2. Estimation results are shown in Table 7. Resilience of the euro interbank repo market is confirmed, with term-adjusted volume being positively affected by risk and negatively related to unsecured funding market volume. The evidence for a substitution effect for large levels of excess liquidity is weaker, indicating that part of the drop in short-term repo volume is compensated by longer-term repos.

[Include Table 7 about here]

5. Why is the repo market resilient?

Our analyses above show that the CCP-based euro interbank repo market is resilient, facilitating short-term funding and accommodating banks' liquidity demands, even in times of crisis. This resilience is in contrast to the non-CCP-based euro interbank repo market (bilateral and triparty; c.f. Figure 2) and the bilateral interdealer market in the United States that experienced a run (Gorton and Metrick, 2012) and credit crunch (Krishnamurthy, Nagel, and Orlov, 2014). Although the triparty repo market in the United States was in general more stable, distressed institutions, such as Bear Stearns and Lehman Brothers, were excluded from the market (Copeland, Martin, and Walker, 2014) and the overall volume declined.

What explains the different behavior across repo markets in times of stress? Why are some repo markets less vulnerable than others? To answer these questions, Table 8 summarizes information about the types of repo and collateral, the market infrastructure, and the empirical findings for the repos considered in our paper and in three representative empirical studies on the U.S. repo market.

The CCP-based euro interbank repo market has at least three characteristics that distinguish it from repo markets that were not resilient during the crisis. First, the market infrastructure (Section 2) is very different compared with the U.S. market. The majority of euro repos rely on anonymous electronic trading through a CCP with a real-time collateral management system. There is no daily unwind mechanism — as in the U.S. triparty market — that contributes to market fragility and may cause runs on distressed institutions (Martin, Skeie, and von Thadden, 2014). Market participants have access to the ECB refinancing facilities, and the CCPs have established clear rules for collateral liquidation and for the distribution of losses in case of default. Thus, the European market infrastructure already incorporates some of the proposed measures to mitigate pre- and post-default fire sales discussed by Begalle et al. (2013).

Second, only fairly safe securities are accepted in the CCP-based euro interbank repo market. Riskier and non-standard securities, like asset-backed securities that experienced the largest increase in haircuts during the crisis (Gorton and Metrick, 2012), are not accepted on the electronic trading platforms.

Third, securities accepted by the CCPs are also accepted for raising funds at the ECB that can be regarded as the repo lender of last resort. Eurex allows an efficient reuse of received collateral within the framework of ECB operations (only GCP ECB basket) and for further money market transactions on the Eurex platform. In particular, the reusability at the central bank provides a form of insurance by allowing repo lenders to cover sudden unexpected funding needs. Moreover, the pooling feature reduces position sizes and thus banks' repo exposure.

Our analyses shed light on the relative importance of each of these characteristics. Table 8 indicates that only CCP-based repos are resilient during the crisis, when jointly considering volume, spread, maturity, and haircuts. Thus, a key distinguishing feature that renders the CCP-based euro interbank repo market resilient appears to be the market infrastructure. This is in line with the theoretical model by Martin, Skeie, and von Thadden (2014), showing that the market structure plays a crucial role for the fragility of funding markets.

Furthermore, in line with the empirical U.S. literature, the riskiness of collateral influences resilience. We find that repos with relatively riskier collateral, such as the GCP ECB EXTended basket, RFR France, and in particular RFR Italy, are less resilient. A novel finding compared with the U.S. literature is that repos secured by the safest collateral (i.e., the GCP ECB basket and RFR Germany) act as a shock absorber.

Other market characteristics appear to be less important for resilience. The fact that the volume of non-CCP-based euro interbank repos declined is a sign that general access to a lender of last resort, which mitigates the risk of pre-default fire sales, is not sufficient to make repo markets resilient. The similar patterns of RFR Germany and the GCP ECB basket suggest that the reusability for central bank operations within the same infrastructure and the pooling of repo transactions are not necessary conditions for repo market resilience.

[Include Table 8 about here]

A word of caution is in order. We find that the CCP-based euro repo market performs well during crisis periods, but we do not claim that establishing a CCP is a necessary condition for repo market resilience. Moreover, it is not straightforward to directly control for overall industry trends or institutional issues that may have impacted money markets. On the one hand, new regulatory initiatives may have increased the demand for collateral securities and collateralized lending (e.g., Dodd-Frank Act in the United States and EMIR in the European Union). On the other hand, the market share of top-quality assets has decreased since the outbreak of the financial crisis in 2007 (International Monetary Fund, 2012), which might have reduced the participation in CCP-based trading venues. We take such effects at least partially into account by (i) including the trend variable in repo volume and (ii) conducting our analyses over two subsamples.

In general, reusability of collateral also has potential drawbacks as it may increase leverage in the financial system, complicate resolving bankrupt financial institutions, and increase procyclicality. In the CCP-based euro interbank market, these pitfalls are less of a concern. For instance, no complicated collateral chains that may cause additional stress if a counterparty defaults arise, because banks trade via a CCP and collateral does not leave the electronic trading platform.

Lastly, an assessment of ECB policy from a social welfare perspective is beyond the scope of this paper. For instance, a substitution effect between private and public liquidity may be acceptable for central bankers and policy makers, if the ECB measures improve funding conditions for banks in GIIPS countries that have trouble obtaining private financing because of a lack of safe collateral.

6. Conclusion

The impairment of short-term funding played a major role in the recent financial crisis. A better understanding and stricter regulation of the repo market are currently at the top of the policy agenda in many countries. Using a novel and comprehensive data set, this paper provides the first systematic study of the euro interbank repo market.

We find that activity in the CCP-based euro interbank repo market is resilient. Our analyses show that repo spreads, volumes, maturities, and haircuts were not negatively affected during crisis episodes. Repos with the safest collateral baskets such as the GCP ECB basket and German government securities even act as a shock absorber, in the sense that repo lending increases with risk and volume migrates from the unsecured money market to the repo market. These patterns indicate that even in times of financial stress and flight-to-quality, market participants view the CCP-based euro interbank market as a safe venue to hoard liquidity. This is in contrast to the non-CCP-based segment of the euro interbank market and U.S. repo markets, whose volumes declined. The distinguishing characteristics of the euro interbank repo market are the infrastructure, including anonymous trading via a CCP, and the reliance on safe collateral.

In addition to risk, we find that central bank liquidity provision is a key driver of repo market activity. Repo rates decrease with central bank liquidity supply but only until a threshold of liquidity saturation that we empirically identify at EUR 300 billion. Once excess liquidity reaches this threshold, repo rates hit the bottom of the ECB's interest rate corridor and no longer respond to additional liquidity provision. Furthermore, we find that central bank liquidity provision can be detrimental to secured interbank lending, in the sense that repo volume decreases with excess liquidity. Such a substitution effect arises when "public" liquidity is supplied at relatively attractive conditions.

This paper delivers important insights for banks, policy makers, and central bankers. First, understanding patterns and key state variables of the repo market is crucial for banks' liquidity planning and risk management. Our finding of resilience indicates that the euro interbank market accommodates banks' need of liquidity hoarding and risk sharing in times of stress.

Second, our results show that the euro interbank repo market can act as a buffer rather than as an amplifier of financial shocks. A market design for short term funding, featuring anonymous trading via a CCP and relying on safe collateral appears to insulate banks from counterparty risk, runs, and credit crunches. Thus, in the context of repo trading, our results support current initiatives (e.g., Dodd-Frank in the United States) intended to bring over-the-counter volume to centrally cleared trading platforms, if sufficiently secure and efficient.

Third, our paper provides valuable insights for the ongoing reform of the U.S. triparty repo market. While there has been progress in addressing the heavy reliance on intraday credit extended by the triparty agent, the risk of fire sales remains an open issue (Begalle et al., 2013). The repo market studied in this paper at least partially addresses this source of financial instability.

Fourth, this paper supports central bankers in assessing the effect of unconventional policies and potential exit strategies. Liquidity provisions are conditionally effective in reducing interest rates, but they can also have unintended consequences, such as a decrease in secured interbank lending.

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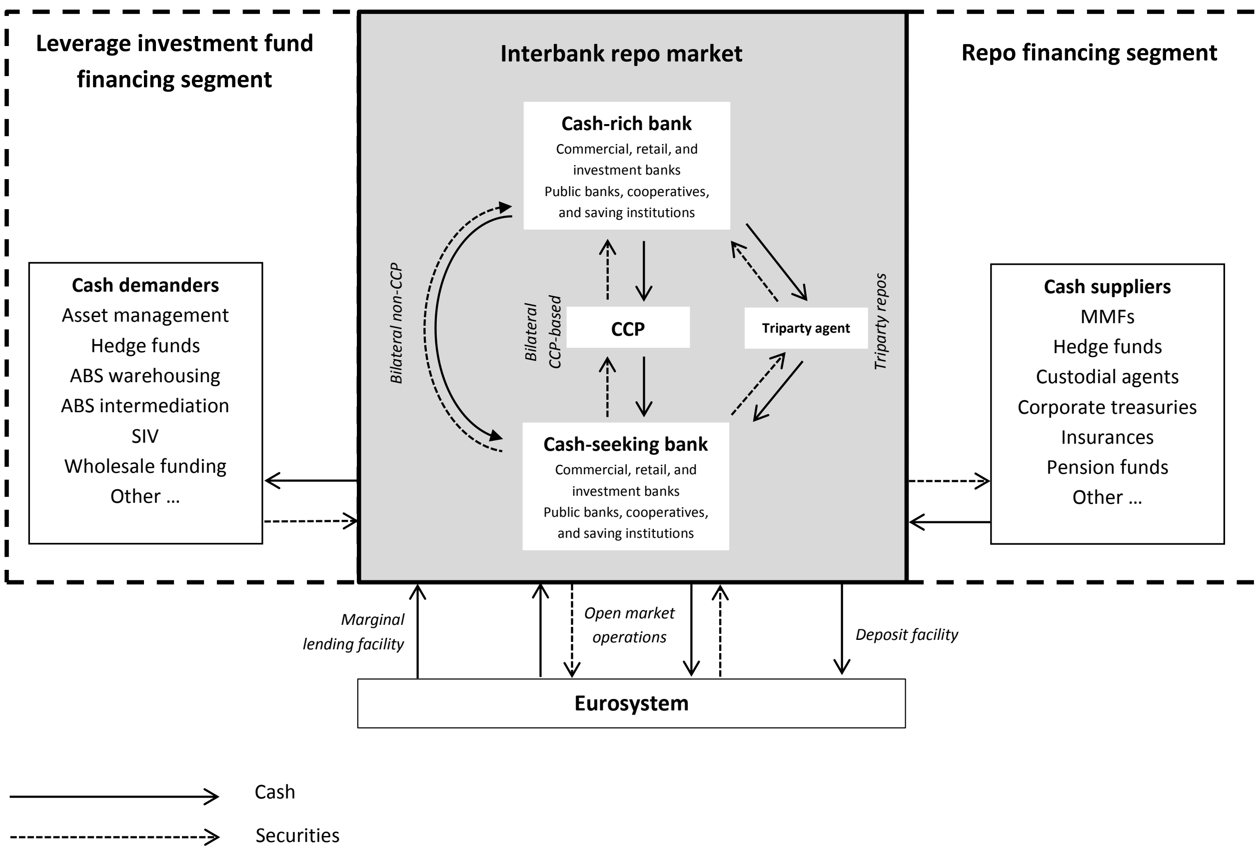


Figure 1. Schematic description of the euro repo market. This figure shows a schematic description of the euro repo market, including the main market participants in the white boxes. At the center is the euro interbank segment that is the focus of this paper. The figure shows the main forms of trading in the interbank repo market (bilateral non-CCP-based, bilateral CCP-based, and triparty), as well as the connection to the repo financing segment, the leverage investment fund financing segment, and the Eurosystem. The solid lines indicate the cash flows on the purchase date of typical repo transactions, whereas the dashed lines correspond to the delivery of collateral.

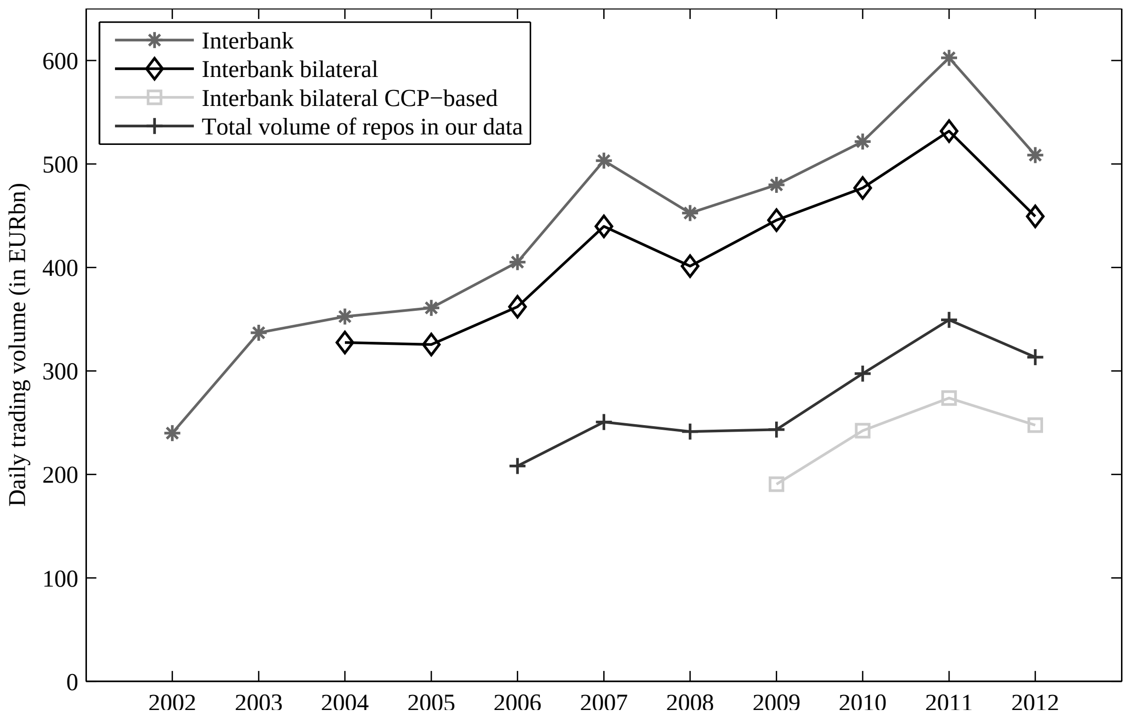
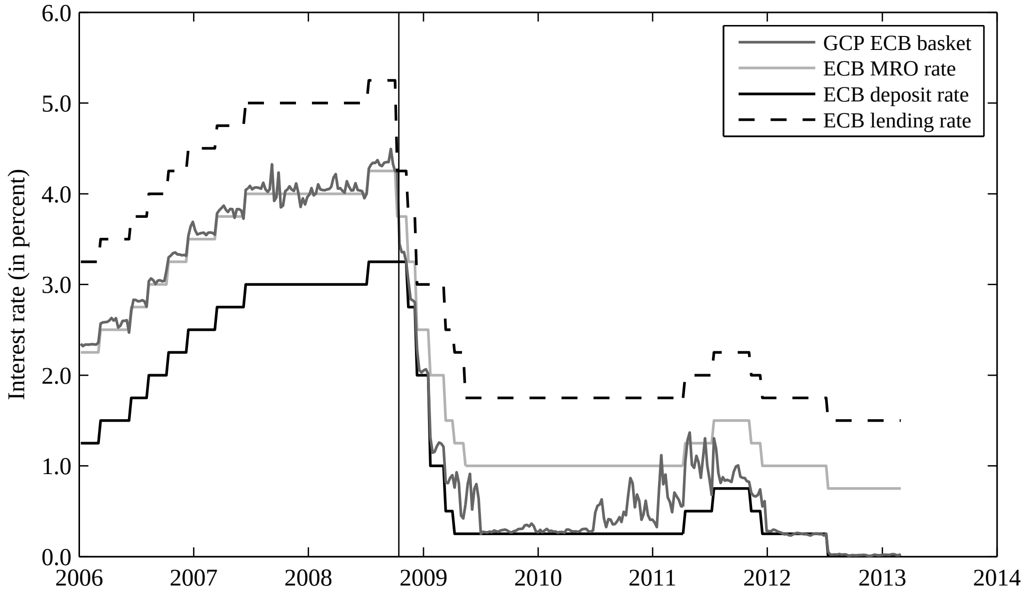


Figure 2. Average daily trading volume of the euro interbank repo market. The double-counted borrowing volume of the overall interbank repo market, the volume of bilateral repos, and the volume of bilateral CCP-based repos are from the European Central Bank (2012). The lines represent the stacked volume of the respective repo types according to the ECB money market studies. The continuous black line marked by crosses indicates the total traded volume in our data set (all repos traded on the Eurex Repo trading platform as well as short-term repos with German, French, and Italian government securities as collateral traded on BrokerTec and MTS).

Panel A. Interest rates



Panel B. Repo spread

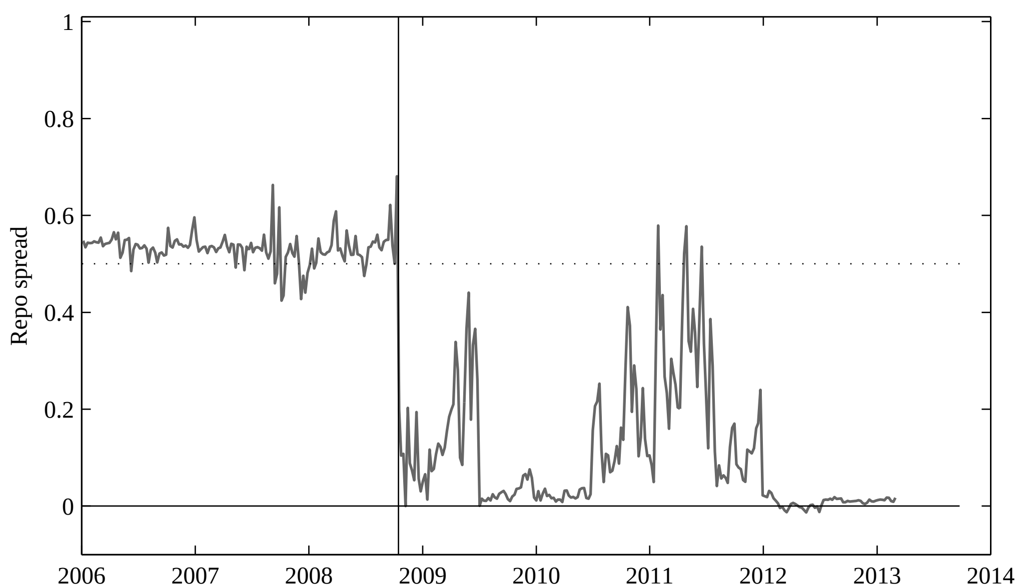
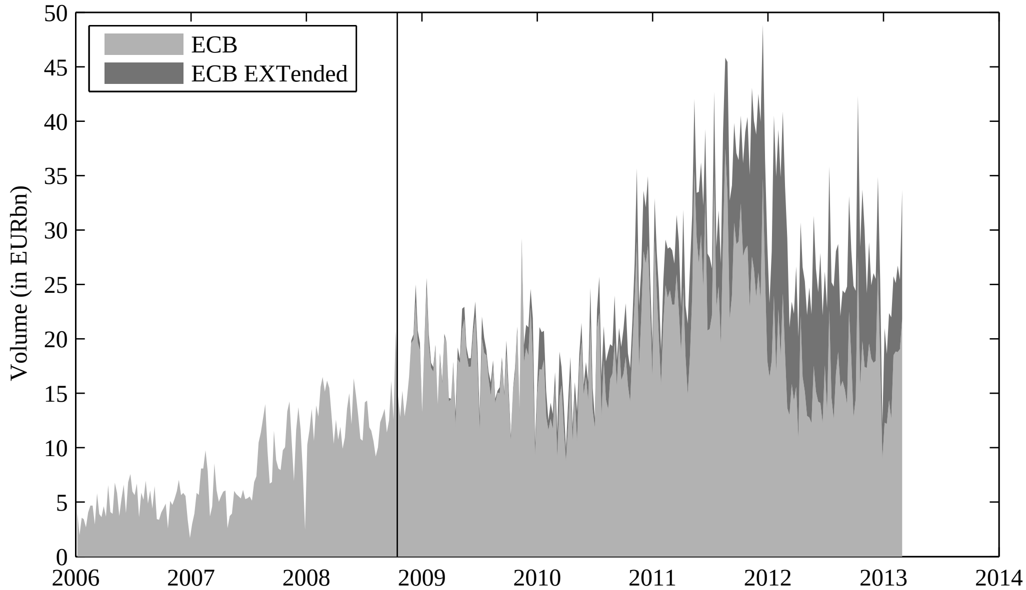


Figure 3. Volume-weighted average GCP ECB basket repo rate. Panel A shows the volume-weighted average GCP repo rate for the ECB basket (o/n, t/n, and s/n maturities) compared with the ECB refinancing rate, the ECB deposit rate, and the ECB lending rate. Panel B shows the repo spread that is computed as $S_t^{1d} = (r_t^{GCP,1d} - r_t^{ECB,deposit})/(r_t^{ECB,lending} - r_t^{ECB,deposit})$. The figures are based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

Panel A. GCP volume



Panel B. Share of ECB EXTended basket of total GCP volume

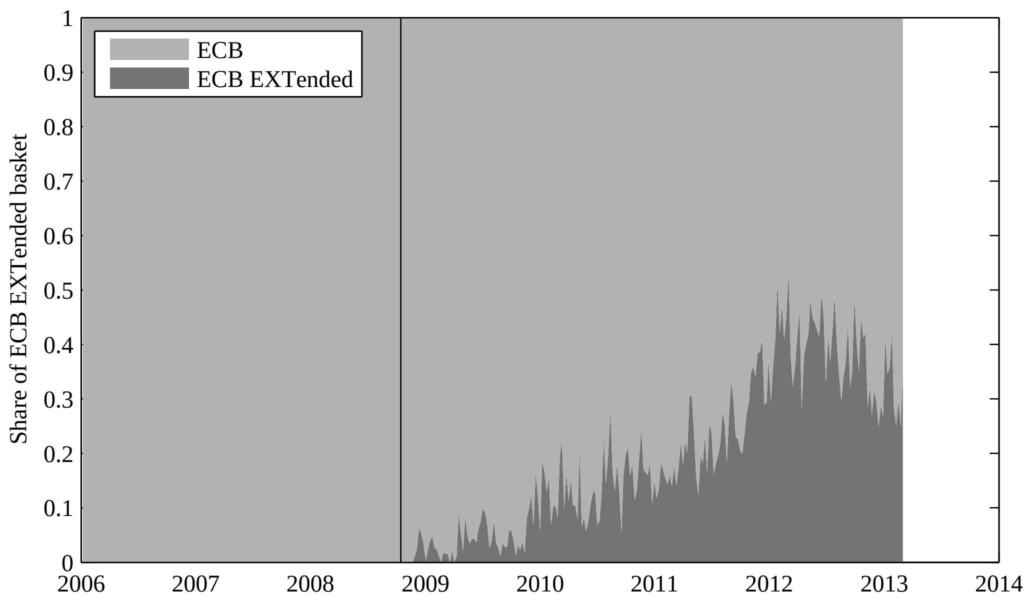


Figure 4. GCP trading volume. Panel A presents the average daily trading volume for all GCP repos. The light gray area is the volume in the ECB basket, whereas the dark gray area that is stacked on top corresponds to the volume in the ECB EXTended basket. The corresponding shares of total trading volume are plotted in Panel B. The figures are based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

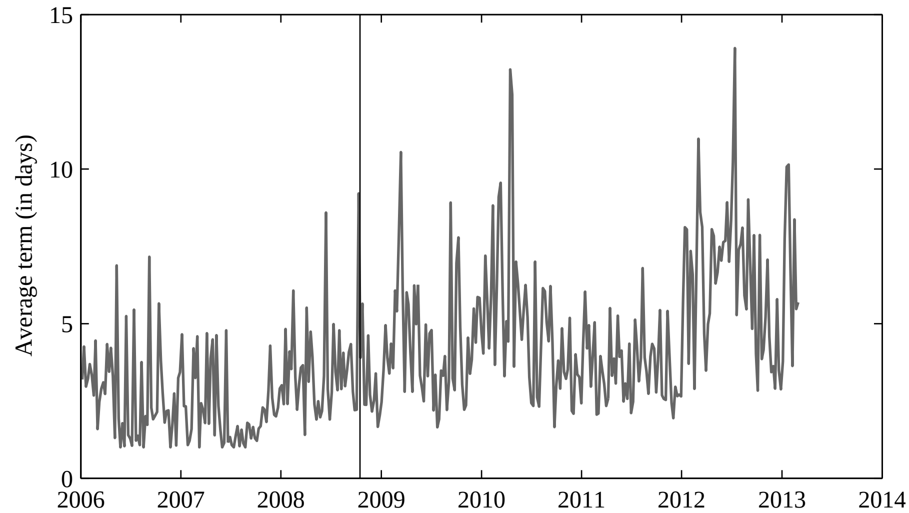


Figure 5. Average repo term. This figure shows the volume-weighted average GCP term (in days) for the ECB basket. The figure is based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

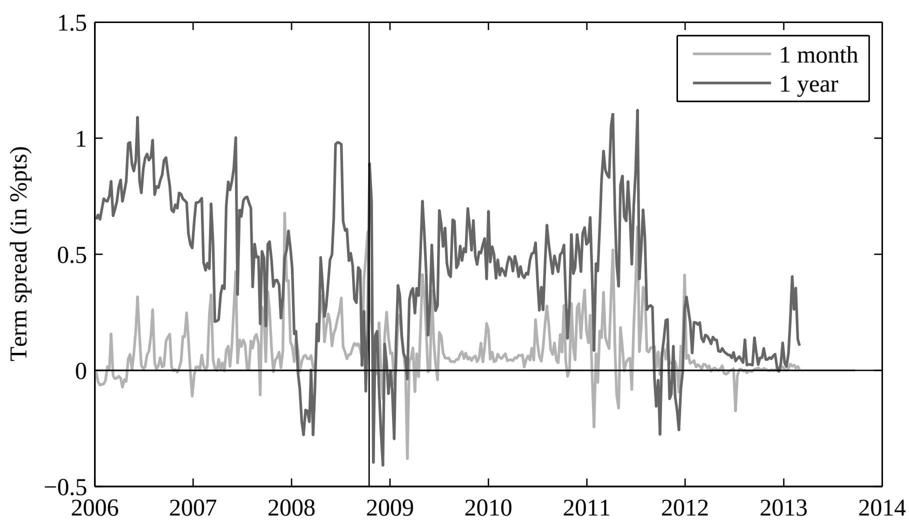
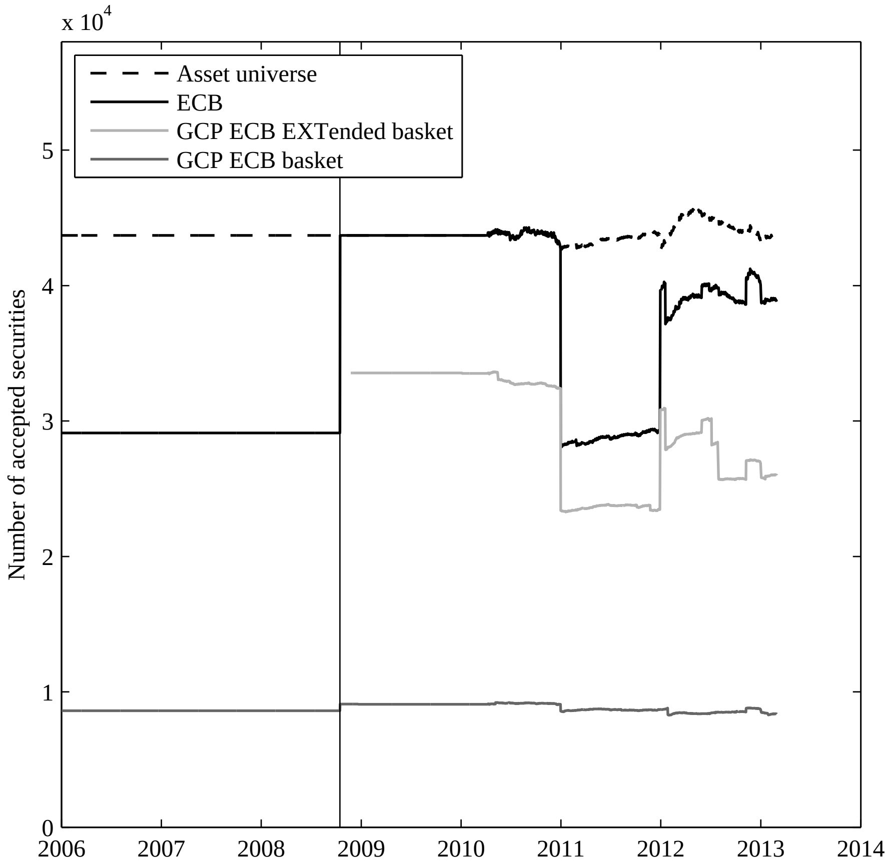


Figure 6. Term spread. This figure shows the term spread, that is, the spread between longer-term repo rates and the rate for short-term (o/n, t/n, and s/n) repos. The dark gray line depicts the spread based on longer-term repos with a maturity between six months and one year, whereas the light gray line shows the spread for medium term repos with a maturity between 9 days and one month. Missing observations are filled with fitted values from a regression of Eurex GCP rates on Eurepo rates from the European Banking Federation obtained via Datastream. The figure is based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

Panel A. Number of accepted securities



Panel B. Average haircut for accepted securities

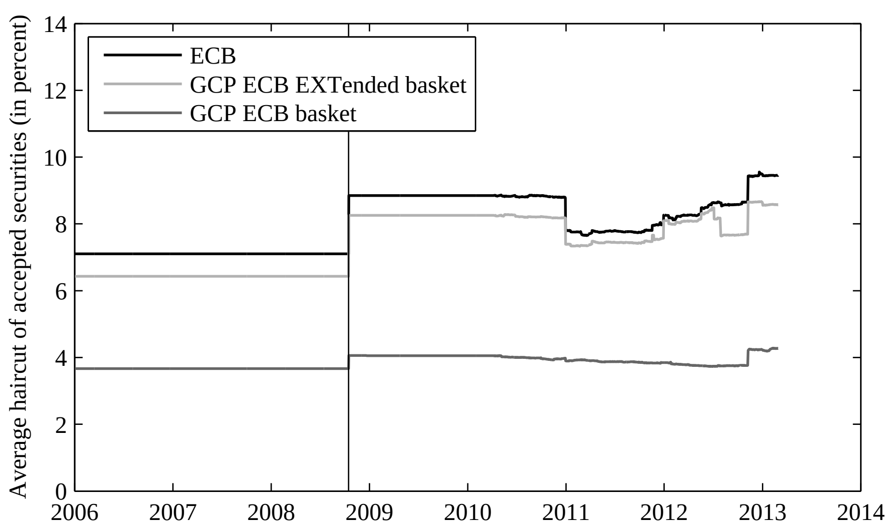


Figure 7. Number of accepted securities and average haircut for accepted securities. Panel A shows the number of accepted securities at the ECB, as well as the subset of those securities included in the two GCP baskets. The black dashed line represents the asset universe, that is, the number of securities outstanding that were accepted at the ECB at least during part of the sample. Panel B shows the equally weighted average haircut for all securities accepted at the ECB and at Eurex. The figures are based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

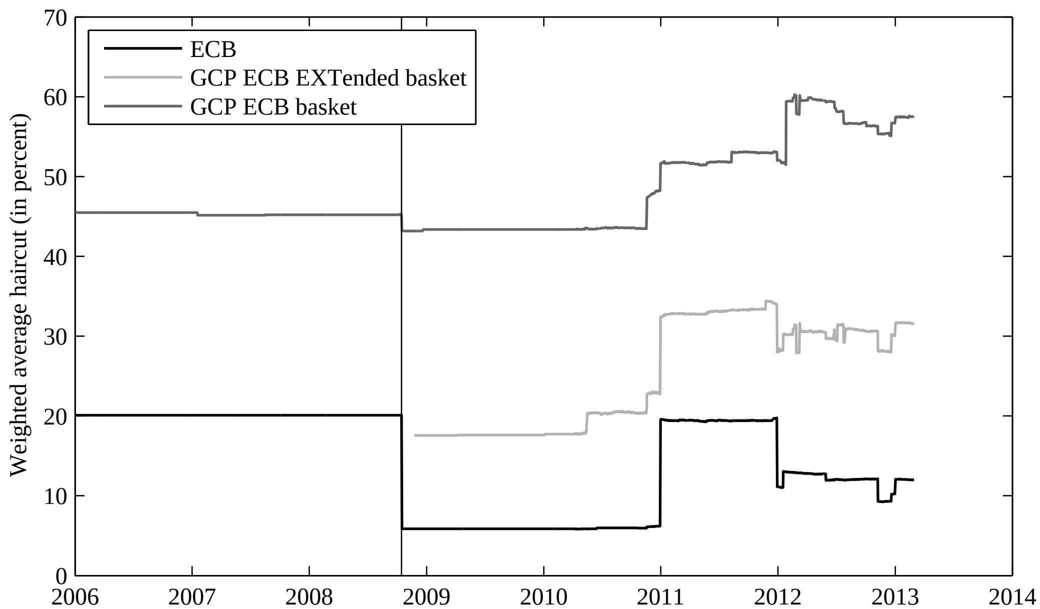
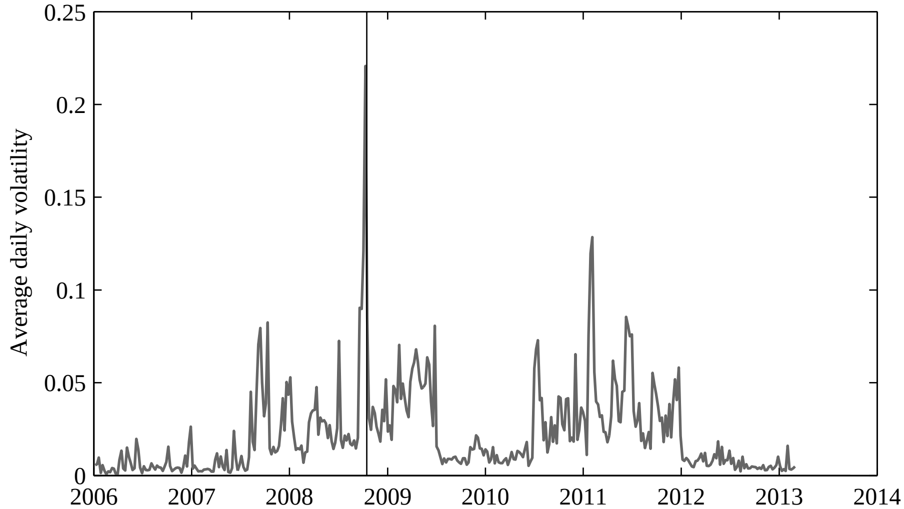


Figure 8. Weighted average haircuts. This figure depicts weighted average haircuts at the ECB and at Eurex GCP for all securities in the asset universe. Assets that are not eligible enter the computation with a haircut of 100%. The weights are determined by the outstanding volume for each security type (data from the ECB). The figure is based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

Panel A. Average daily volatility per week



Panel B. Illiquidity

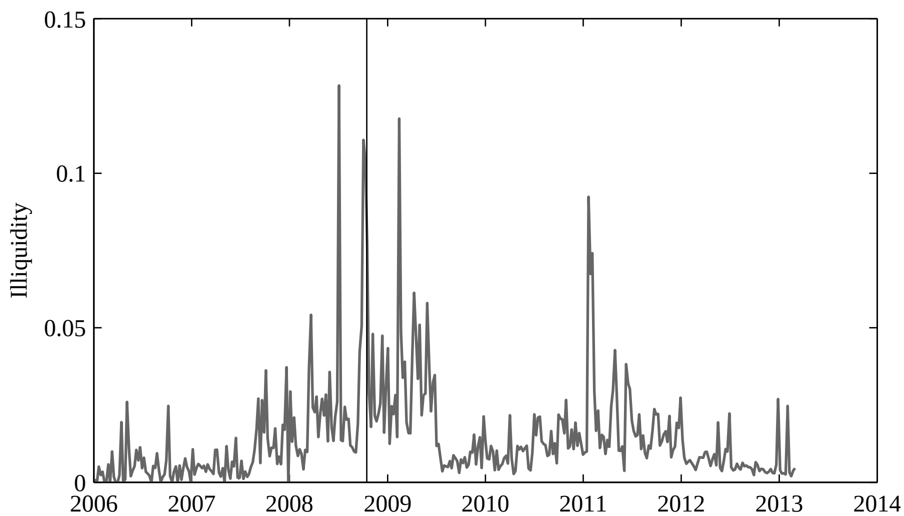


Figure 9. Volatility and illiquidity. Panel A shows the annualized average daily volatility per week computed as the realized volatility of all intraday trades. Panel B depicts Roll's (1984) measure of the bid-ask spread as a proxy for market illiquidity. For each day d with intraday trades indexed by i, we compute $Roll_d = 2\sqrt{min(0, -Cov(\Delta r_{GCP,i}, \Delta r_{GCP,i-1}))}$. Then we average $Roll_d$ over all trading days of each week to obtain the illiquidity measure. The figures are based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

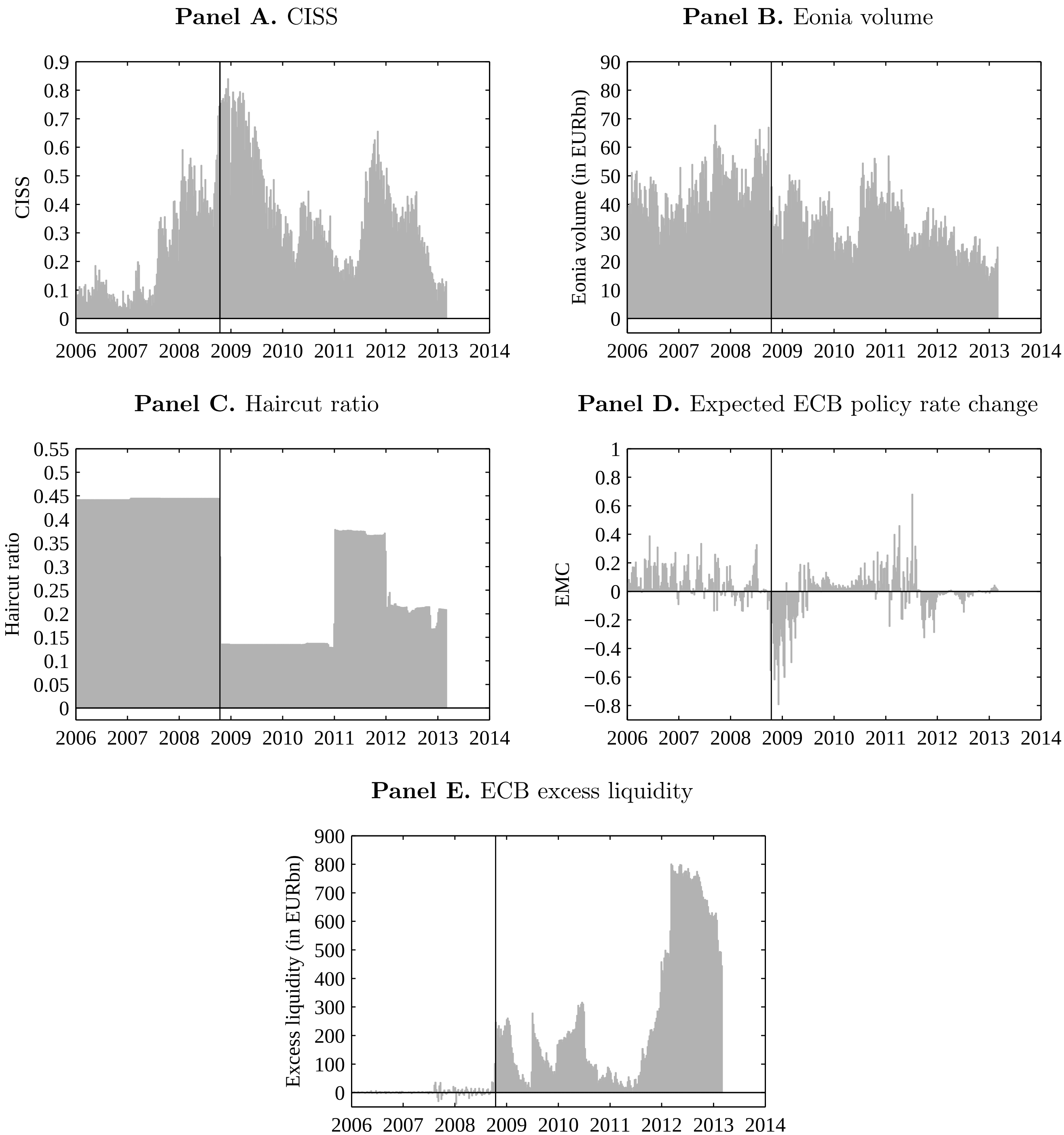
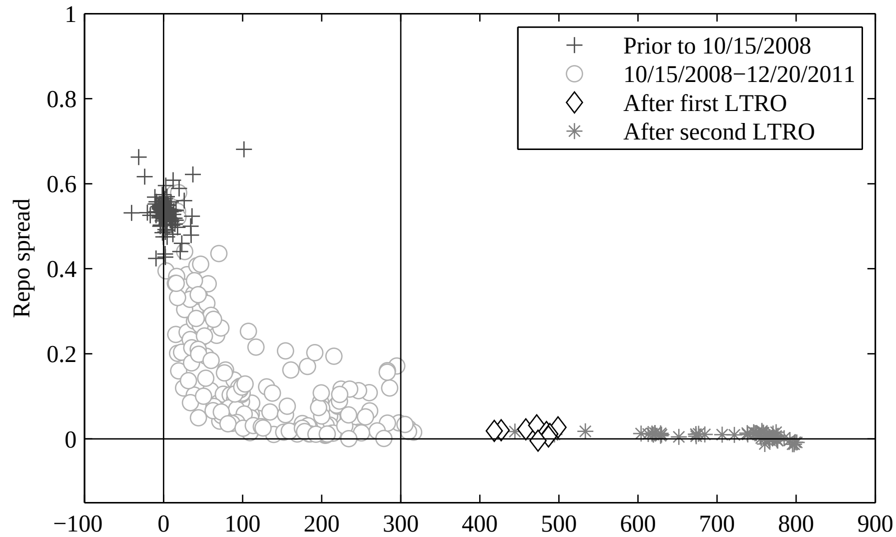


Figure 10. State variables. This figure shows the main state variables for repo market activity. Panel A depicts the composite indicator of systemic stress, CISS (Hollo, Kremer, and Lo Duca, 2012), which is a comprehensive measure of risk in the European financial system. Panel B shows Eonia (euro overnight index average) volume, representing the unsecured overnight money market in the euro area. Panel C shows the ratio of average haircuts at the ECB over those for the Eurex GCP ECB basket. Haircuts for all assets are computed from the point of view of a bank, that is, securities that are not accepted enter the computation with a haircut of 100%. Panel D shows expected changes of the ECB policy rate, which we extract from futures data. Panel E depicts ECB excess liquidity in the financial system, defined as credit institutions' current account holdings at the ECB plus funds in the ECB deposit facility minus reserve requirements. All figures are based on weekly data from January 2006 to February 2013. The vertical line represents the ECB's switch to fixed-rate full allotment refinancing operations on October 15, 2008.

Panel A. Repo spread



Panel B. Detrended repo volume

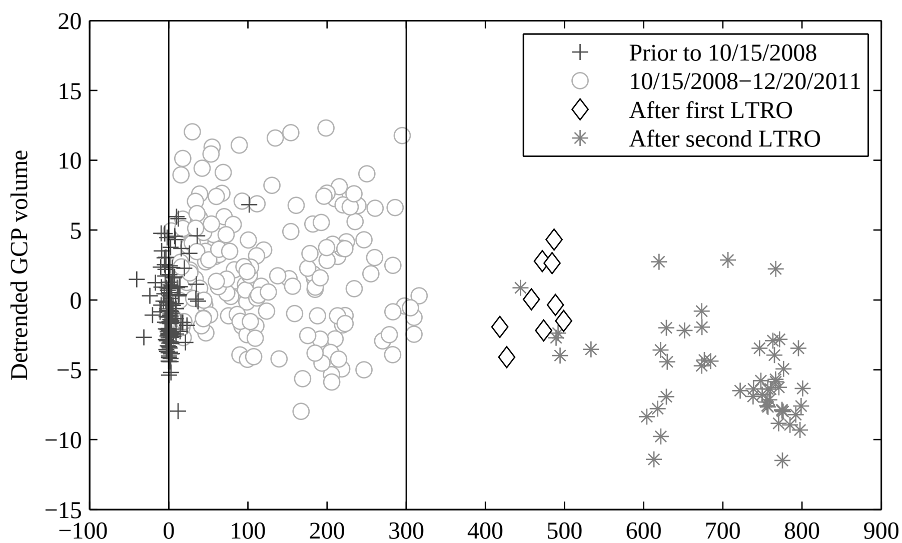


Figure 11. Relation between ECB excess liquidity and the repo spread as well as detrended GCP volume. Panel A shows a scatter plot of the repo spread (y-axis) and ECB excess liquidity (x-axis), defined as credit institutions' current account holdings at the ECB plus funds in the ECB deposit facility minus reserve requirements. Panel B shows a similar plot with linearly detrended Eurex GCP trading volume on the y-axis. Both plots are based on weekly data from January 2006 to February 2013.

Table 1
Descriptive statistics for repo market activity and the state variables

This table shows descriptive statistics for the repo spread, the detrended repo volume, the average repo term, and the state variables. Excess liquidity is measured in EUR trillion, whereas Eonia volume in EUR 10 billion. The results are based on weekly data from January 2006 to February 2013. Panel A shows results for the sample prior to the introduction of fixed-rate full allotment refinancing operations at the ECB on October 15, 2008. Panel B presents results for the sample period after this date, but prior to the first 3-year LTRO in December 2011. Panel C shows descriptive statistics for the sample period after the first 3-year LTRO.

Panel A: Prior to full allotment

	S_t^{1d}	$\widetilde{VOL}_t^{1d}$	$AVGTERM_t$	$CISS_t$	VOL_t^{EONIA}	HCR_t	EMC_t	EL_t
Mean	0.532	−0.073	2.782	0.225	4.567	0.443	0.069	0.003
Median	0.534	−0.119	2.396	0.132	4.488	0.444	0.056	0.001
Max	0.681	0.682	9.209	0.744	6.775	0.444	0.389	0.102
Min	0.424	−0.796	1.000	0.032	2.567	0.441	−0.554	−0.040
SD	0.034	0.255	1.517	0.176	0.854	0.001	0.118	0.013
Skewness	0.417	0.576	1.364	0.736	0.266	−0.460	−0.643	3.112
Kurtosis	8.080	3.347	5.640	2.381	2.605	1.290	7.294	26.354

Panel B: After full allotment and prior to 3-year LTRO

	S_t^{1d}	$\widetilde{VOL}_t^{1d}$	$AVGTERM_t$	$CISS_t$	VOL_t^{EONIA}	HCR_t	EMC_t	EL_t
Mean	0.138	0.230	4.258	0.418	3.550	0.207	−0.013	0.129
Median	0.100	0.203	3.907	0.380	3.551	0.135	0.030	0.107
Max	0.579	1.231	13.225	0.840	5.697	0.379	0.680	0.316
Min	0.000	−0.798	1.648	0.131	1.936	0.128	−0.793	0.003
SD	0.132	0.426	1.938	0.196	0.818	0.109	0.201	0.085
Skewness	1.259	0.218	1.632	0.510	0.299	0.856	−0.773	0.405
Kurtosis	3.984	2.578	7.044	2.131	2.410	1.739	5.202	1.957

Panel C: After 3-year LTRO

	S_t^{1d}	$\widetilde{VOL}_t^{1d}$	$AVGTERM_t$	$CISS_t$	VOL_t^{EONIA}	HCR_t	EMC_t	EL_t
Mean	0.008	−0.453	6.403	0.287	2.370	0.210	−0.014	0.666
Median	0.010	−0.482	6.709	0.315	2.358	0.213	−0.007	0.714
Max	0.032	0.432	13.913	0.527	3.587	0.332	0.044	0.801
Min	−0.013	−1.149	2.648	0.062	1.313	0.167	−0.145	0.418
SD	0.009	0.367	2.330	0.120	0.520	0.022	0.029	0.120
Skewness	−0.306	0.508	0.433	−0.230	0.162	2.275	−1.844	−0.686
Kurtosis	3.074	2.736	3.286	1.856	2.355	17.586	8.829	2.035

Table 2
Regression results for the GCP ECB basket

This table shows the results of regressing the repo spread, repo trading volume, and the average repo term of the GCP ECB basket on various state variables (Equations (1) to (3)). Each column corresponds to a regression with the dependent variable shown in the first row, whereas the explanatory variables are shown in the first column. Regressions are based on weekly data from January 2006 to February 2013. Columns 2 to 4 show results for the sample prior to the introduction of fixed-rate full allotment refinancing operations at the ECB on October 15, 2008. Columns 5 to 7 present regression results for the sample period after this date. EL is measured in EURtn, VOL^{1d} in EUR10bn, and VOL^{EONIA} in EURbn. HAC standard errors are shown in parentheses. The stars ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Prior to full allotment			After full allotment		
	S_t^{1d}	VOL_t^{1d}	$AVGTERM_t$	S_t^{1d}	VOL_t^{1d}	$AVGTERM_t$
const.	0.571***	0.042	3.154	0.046	0.199	4.971***
	(0.151)	(0.555)	(3.156)	(0.037)	(0.242)	(0.840)
trend		0.003***			0.005***	
		(0.001)			(0.001)	
S_{t-1}^{1d}	−0.046	0.465	−1.065	0.625***	0.228	−4.010***
	(0.260)	(0.910)	(5.450)	(0.083)	(0.261)	(1.338)
$AVGTERM_{t-1}$	−0.002	−0.032***	0.016	−0.001	−0.031***	0.306***
	(0.004)	(0.012)	(0.081)	(0.002)	(0.011)	(0.058)
VOL_{t-1}^{1d}	−0.031	0.446***	−1.223*	−0.001	0.264***	−0.911***
	(0.030)	(0.113)	(0.704)	(0.015)	(0.068)	(0.334)
$VOL_{t-1}^{1d} * DUM_{t-1}^{EL>300}$				−0.032*		
				(0.019)		
VOL_{t-1}^{EONIA}		−0.033			−0.083***	
		(0.021)			(0.031)	
$CISS_{t-1}$	0.046	0.558**	4.569***	0.043	0.708***	−0.055
	(0.075)	(0.224)	(1.675)	(0.038)	(0.180)	(0.897)
EL_{t-1}	−0.709	0.508	−13.429	−0.301***	−0.757*	−3.443
	(0.726)	(1.519)	(11.819)	(0.116)	(0.425)	(3.024)
$EL_{t-1} * DUM_{t-1}^{EL>300}$				0.245***	−0.343	3.823
				(0.091)	(0.317)	(2.441)
HCR_{t-1}				0.153*	0.458	2.119
				(0.090)	(0.490)	(1.465)
EMC_{t-1}	0.039	0.234	−0.016	0.048	−0.094	−0.435
	(0.047)	(0.211)	(1.684)	(0.059)	(0.202)	(0.991)
Adj.-R^2	0.079	0.774	0.070	0.713	0.543	0.320

Table 3
Regression results for the GCP ECB EXTended basket

This table shows the results of regressing the repo spread, repo trading volume, and the average repo term of the GCP ECB EXTended basket on various state variables. The regressions are the same as in Equations (1) to (3), but with the dependent variables and the haircut ratio being computed based on the ECB EXTended basket rather than the ECB basket. Each column corresponds to a regression with the dependent variable shown in the first row, whereas the explanatory variables are shown in the first column. Regressions are based on weekly data from October 2008 to February 2013. Columns 2 to 4 show estimation results with HAC standard errors shown in parentheses. The stars ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	S_t^{1d}	VOL_t^{1d}	$AVGTERM_t$
const.	0.020	−0.609∗∗∗	3.171∗∗
	(0.036)	(0.150)	(1.356)
trend		0.002∗∗∗	
		(0.001)	
$S_{t-1}^{ext,1d}$	0.599∗∗∗	−0.113	−2.130
	(0.086)	(0.108)	(2.922)
$AVGTERM_{t-1}^{ext}$	−0.001	0.000	0.150∗
	(0.001)	(0.003)	(0.085)
$VOL_{t-1}^{ext,1d}$	0.021	0.672∗∗∗	−0.382
	(0.030)	(0.079)	(0.679)
$VOL_{t-1}^{ext,1d} * DUM_{t-1}^{EL>300}$	−0.070∗∗		
	(0.031)		
VOL_{t-1}^{EONIA}		0.007	
		(0.012)	
$CISS_{t-1}$	0.090∗∗	0.287∗∗∗	−2.723∗
	(0.038)	(0.088)	(1.472)
EL_{t-1}	−0.394∗∗∗	−0.046	7.993
	(0.129)	(0.262)	(7.327)
$EL_{t-1} * DUM_{t-1}^{EL>300}$	0.324∗∗∗	−0.032	−5.172
	(0.097)	(0.187)	(5.685)
HCR_{t-1}^{ext}	0.143	0.236∗	1.045
	(0.096)	(0.138)	(2.157)
EMC_{t-1}	0.044	−0.024	1.996
	(0.078)	(0.080)	(1.962)
Adj.-R^2	0.724	0.865	0.116

Table 4
Regression results for repos traded on BrokerTec and MTS

This table shows the results of regressing the repo spread and repo trading volume for RepoFunds Rate (RFR) index data on various state variables. RFR indexes for repo rates and volumes are based on GC and special repo trades executed on the BrokerTec and MTS electronic trading platforms. Each column corresponds to a regression with the dependent variable shown in the first two rows, while the explanatory variables are shown in the first column. Regressions are based on weekly data from October 2008 to February 2013, covering the period after the introduction of fixed-rate full allotment refinancing operations at the ECB. Columns 2 and 3 show results for the RFR Germany index; columns 4 and 5 show results for the RFR France index; and columns 6 and 7 show results for the RFR Italy index. HAC standard errors are shown in parentheses. The stars ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Germany		France		Italy	
	S_t^{RFR}	VOL_t^{RFR}	S_t^{RFR}	VOL_t^{RFR}	S_t^{RFR}	VOL_t^{RFR}
const.	0.126	64.400***	−0.001	36.478***	0.014	24.473**
	(0.086)	(15.890)	(0.133)	(6.152)	(0.061)	(10.250)
trend		0.030		0.098***		0.033
		(0.028)		(0.020)		(0.022)
S_{t-1}^{1d}	0.614***	−1.214	0.597***	−10.113***	0.602***	−5.826
	(0.059)	(6.160)	(0.062)	(3.621)	(0.070)	(5.915)
VOL_{t-1}^{RFR}	0.001	0.437***	0.002*	0.210**	0.002**	0.388***
	(0.001)	(0.069)	(0.001)	(0.085)	(0.001)	(0.075)
$VOL_{t-1}^{GC,1d} * DUM_{t-1}^{EL>300}$	−0.002***		−0.003**		−0.001**	
	(0.000)		(0.001)		(0.001)	
VOL_{t-1}^{EONIA}		−1.451*		−1.127***		−1.258*
		(0.742)		(0.378)		(0.642)
$CISS_{t-1}$	0.000	5.852***	0.057**	9.008***	0.059**	−11.920***
	(0.034)	(1.920)	(0.026)	(2.951)	(0.027)	(4.423)
EL_{t-1}	−0.544***	−19.221**	−0.408***	−12.628**	−0.461***	−29.587**
	(0.106)	(9.303)	(0.110)	(5.066)	(0.113)	(12.311)
$EL_{t-1} * DUM_{t-1}^{EL>300}$	0.515***	10.724*	0.378***	7.054*	0.390***	19.152**
	(0.104)	(5.573)	(0.110)	(4.220)	(0.105)	(9.588)
HCR_{t-1}	−0.104	31.437	0.212	39.761***	−0.026	−21.784
	(0.127)	(22.745)	(0.162)	(9.628)	(0.129)	(15.501)
EMC_{t-1}	−0.042	−0.036	−0.037	1.985	0.030	−2.370
	(0.039)	(5.689)	(0.038)	(2.672)	(0.044)	(3.871)
Adj.-R^2	0.783	0.393	0.747	0.708	0.757	0.491

Table 5
Regression results for different risk measures

This table shows the estimated coefficients of different risk measures when regressing the repo spread, repo trading volume, and the average repo term on various state variables. Each column corresponds to a regression with the dependent variable shown in the first row. The regressions are the same as in Equations (1) to (3), but in each row a different proxy for risk is used, which is indicated in the first column. The interest rate spreads ($LIBOIS$, $10ySpread^{ESP-GER}$, and $10ySpread^{ITA-GER}$) are measured in percentage points. CDS spreads and volatility ($iTraxx$ and $VSTOXX$) are measured in percent. Absolute values of target balances ($TARGET^{Germany}$ and $TARGET^{GIIPS}$) are measured in EUR trillion. Regressions are based on weekly data from January 2006 to February 2013. Columns 2 to 4 show results for the sample prior to the introduction of fixed-rate full allotment refinancing operations at the ECB on October 15, 2008. Columns 5 to 7 present regression results for the sample period after this date. HAC standard errors are shown in parentheses. The stars ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Prior to full allotment			After full allotment		
	S_t^{1d}	VOL_t^{1d}	$AVGTERM_t$	S_t^{1d}	VOL_t^{1d}	$AVGTERM_t$
$CISS_{t-1}$	0.046	0.558**	4.569***	0.043	0.708***	−0.055
	(0.075)	(0.224)	(1.675)	(0.038)	(0.180)	(0.897)
$LIBOIS_{t-1}$	−0.037*	−0.047	1.134	0.030	0.362***	−0.615
	(0.022)	(0.123)	(0.843)	(0.021)	(0.134)	(0.506)
$iTraxx_{t-1}$	0.055	0.236**	2.138***	0.006	0.118**	0.264
	(0.035)	(0.100)	(0.559)	(0.010)	(0.057)	(0.287)
$TARGET_{t-1}^{Germany}$	0.014	3.004***	9.515**	−0.041	1.533*	2.065
	(0.198)	(0.934)	(4.385)	(0.073)	(0.814)	(1.785)
$TARGET_{t-1}^{GIIPS}$	0.297	0.203	25.561***	0.024	1.078**	1.283
	(0.331)	(0.979)	(6.608)	(0.051)	(0.512)	(1.355)
$VSTOXX_{t-1}$	0.000	0.016***	0.070	0.000	0.009**	−0.016
	(0.001)	(0.004)	(0.056)	(0.001)	(0.004)	(0.016)
$10ySpread_{t-1}^{ESP-GER}$	0.100	0.179	5.038***	−0.003	0.070**	0.124
	(0.070)	(0.234)	(1.435)	(0.007)	(0.035)	(0.171)
$10ySpread_{t-1}^{ITA-GER}$	0.088	0.295	5.713***	0.001	0.073	0.071
	(0.094)	(0.372)	(1.554)	(0.007)	(0.045)	(0.177)

Table 6
Drivers of the term spread

This table shows the results of regressing the one-year repo term spread on various state variables. The term spread is the spread between the repo rates of repos with a maturity of one year and repos with a term of one day (o/n, t/n, and s/n). The state variables are explained in Section 4.1. Regressions are based on weekly data from January 2006 to February 2013. Column 2 shows results for the sample prior to the introduction of fixed-rate full allotment refinancing operations at the ECB on October 15, 2008. Column 3 presents regression results for the sample period after this date. HAC standard errors are shown in parentheses. The stars ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Prior to full allotment	After full allotment
const.	−0.518	0.696 * **
	(0.535)	(0.096)
S^{1d}_{t-1}	2.307 * *	0.306
	(0.918)	(0.231)
$AVGTERM_{t-1}$	0.007	0.006
	(0.016)	(0.005)
VOL^{1d}_{t-1}	−0.189	−0.079 * *
	(0.119)	(0.033)
$VOL^{1d}_{t-1} * DUM^{EL>300}_{t-1}$		0.009
		(0.031)
$CISS_{t-1}$	−0.549*	−0.279 * *
	(0.295)	(0.112)
EL_{t-1}	3.846	−0.704*
	(2.854)	(0.359)
$EL_{t-1} * DUM^{EL>300}_{t-1}$		0.088
		(0.290)
HCR_{t-1}		−0.118
		(0.294)
EMC_{t-1}	1.002 * *	0.617 * **
	(0.397)	(0.146)
Adj. - R^2	0.462	0.599

Table 7
Term-adjusted trading volume

This table shows the results of regressing the term-adjusted repo volume on various state variables. The term-adjusted trading volume is constructed by multiplying trading volume for each repo transaction by the corresponding repo maturity in days. Regressions are based on weekly data from January 2006 to February 2013. Column 2 shows results for the sample prior to the introduction of fixed-rate full allotment refinancing operations at the ECB on October 15, 2008. Column 3 presents regression results for the sample period after this date. HAC standard errors are shown in parentheses. The stars ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Prior to full allotment	After full allotment
const.	4.525	0.921
	(5.125)	(3.176)
trend	0.003	0.034***
	(0.005)	(0.009)
S^{1d}_{t-1}	−3.403	−6.960**
	(7.950)	(3.109)
$AVGTERM_{t-1}$	−0.073	0.802***
	(0.165)	(0.281)
$VOL^{GC,ta}_{t-1}$	−0.013	−0.259**
	(0.234)	(0.124)
VOL^{EONIA}_{t-1}	−0.574	−0.740**
	(0.363)	(0.321)
$CISS_{t-1}$	10.459***	7.396***
	(3.356)	(2.236)
EL_{t-1}	−20.468	−18.513***
	(18.426)	(6.280)
$EL_{t-1} * DUM^{EL>300}_{t-1}$		10.348**
		(4.734)
HCR_{t-1}		4.474
		(3.800)
EMC_{t-1}	0.584	−0.708
	(1.772)	(2.267)
Adj. - R^2	0.469	0.183

Table 8
Comparison of different repo markets

This table schematically summarizes information about the type of repo and collateral, the market infrastructure, and the main empirical results for the repos considered in this paper and in the empirical literature on the U.S. repo market. We use the following abbreviations for the studies about the U.S. repo markets: *GM* for Gorton and Metrick (2012), *KNO* for Krishnamurthy, Nagel, and Orlov (2014), and *CMW* for Copeland, Martin, and Walker (2014). We distinguish four categories of collateral: Very safe collateral includes high quality government bonds. Safe collateral includes agency and medium risk government bonds. Risky government bonds and high quality corporate bonds are included in the intermediate category. Risky collateral includes, for instance, private asset-backed securities. We use the following abbreviations: CB means central bank, MMFs money market funds, SLs security lenders, and n/a not available.

	Euro Interbank repo market						U.S. repo market			
	This paper						*GM*	*KNO*		*CMW*
	Eurex GC Pooling		BrokerTec and MTS			Bilateral	Bilateral	Repo lending by MMFs and SLs		Triparty
	ECB	ECB EXTended	Germany	France	Italy	non-CCP		MMFs	SLs	
Type of repos										
Bilateral CCP-based	✓	✓	✓	✓	✓					
Bilateral non-CCP-based						✓	✓			
Triparty								✓	✓	✓
Infrastructure										
Anonymous trading	✓	✓	✓	✓	✓					(✓)[32]
Integrated reusability of collateral for CB operations	✓									
Pooling of repo trades	✓	✓								
Collateral										
Very safe	✓		✓					✓		✓
Safe		✓		✓				✓		✓
Intermediate					✓	✓	✓		✓	✓
Risky						✓	✓		✓	✓
Development during crisis										
Volume	+	+	+	+	=	–	n/a	–	–	–
Spread	=	+	=	+	+	n/a	+	=	+	n/a
Maturity	+	–	n/a	n/a	n/a	n/a	n/a	–	–	n/a
Haircuts	=	=	n/a	n/a	n/a	n/a	+	=	+	=
Sample										
Period	2006–2013						2007–2009	2007–2010		2008–2010
Frequency	intradaily, daily, weekly		daily, weekly			annually	weekly	quarterly		daily

[32] The sample investigated by Copeland, Martin, and Walker (2014) includes anonymous GCF repos. However, the majority of the triparty repos investigated in their paper are not anonymous.