

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 the central counterparty (CCP)-based euro interbank repo market features this quality. Using a unique and comprehensive data set, we show that the market is resilient during crisis episodes and may even act as a shock absorber, in the sense that repo lending increases with risk, while spreads, maturities, and haircuts remain stable. Our comparison across different repo markets shows that anonymous CCP-based trading, safe collateral, and the absence of an unwind mechanism are the key characteristics to ensure market resilience.

KEYWORDS: Repurchase agreements, money market structure, central counterparty, short-term debt, financial crisis, unconventional monetary policy

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

1. Introduction

Banks heavily rely on short-term funding, which exposes them to runs, rollover risk, and wider financial contagion. The fragility of funding markets crucially depends on the market structure (Martin, Skeie, and von Thadden, 2014a). Is there a short-term funding market 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 risk is high and overall funding conditions tighten?

This paper empirically addresses the questions above by analyzing the euro interbank repo market,¹ and by comparing the characteristics and development of different repo markets in the United States and Europe. We show that the central counterparty (CCP)-based euro interbank repo market functions well, even during crisis periods. It can even act as a *shock absorber*, in the sense that repo lending *increases* with risk, while spreads, maturities, and haircuts (or margins) remain stable. The key market features to ensure resilience are anonymous CCP-based trading, safe collateral, and the absence of an “unwind” mechanism.²

A basic prediction of money market theory is that banks reduce lending in crisis times, e.g., when aggregate risk (Allen, Carletti, and Gale, 2009), uncertainty (Caballero and Krishnamurthy, 2008), lenders’ rollover risk (Acharya and Skeie, 2011), informational frictions (e.g., Stiglitz and Weiss, 1981), or risk of fire sales (Diamond and Rajan, 2011) increase. Recent research highlights the importance of the market structure for the fragility of funding markets (Martin, Skeie, and

¹A repo is essentially a collateralized loan based on a simultaneous sale and forward agreement to repurchase securities at the maturity date.

²Prior to the ongoing U.S. triparty repo market reform, an unwind of the repo trade occurred every morning to give borrowers the opportunity to substitute collateral and to adjust for price fluctuations. Until the repo agreement was rewound in the afternoon, the triparty clearing bank was lending to the repo borrower between this 8:00–8:30 a.m. unwind and the rewind after 3:30 p.m. Nowadays, much less intraday credit is extended by the clearing bank.

von Thadden, 2014a). The euro interbank repo market has a unique structure as the majority of repos are traded anonymously via CCPs. Haircuts are set by the CCP and are thus exogenous to repo traders. Moreover, euro interbank repos are collateralized by relatively safe securities (e.g., government bonds), and are not subject to the daily unwind that has proven to be problematic in the United States. Thus, analyzing the euro interbank repo market helps understand how these unique features impact repo market activity and which market features are key for repo market stability.

Existing theory provides no clear prediction about the functioning of the euro interbank repo market in distressed periods. On the one hand, trading anonymously via a CCP eliminates direct counterparty exposures. With respect to first-come-first-served and coordination failure issues, a CCP-based market is similar to the triparty repo market without unwind in Martin, Skeie, and von Thadden (2014a). Their model shows that there are no strict incentives to run on borrowers in this case. Moreover, the CCP liquidates collateral and distributes losses in case of default of a participating bank, which alleviates the risk of disorderly liquidation of collateral (see Oehmke, 2014). On the other hand, CCPs involve a larger concentration of credit and operational risks (e.g., Singh, 2010) and moral hazard (Biais, Heider, and Hoerova, 2012). Moreover, if banks forgo bilateral netting opportunities across different contracts by trading in a CCP-based market for repos, this may actually increase their overall counterparty exposure and thus increase the fragility of the financial system (Duffie and Zhu, 2011).

Recent theories also discuss the role of safe collateral, the flexibility of haircuts, and the daily unwind. Relying on safe and liquid collateral reduces the risk of individual and systemic runs (Martin, Skeie, and von Thadden, 2014b). However, a market structure in which repo traders cannot adjust haircuts dynamically may actually increase market fragility. The volatility of hair-

cuts should reflect the volatility of collateral value (Brunnermeier and Pedersen, 2009; Jurek and Stafford, 2012), and the flexibility of haircuts is important for distressed borrowers to receive funding (Martin, Skeie, and von Thadden, 2014a). Repo traders being able to increase haircuts during times of stress contributes to making repo loans informational insensitive (e.g., Dang, Gorton, and Holmström, 2012; Gorton and Ordoñez, 2014). A daily unwind makes a repo market fragile and increases the risk of runs on borrowers (Martin, Skeie, and von Thadden, 2014a).

Overall, it is a priori unclear how fragile a repo market with anonymous CCP-based trading, safe collateral, and no unwind is during crisis periods. No previous theoretical or empirical study has conducted a joint analysis of these market features. Using a unique and comprehensive data set, this paper fills this gap by providing the first systematic analysis of the euro interbank repo market and by highlighting which market features fosters repo market stability. Our data cover the vast majority of CCP-based repo transactions. By investigating repo spreads, volumes, maturities, and haircuts, we cover all main channels of risk mitigation that banks or the CCP may use. 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 monetary policy changes.

Contrary to the basic theoretical prediction that lending decreases in times of crisis, our empirical results indicate that the CCP-based euro interbank repo market is resilient. In contrast to the other parts of the euro interbank 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 repo spreads or a shortening of the average repo term during the recent financial crisis or the European debt crisis. Consistent with a substitution effect from unsecured to secured lending, we show that repo volume is negatively related to volume in the unsecured money market.

While we find evidence that the whole CCP-based euro repo market is resilient, there are also cross-sectional differences, highlighting the importance of collateral quality. On the one hand, repos with relatively riskier collateral, such as Italian government bonds, exhibit weaker resilience. On the other hand, volume for repos secured by the safest securities (e.g., German government bonds) increases, suggesting that these repos may actually behave as a shock absorber.

What are the features that make a repo market resilient? To answer that question, we compare the developments and main characteristics of the CCP-based euro interbank repo market with other repo markets in Europe and the United States. We conclude that anonymous trading via a CCP, safe collateral, and the absence of an unwind mechanism are *jointly* sufficient to ensure market resilience. Individually, safe collateral or an anonymous CCP-based infrastructure are not sufficient.

Our paper contributes to the literature on repo markets along various dimensions. 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 normal and distressed periods such as the European sovereign debt crisis. Given that most euro repos are collateralized by government bonds, the sovereign risk of countries such as Greece, Ireland, Italy, Portugal, and Spain (GIIPS) may have impaired repo market activity. In addition, the euro repo market

may have been affected by the worsened funding conditions of European banks, the threat of a euro zone-breakup, the ensuing redenomination risk, and the uncertainty about the regulatory framework (e.g., related to the proposed European banking union).

By discussing the importance of different repo market features, we provide empirical evidence on the theoretical debate about the repo market structure. Because CCPs have mostly been studied theoretically (e.g., Duffie and Zhu, 2011; Capponi, Cheng, and Rajan, 2015), we contribute to the more general debate about benefits and drawbacks of CCPs by providing empirical evidence that a CCP-based market performed well during crises periods. Lastly, we extend this literature by conducting regression analysis to identify the main determinants of repo rates, volume, and maturity.

We also contribute to the literature about (unconventional) central bank policy (e.g., Freixas, Martin, and Skeie, 2011; Giannone et al., 2012; Drechsel et al., 2015; Eser and Schwaab, 2015) by highlighting the effect of central bank policy on repo market activity. Our results show that repo rates decrease with ECB liquidity provision up to a saturation threshold of EUR 300 billion of excess liquidity,³ 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. 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 from “private” to “public” liquidity suggests that accommodative central bank liquidity provision can reduce the demand for private funding, providing empirical support to the model by Bolton, Santos, and Scheinkman (2009).

³Consistent 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.

2. Institutional background of the euro repo market

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 by the Financial Stability Board (2012). The interbank repo market is the part excluding all repos outside the banking sector, or with customers or intragroup trades. It is crucial for an efficient allocation of liquidity and collateral among banks and broker-dealers, facilitating price discovery for funding liquidity. The majority of euro repo transactions are conducted in this segment (Bakk-Simon et al., 2012). Participants include commercial, retail, and investment banks, as well as more specialized institutions (e.g., public banks, cooperatives, saving institutions, and national central banks).

The euro interbank repo market can be divided into three parts: CCP-based, bilateral, and triparty. CCP-based repos constitute the majority in the euro interbank repo market. From 2009 to 2013 the market share of CCP-based repos increased from 42% to 71%, whereas the share of bilateral repos declined from 50% to 19%. The share of triparty repos remained relatively constant at around 10% (European Central Bank, 2013). Bilateral repos constitute the traditional over-the-counter market, in which the borrower and the lender trade directly with each other. Haircuts are part of the negotiation and both parties are exposed to each other's counterparty risk. Bilateral repos typically involve less standard securities as collateral and more customized contract terms. In triparty repos, a third party organizes the settlement and collateral management. However, the counterparty risk remains with the repo traders. Triparty repos are typically used to manage non-government bonds and equity.⁴ Repos with government bonds and other relatively safe securities

⁴The 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).

as collateral are predominantly CCP-based and traded via anonymous electronic platforms.

In a CCP-based repo transaction, a central counterparty bears the counterparty risk — the borrower and lender remain anonymous and do not have any direct exposure to each other. The CCPs have various lines of defense and clear rules in place to protect itself and the participants against the default of a counterparty. Thus, banks lending via a CCP are essentially protected from losses in case of default of a borrower.⁵ CCP-based repos are multilaterally-cleared, resulting in smaller net payment and collateral delivery obligations between the banks and the CCP. The haircuts in this market are not subject to negotiation between lender and borrower, but are set centrally by the CCP, which is responsible for risk management. There are three main electronic trading platforms constituting the CCP-based euro interbank repo market, namely Eurex Repo, BrokerTec, and MTS. Eurex Repo GmbH is the leading electronic trading platform for euro general collateral (GC) repos, whereas the majority of trading volume on BrokerTec and MTS is in repos with specific collateral.⁶ We discuss their institutional features in more detail in the Appendix.

[Include Figure 1 about here]

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). However, the euro repo market structure is very

⁵For instance, at Eurex Repo, the market is structured in a way that a lender does not learn about the default of a borrower. The lender and any other market 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 the CCP, Eurex Clearing, runs out of reserves. LCH.Clearnet, another important CCP, has a similar waterfall procedure in case of default of a clearing member.

⁶Repo transactions are typically used for funding 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.

different than that in the United States.⁷ For instance, with more than 50%, the share of triparty repos is much larger in the United States (Copeland et al., 2012a). Moreover, the euro interbank repo market is populated by banks, who have access to the ECB’s refinancing facilities, whereas the dealers, who dominate the repo market in the United States may not have access to such a liquidity backstop in times of crisis.

The repo infrastructure most similar to the CCP-based euro interbank repo market in the United States is the GCF (General Collateral Finance) repo market, which is an anonymous, brokered market run by the Fixed Income Clearing Corporation (FICC). In this market, which is explained in detail in Agueci et al. (2014), the FICC has the role of a central counterparty. Repo traders are not exposed to each other’s counterparty risk and the FICC decides which classes of safe securities are eligible as collateral. There are some important differences though. The GCF market depends on clearing banks settling repos on their own books. This entails several (possibly systemic) threats, including the collapse of clearing banks and issues related to the daily unwind mechanism. In Europe, triparty and CCP-based repos are not unwound daily. Instead, direct substitution of collateral is possible and margining is used to account for changes in the value of collateral.

3. Empirical analysis

3.1. Data set

To conduct a comprehensive study of the euro interbank repo market, we collect data on all main risk mitigation channels a lender or the CCP may use. Namely, we investigate repo rates, volume, maturity, and haircuts for different collateral baskets. Our data set includes repos traded on

⁷Adrian et al. (2013) and Copeland et al. (2012b) provide a detailed explanation of the institutional setting of the U.S. repo market.

all three major electronic platforms and allows us to accurately investigate the CCP-based repo market.⁸

Our main data set includes all GC Pooling (GCP) transactions that were executed on the Eurex Repo trading platform between January 2006 and February 2013. 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. The GCP ECB basket consists of the safest, very high quality collateral securities. More precisely, it includes those securities admitted for collateralization of open market operations by the ECB that have been rated at least A−/A3, subject to a number of further restrictions.⁹ The GCP ECB EXTended basket consists of a larger subset of the securities admitted at the ECB. Compared to the GCP ECB basket, the list of eligible securities includes riskier, but still safe securities. For instance, the minimum rating requirement is equal to the one applied by the ECB, implying that Italian and Spanish government bonds are eligible.¹⁰

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

⁸The data are representative for the CCP-based euro interbank repo market. The average daily trading volume in our data is actually larger than the CCP-based volume reported in the ECB's money market study (European Central Bank, 2012), in which only 172 banks participate.

⁹The 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 currently not eligible. In addition, Eurex has concentration limits in place to ensure adequate diversification of collateral.

¹⁰Compared with the GCP ECB basket, 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.

mature on days at the end of maintenance period or at the end of the quarter.¹¹

Repos collateralized by the GCP ECB basket are regarded as a benchmark in the euro repo market and thus also serve as a benchmark for our analysis. Our main focus are short-term repos (o/n, t/n, and s/n), because more than 80% of GCP repos have a term of one day. The short-term segment of the repo market is by far the most active and it is important for the functioning of the overall secured interbank market.

To analyze repos traded on 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.¹² 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. These repos constitute more than 80% of the trading volume on BrokerTec and MTS. RFR Germany represents very safe collateral similar to the GCP ECB basket. The risk of RFR France is close to the ECB EXTended basket, whereas RFR Italy is the most risky of the three.¹³ While Eurex GCP repos are unambiguously used for funding purposes, the trades underlying the RFR indexes also contain specials and may thus be partially driven by the demand for specific securities rather than the demand for funding. Moreover, 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 spreads and volume.

¹¹In 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 due to possible day of the week effects.

¹²BrokerTec repos are also studied in Dunne, Fleming, and Zholos (2011), who conduct a microstructure analysis and relate repo transactions to the bidding behaviors at ECB auctions.

¹³Italian securities are among the riskiest securities included in the GCP ECB EXTended basket and compared to the broad GCP baskets there is less diversification in the collateral of RFR repos. Thus, RFR Italy can be regarded as riskier than the GCP EXTended basket.

3.2. Repo rates, volume, and maturity

A repo market is resilient if lending volume and maturity are non-decreasing and repo rates and haircuts are non-increasing during crisis periods. To provide initial evidence regarding resilience of the CCP-based repo market, this subsection analyzes the main market developments in terms of rates, volume, and maturity. For the sake of brevity, we focus on Eurex Repo data. Repo rates and volumes for BrokerTec and MTS repos, which we report in the Internet Appendix, exhibit similar patterns.

Panel A of Figure 2 shows the evolution of short-term GCP ECB basket repo rates over time. Until the fall of 2008, repo rates increase in line with the ECB's interest rate 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, 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 rate at which banks can deposit liquidity at the ECB ($r_t^{ECB,deposit}$), whereas a repo spread of one occurs when repo rates equal the rate for 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 2; 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.¹⁴ This pattern changed dramatically after the ECB moved to the FRFA regime and repo rates dropped toward the floor of the corridor. Even in 2010 and 2011 when repo rates increased from the bottom towards the middle of the corridor, rates generally remained at a lower level than before the financial crisis. In the period following the 3-year longer-term refinancing operations (LTROs), repo rates hovered near the ECB deposit rate.¹⁵ These developments are consistent with the repo market being resilient, as there is no evidence that repo spreads increased above pre-crisis levels.

Repo volume in Figure 3 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 supports the resilience hypothesis and 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 (see, e.g., Gorton and Metrick, 2012). After the 3-year LTRO in December 2011, euro repo volume declined again to approximately EUR 25 billion. 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.

We neither observe a reduction of the average term (AT) during the financial crisis nor during the European debt crisis, suggesting that repo traders did also not reduce risk exposure via this channel. Table 1 shows that the average term even increased during our sample period (from 2.8

¹⁴The 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.

¹⁵The ECB introduced LTROs to extend the standard (bi)weekly maturity of its MROs up to three, six, 12, and 36 months.

in the first subsample to 6.4 days after the first 3-year LTRO). This increase is in contrast to the shortening of maturity in the United States (Gorton, Metrick, and Xei, 2012).

[Include Figures 2 and 3 and Table 1 about here]

3.3. Eligible collateral and haircuts

The last component to investigate the resilience of the repo market is the haircut applied to the collateral in the repo transactions. Haircuts in the CCP-based euro interbank repo market are not subject to negotiation between borrower and lender. Instead, the CCP determines which collateral is eligible and specifies haircut rules. Thus, haircuts are exogenous to repo traders and the lender cannot increase haircuts as a means of risk mitigation. In the Eurex GCP 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. The main decision for the CCP is to choose which securities it accepts as collateral. Eurex excludes certain riskier securities from its GCP baskets, resulting in fewer securities being eligible in the GCP market compared to the ECB. For instance, asset-backed securities were never eligible as collateral within the GCP baskets.

To analyze the number of accepted securities, we obtained the list of eligible securities for ECB operations from the ECB website¹⁶ and used this list as the basis for our calculations. For each week in our sample, we apply eligibility rules¹⁷ and determine the number of accepted securities that is shown in Panel A of Figure 4. The number 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

¹⁶The list of securities 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.

¹⁷Because 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.

part of the GCP ECB basket. The ECB EXTended basket lies in between the two.

The main increases in the number of eligible securities at the ECB in October 2008 and in January 2012 are due to decisions to expand the list of eligible securities for ECB refinancing operations to alleviate funding strains. At the beginning of 2011 some of these crisis measures expired, reducing the list of eligible securities. The number of eligible securities in the GCP ECB basket remains much more stable. It was reduced on January 27, 2012 when Italian securities became ineligible.

The equally weighted average haircut for each basket is shown in Panel B of Figure 4, 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 4 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 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 type¹⁸ 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

¹⁸We 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.

EXTended basket. See the Internet Appendix for a more detailed description on how we construct our haircut measures and a figure showing volume-weighted average haircuts over time. Overall, haircuts remain relatively stable, supporting the resilience hypothesis.

4. What drives repo market activity?

In this section we study which variables drive repo rates, volumes, and terms. We first introduce the state variables for repo market activity and conduct a comprehensive regression analysis for Eurex GCP ECB basket repos. Then, we extend our analysis to other collateral baskets, namely the GCP ECB EXTended basket and repos traded on BrokertTec and MTS with German, French, and Italian government bonds as collateral.

4.1. Determinants of repo market activity

Although no comprehensive model for repo market activity exists, 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. Descriptive statistics for all state variables are provided in Table 1.

4.1.1 Risk

As discussed in the introduction, the literature suggests various mechanisms that relate risk to money market rates, volume, and maturity. Three scenarios are possible: repo market activity is negatively affected by risk, unaffected by risk, or positively impacted by risk. In line with the basic prediction discussed above, the first scenario is that credit rationing and liquidity hoarding

in times of crises induces banks to reduce or even stop lending irrespective of the whether loans are unsecured or secured. In the second scenario, that is, repo market activity is unaffected by risk, the repo market is resilient. 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, which can happen if repo lending replaces riskier funding sources. Under this shock absorber hypothesis, risk positively impacts repo volume, while repo spreads are not positively affected and maturity is not decreasing. Moreover, a decrease in unsecured trading volume is associated with an increase in repo volume.

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 a proxy for stress in the European financial system. This risk indicator, that we plot in Panel A of Figure 5, 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 the Internet Appendix that our results are robust to using various different risk measures, capturing 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.¹⁹

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 5) as a state

¹⁹The risk measures are 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 of Germany and countries most affected by the European debt crisis (Greece, Ireland, Italy, Portugal, and Spain, abbreviated as GIIPS).

variable for repo volume.²⁰ Panel B of Figure 5 shows that overnight unsecured lending declined significantly from 2008 to 2013.

[Include Figure 5 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 risky securities accepted at the ECB is increased relative to that in the private market, banks 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). Similarly, if the CCP excludes the riskiest securities from the collateral basket, this can 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,

²⁰The 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.

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 5. The main changes in this variable mirror the changes in eligibility rules discussed in Section 3.3.

4.1.3 Central bank policy

Central bank policy is a main driver of interest rates in general and repo market activity in particular. 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. We consider both in our analysis.

First, 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 5, 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.²¹

Second, consistent with the European Central Bank (2002, 2010), we define excess liquidity (denoted by *EL*) as credit institutions’ current account holdings at the ECB plus funds in the ECB deposit facility minus reserve requirements.²² Panel E of Figure 5 shows how *EL* changed over time. When this variable is above zero, the liquidity supplied by the ECB via its refinancing

²¹Our 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.

²²We downloaded data on daily liquidity conditions from the ECB website www.ecb.int/stats/monetary/res/html/index.en.html.

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 6 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. Thus, to indicate high levels of excess liquidity, we define a dummy variable that equals one if EL is larger than EUR 300 billion.²³ 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 money market study (European Central Bank, 2012). Thus, we deem EL to be high if it exceeds private money market funding.

[Include Figure 6 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 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

²³We experimented with other excess liquidity thresholds, such as EUR 250 or EUR 350 billion, and our results are virtually unchanged.

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 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.

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. We use past values of the state variables as regressors to 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.²⁴ 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.²⁵

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

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

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

²⁴The 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.

²⁵Additional 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.

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 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.

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. Overall, our empirical results suggest that Eurex GCP repos even behave as a shock absorber, facilitating interbank lending during financial crises.²⁶

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

²⁶In the Internet Appendix we analyze the term spread and term-adjusted trading volume as dependent variables. We do not find that the term spread increases with risk, suggesting that longer-term repos are also resilient. Repeating our regression analysis with term-adjusted trading volume to account for potential shifts in the maturity structure of traded repos does not alter our conclusions.

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 smaller and safer compared with the one at the ECB. This lower risk and fewer options for banks that only lend with the very safe GCP ECB basket as collateral pushes repo rates down.

In the FRFA period, a lower repo spread (S_{t-1}^{1d}) 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_{t-1}^{1d}) 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 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. 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.

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 the repo market, when the ECB is offering unlimited liquidity at relatively favorable terms. Our 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.²⁷

[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.

²⁷According to Figure 6, the EUR 300 billion threshold is closely related to the introduction of the two 3-year LTROs in December 2011 and February 2012. In the Internet Appendix we analyze the role of the LTROs in more detail and show that our results are very similar if we replace $DUM^{EL>300}$ with a dummy variable that is one in the period following the first 3-year LTRO. Moreover, we show that our results are robust to allowing for separate effects of the 3-year LTRO by including a dummy variable that equals one after the first 3-year LTRO and by allowing risk to have a different effect on repo market activity in the period after the first 3-year LTRO. Our conclusions also remain unchanged when we decompose EL into volume from 3-year LTROs and regular refinancing operations.

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 safest repos. 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. An increase (decrease) of repo volume with risk when repo trades are collateralized by German (Italian) bonds would corroborate the hypothesis that the safety of collateral is a necessary condition for the resilience 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 GCP ECB basket, lending volume of RFR Germany repos, which are the safest among the three indexes, increases with risk, while repo spreads remain unaffected. 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 (RFR Germany) 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]

5. Which characteristics make a repo market resilient?

The previous analysis shows that the CCP-based euro interbank repo market is resilient, facilitating short-term funding, even in times of crisis. In this section, we analyze which characteristics

make a repo market resilient. To that end, we compare the development of the CCP-based euro interbank repo market with that of other repo segments in Europe and U.S. repo markets as documented in Gorton and Metrick (2012), Krishnamurthy, Nagel, and Orlov (2014), Copeland, Martin, and Walker (2014), and Agueci et al. (2014). Table 5 summarizes the main developments of the European and U.S. repo markets in terms of lending volume, rates, maturity, and haircuts during the 2007–10 crisis together with the main market features. We collect information on the types of repo (CCP-based, bilateral, or triparty), the infrastructure (anonymous trading, unwind mechanism, collateral reusability, pooling feature, third party collateral management), and the collateral quality (from very safe to risky securities).

First, we focus on Europe and compare developments in the bilateral, triparty, and CCP-based segments of the euro interbank repo market. The ECB money market surveys (European Central Bank, 2013) show that bilateral repo volume declined significantly during our sample period. Triparty repo volume remained more stable than the bilateral segment, but it also declined during the years of financial and European sovereign debt crisis. Figure 7 shows the time series evolution of volume in these segments, together with CCP-based repo volume, which exhibits an increasing trend. Thus, the CCP-based segment represents the sole resilient part of the euro repo market, suggesting that anonymous CCP-based trading is a necessary condition for repo market resilience. However, the results in the previous section indicate that it is not a sufficient condition, because CCP-based repos with relatively riskier collateral exhibit weaker resilience. Moreover, the reputation of the CCP might be threatened if it accepted risky collateral (Kroszner, 2006). Hence, high quality collateral and a CCP-based infrastructure appear to be complements for creating a resilient repo market.

Other market characteristics of the CCP-based euro repo market appear to be less important

for resilience. First, the fact that the volume of non-CCP-based euro interbank repos declined is a sign that general access to the ECB as the lender of last resort, which may mitigate the impact of fire-sales (Begalle et al., 2013), is not sufficient to make a repo market resilient. Second, Eurex GCP features an integrated reusability of collateral for central bank operations, the pooling of repo transactions, and third-party collateral management while BrokerTec and MTS do not. The similar patterns of repos secured by the safest collateral (Eurex GCP ECB basket and RFR Germany) suggest that these characteristics are not necessary conditions for resilience.

[Include Table 5 and Figure 7 about here]

We now turn to the comparison between European and U.S. repo markets. Comparing the results across studies on U.S. repos provides further support to our conclusion that both the type of repo and the riskiness of collateral matter for repo market resilience. Similar to Europe, the U.S. bilateral repo market was vulnerable during the recent financial crisis (Gorton and Metrick, 2012). Copeland, Martin, and Walker (2014) show that the overall lending volume of U.S. triparty repos declined and that distressed institutions, such as Bear Stearns and Lehman Brothers, were excluded from the market even for repos with safe collateral. Krishnamurthy, Nagel, and Orlov (2014) show that repos by security lenders contracted strongly after the Lehman bankruptcy, whereas repos of money market funds remained more stable, because the latter replaced repos with riskier collateral with repos collateralized by U.S. Treasuries. This finding provides further support that collateral quality is necessary for repo market resilience. However, the fragility of the U.S. bilateral and triparty markets even with safe collateral shows that safe collateral is not sufficient for repo market resilience.

The two remaining characteristics that potentially explain why the U.S. triparty market is more fragile than the CCP-based euro repo market are the anonymous CCP-based infrastructure

in Europe and the unwind mechanism in the United States. To shed light on the role of these characteristics, GCF repos in the United States represent an interesting case, because they rely on an anonymous, brokered system with a central counterparty and safe collateral, similar to the CCP-based euro repo market. However, they are exposed to issues related to the daily unwind. Using data from March 2011 to September 2012, Agueci et al. (2014) show that GCF repos tend to be a substitute for triparty repo borrowing in normal periods. Moreover, they provide anecdotal evidence that a dealer experiencing a loss of funding in triparty repo, was able to increase its net cash position in the GCF repo market even in times of stress. Thus, GCF repos appear to represent a relatively resilient market, supporting that an anonymous CCP-based infrastructure and high-quality collateral strengthen market resilience. However, it is difficult to draw conclusions about the resilience of the GCF market, because we do not know how stable GCF repos were during severe crisis periods (e.g., after Lehman bankruptcy) and whether distressed dealers lost access to the market because of the reliance on intraday credit from the clearing banks due to the daily unwind. Repo market theory Martin, Skeie, and von Thadden (2014a) and the discussion in Agueci et al. (2014) clearly highlight that the daily unwind increases repo market fragility.

We conclude that resilience of the CCP-based euro interbank repo market stems from the combination of three important characteristics: an anonymous CCP-based infrastructure, safe collateral, and the absence of the unwind mechanism.

6. Conclusion

The structure of the repo market plays a key role for its fragility. Using a novel and comprehensive data set, this paper provides the first systematic study of the euro interbank repo market, which has a unique CCP-based market structure. We find that the market is resilient, in the sense that

repo spreads, volumes, maturities, and haircuts were not negatively affected during crisis periods. Repo loans secured by very safe collateral even act as a shock absorber, in the sense that repo lending increases with risk, while spreads, maturities, and haircuts remain stable.

The comparative analysis between different segments of the European and the U.S. repo markets suggests that the CCP-based euro interbank repo market is the most resilient market structure. Its resilience stems from the combination of three main characteristics: an anonymous CCP-based infrastructure, safe collateral, and the absence of the unwind mechanism. However, each of these characteristics taken separately is a necessary rather than sufficient condition for market resilience. Only if properly combined, these characteristics appear to be sufficient to prevent market fragility.

This paper delivers important insights for policy makers, funding market participants, and central bankers. First, the redesign of short-term funding markets is at the top of regulators' policy agenda (Financial Stability Board, 2012) and understanding which characteristics make a repo market resilient is crucial for financial stability. Our study suggests that European policy makers can strengthen the stability of the Euro money market by endorsing CCP-based repos as substitutes for unsecured loans and bilateral repos. For U.S. policy makers, our results suggest that the GCF segment of the U.S. triparty market already incorporates two out of the three main characteristics for resilience, i.e., anonymous CCP-based trading and safe collateral. Although the ongoing reform of the U.S. triparty repo market has already made progress, the next crucial step is the removal of remaining issues related to the unwind mechanism, such as the reliance on intraday credit to settle GCF repo positions (Aguerci et al., 2014).

Second, our study delivers important insights for participants in short-term funding markets. We show that banks holding eligible collateral securities can always satisfy their liquidity needs in an important part of the euro interbank repo market, even during severe crisis periods. Moreover,

we identify the key drivers of repo market activity in general and show how repo rates, volumes, and terms, react to risk and central bank liquidity. Thus, our paper facilitates banks' liquidity planning and risk management.

Third, this paper supports central bankers in assessing the effect of (unconventional) policies and potential exit strategies. We show that central bank liquidity provisions are effective in reducing interest rates, but only until a saturation threshold (around EUR 300 billion, in the case of the euro money market). Moreover, we show that excess liquidity supply can also have unintended consequences, such as a decrease in secured interbank lending.

Appendix:

Detailed description of the CCP-based repo market infrastructure

In this appendix we describe the institutional features of the CCP-based repo market. First, we discuss common characteristics across the three major electronic trading platforms: Eurex Repo, BrokerTec, and MTS. Then, we describe platform-specific features. All platforms facilitate anonymous trading via CCPs that are authorized as central counterparties under the European Markets Infrastructure Regulation (EMIR). The CCPs are regulated by the local regulators and central banks in the countries in which they operate. Also all participants are regulated, and there are various safeguards in place to protect the market in times of stress. Participants have to meet a number of criteria to be deemed eligible for clearing membership by the CCP. For instance, they need to be subject to a financial market supervisory authority in their country of domicile, meet minimum capital requirements, contribute to the clearing fund, fulfill regular stress tests or meet credit rating requirements. Another common feature is that repos with a maturity longer than one day are true term repos in the sense that there is no daily unwind mechanism as in the United

States. There are also some differences between trading venues, which we discuss in detail below.

Eurex Repo

Eurex Repo GmbH is the leading electronic trading platform for euro GC repos. GC Pooling repos, which constitute the vast majority of repo volume (more than 85%) traded on the Eurex platform, are traded via 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 for collateral management and settlement.²⁸ The CCP is owned by Deutsche Boerse Group, which is a publicly traded company. It fully complies with the recommendations for CCPs from the Committee on Payment and Settlement Systems (CPSS) and the Technical Committee of the International Organization of Securities Organization (IOSCO).

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.

²⁸Once 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.

BrokerTec and MTS

The other two major anonymous electronic trading platforms are BrokerTec and MTS Repo. BrokerTec is the larger of the two and operated by ICAP plc. Repos traded on MTS, which is part of MTS Group, and majority owned by the London Stock Exchange, predominantly rely on Italian government securities as collateral. BrokerTec and MTS link to several CCPs, namely LCH.Clearnet LTD, LCH.Clearnet SA, and Cassa di Compensazione e Garanzia (CC&G). CC&G solely clears repos with Italian government securities traded on MTS. LCH.Clearnet LTD and LCH.Clearnet SA, which are both part of LCH.Clearnet Group, provide clearing services for various assets.

In contrast to Eurex GCP repos, the repos underlying the RepoFunds Rate data published by BrokerTec and MTS rely on bilateral collateral management, i.e., the counterparties select the securities that are to be delivered as collateral by themselves. This is in line with the fact that the majority of repos traded on BrokerTec and MTS (about 80%) are specials, i.e., collateral is a single security rather than a basket. Integrated reusability for central bank operations or a pooling of collateral is not offered for the RFR repos.

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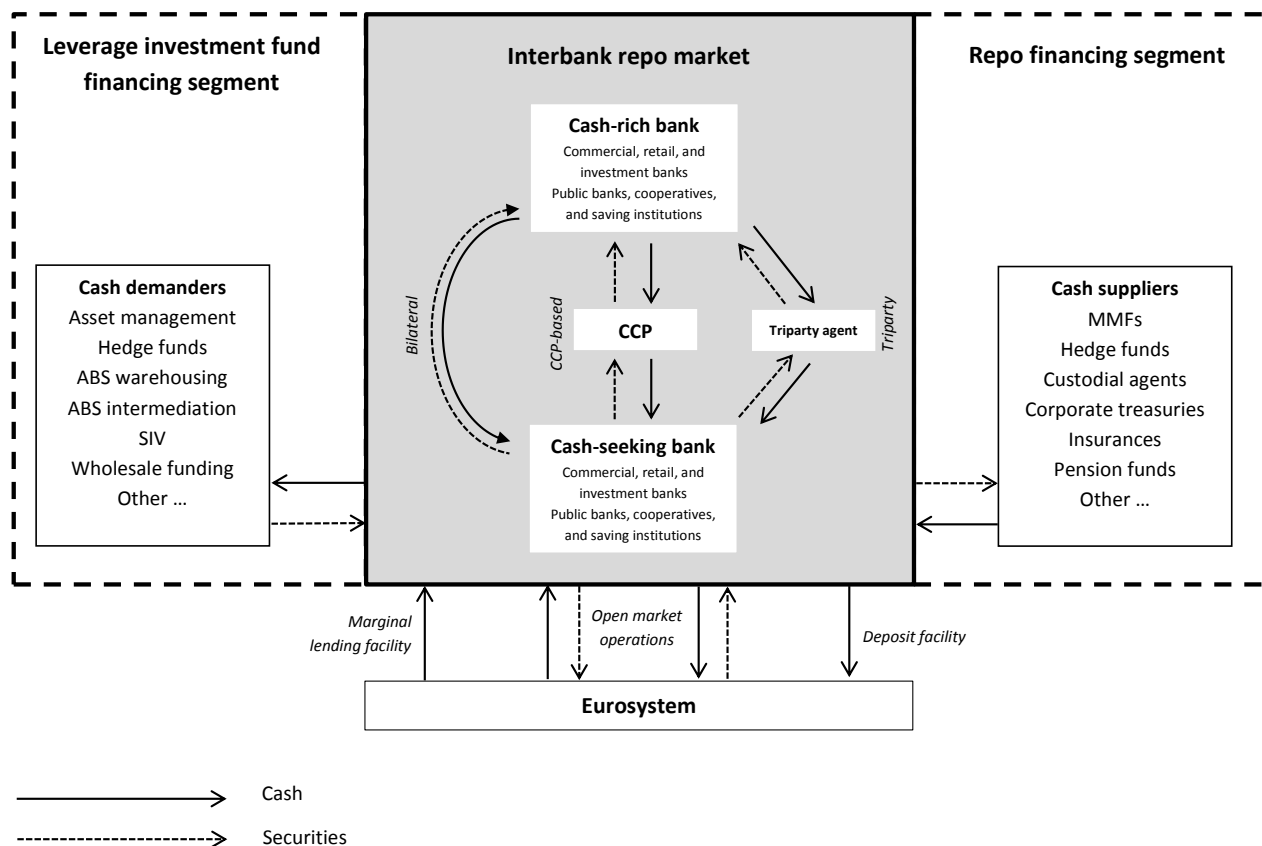


Figure 1. Schematic description of the euro repo market. This figure shows a schematic description of the euro repo market, including the main market participants in the white boxes. At the center is the euro interbank segment that is the focus of this paper. The figure shows the main forms of trading in the interbank repo market (bilateral, 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.

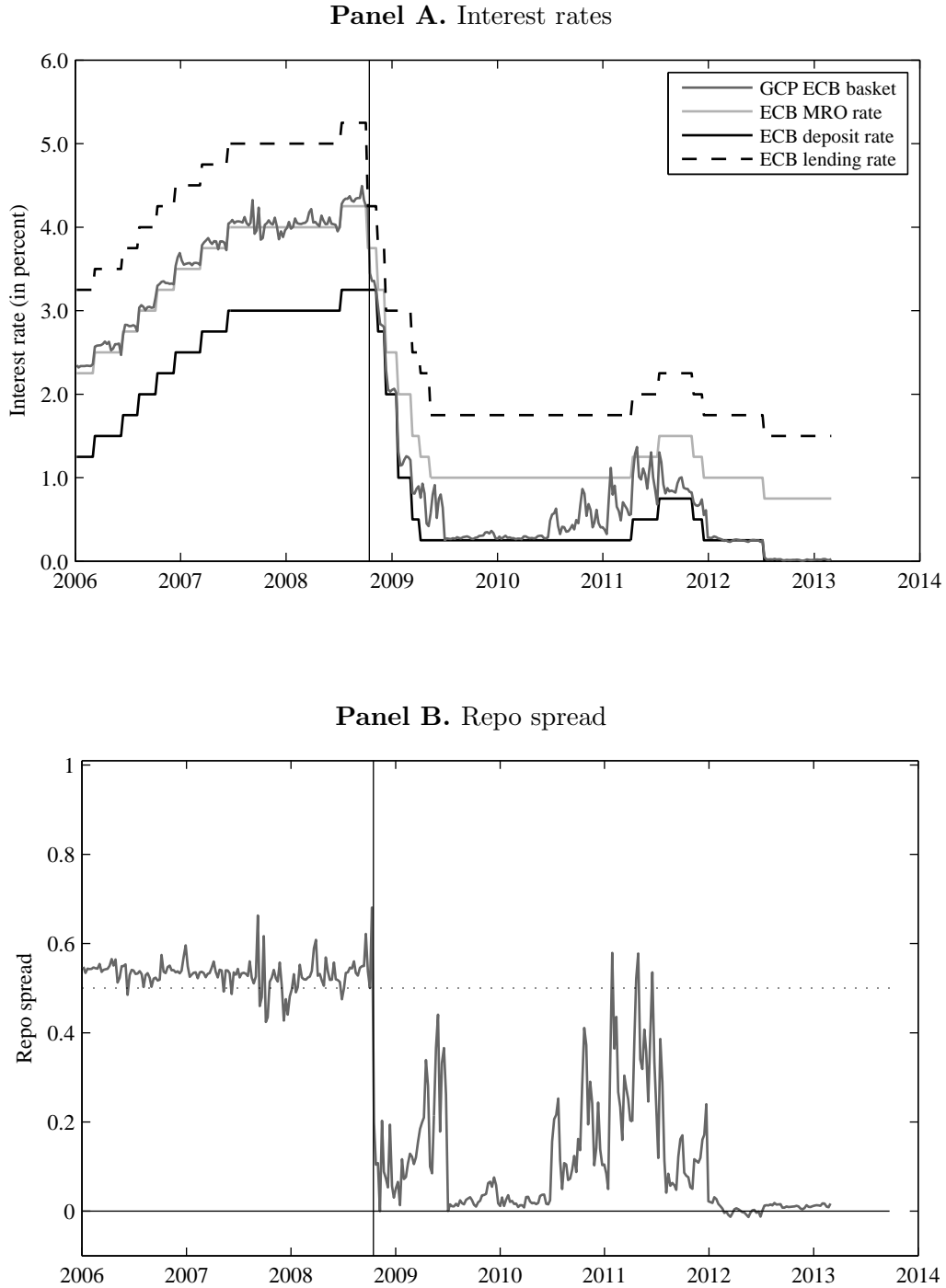


Figure 2. Volume-weighted average GCP ECB basket repo rate. Panel A shows the volume-weighted average GCP repo rate for the ECB basket (o/n, t/n, and s/n maturities) compared with the ECB refinancing rate, the ECB deposit rate, and the ECB lending rate. Panel B shows the repo spread that is computed 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.

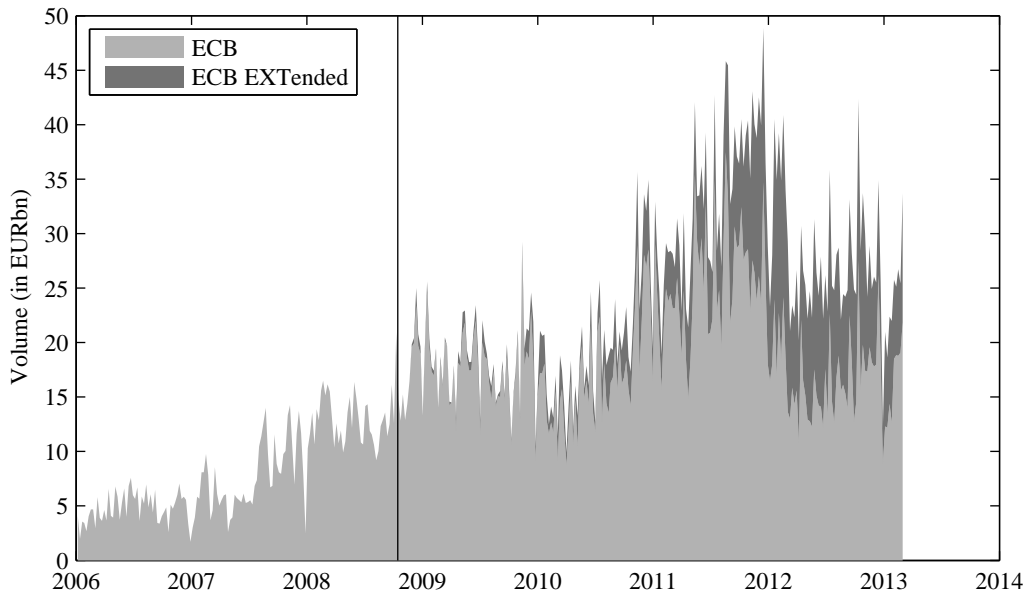
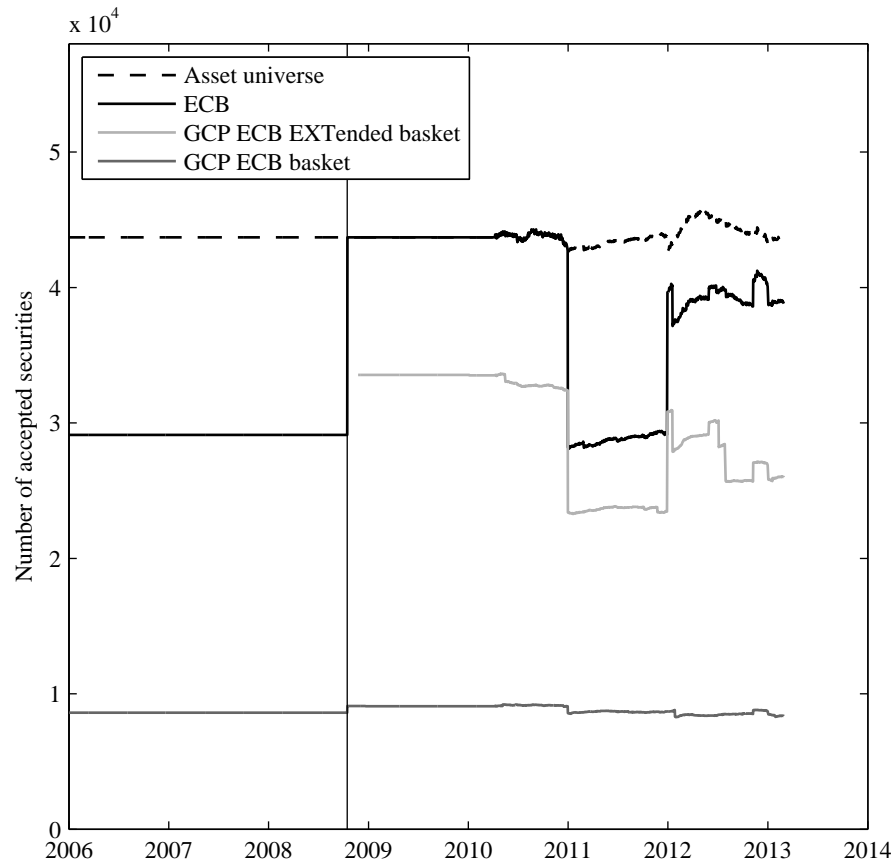


Figure 3. GCP trading volume. This figure presents the average daily trading volume for all GCP repos. The light gray area is the volume in the ECB basket, whereas the dark gray area that is stacked on top corresponds to the volume in the ECB EXTended basket. The figure is based on weekly data from January 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

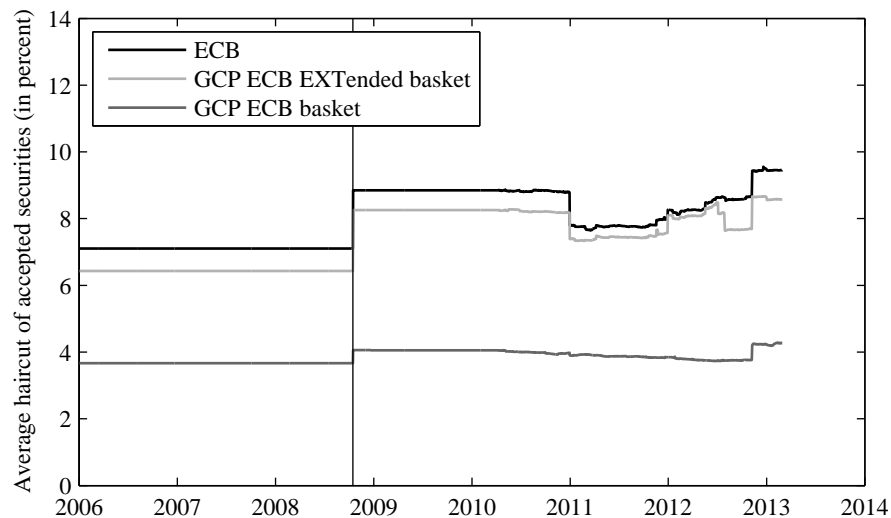


Figure 4. Number of accepted securities and average haircut for accepted securities. Panel A shows the number of accepted securities at the ECB, as well as the subset of those securities included in the two GCP baskets. The black dashed line represents the asset universe, that is, the number of securities 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.

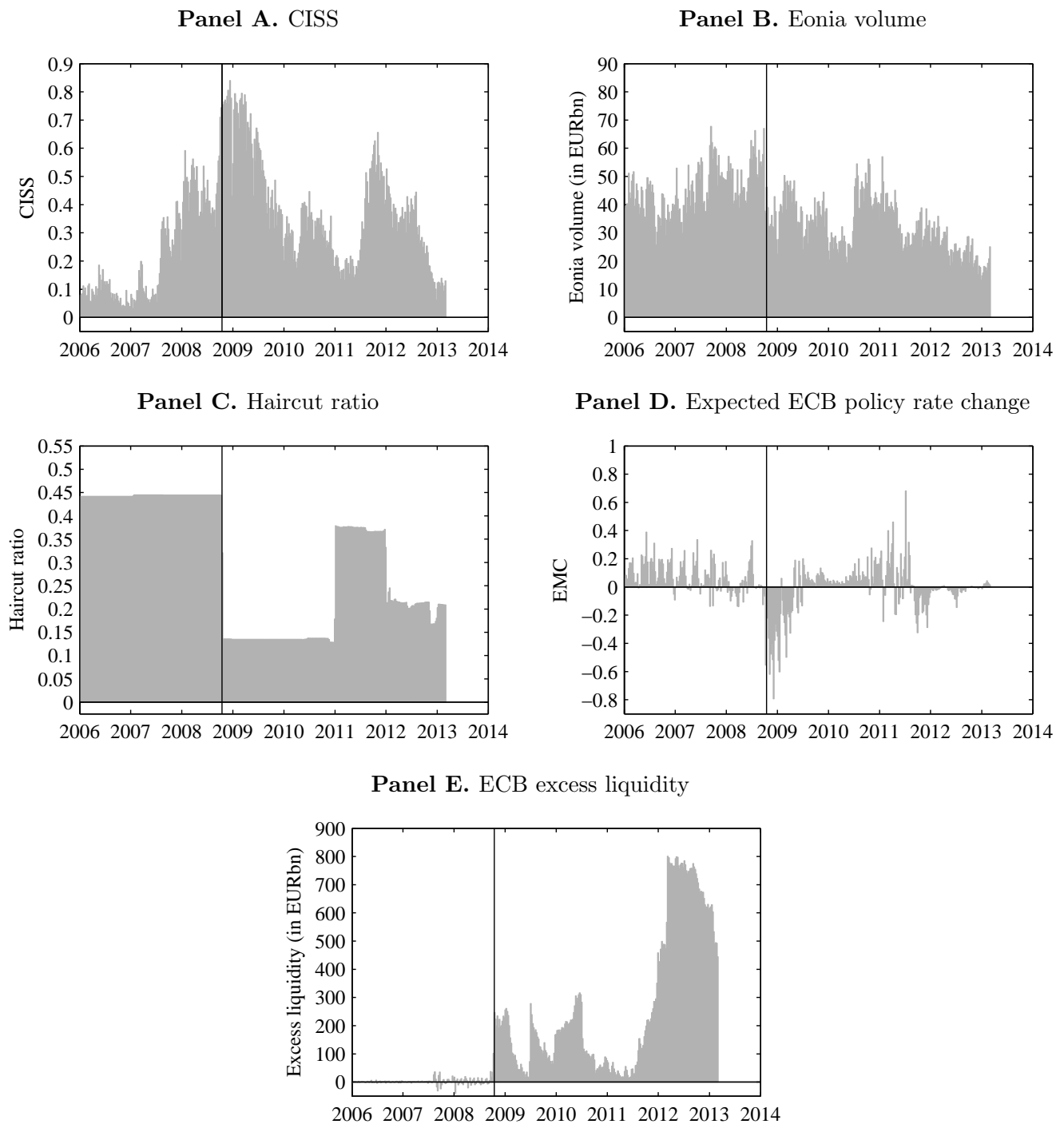
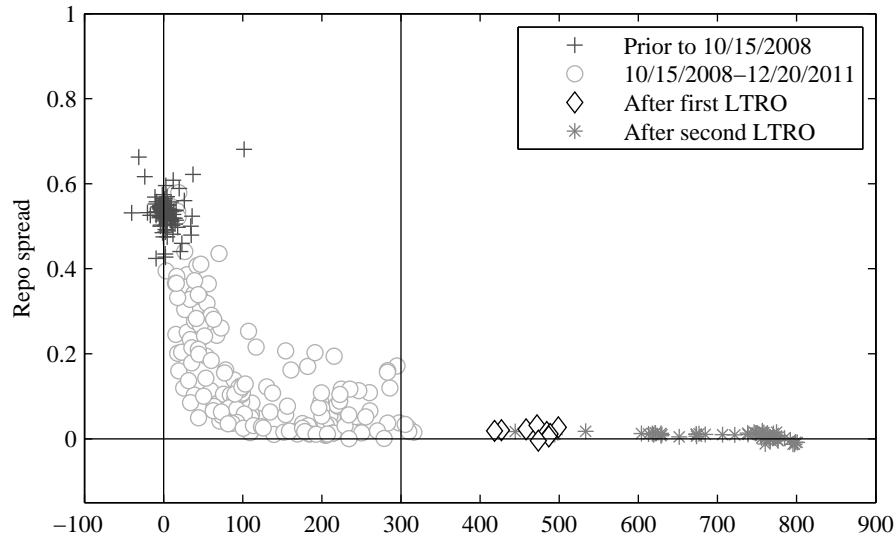


Figure 5. State variables. This figure shows the main state variables for repo market activity. Panel A depicts the composite indicator of systemic stress, CISS (Hollo, Kremer, and Lo Duca, 2012), which is a comprehensive measure of risk in the European financial system. Panel B shows Eonia (euro overnight 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

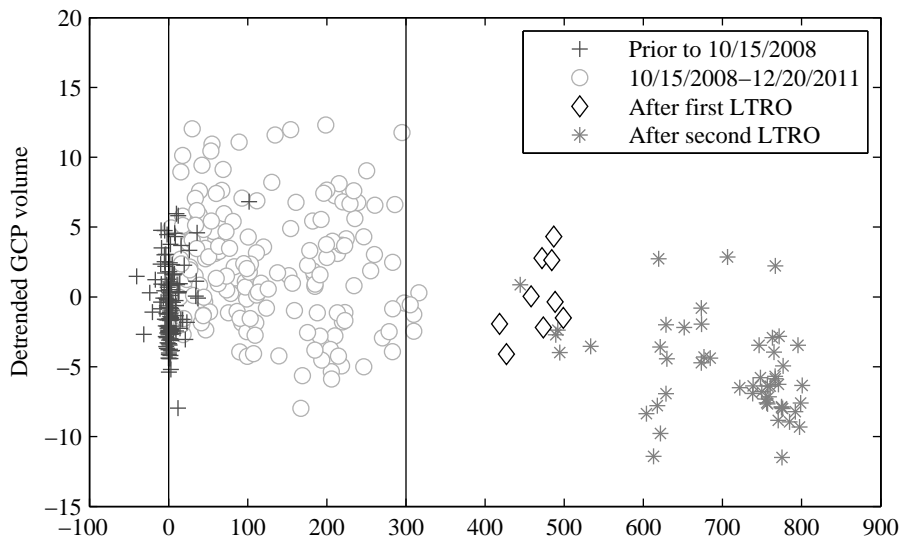


Figure 6. Relation between ECB excess liquidity and the repo spread as well as detrended GCP volume. Panel A shows a scatter plot of the repo spread (y-axis) and ECB excess liquidity (x-axis), defined as credit institutions' current account holdings at the ECB plus funds in the ECB deposit facility minus 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.

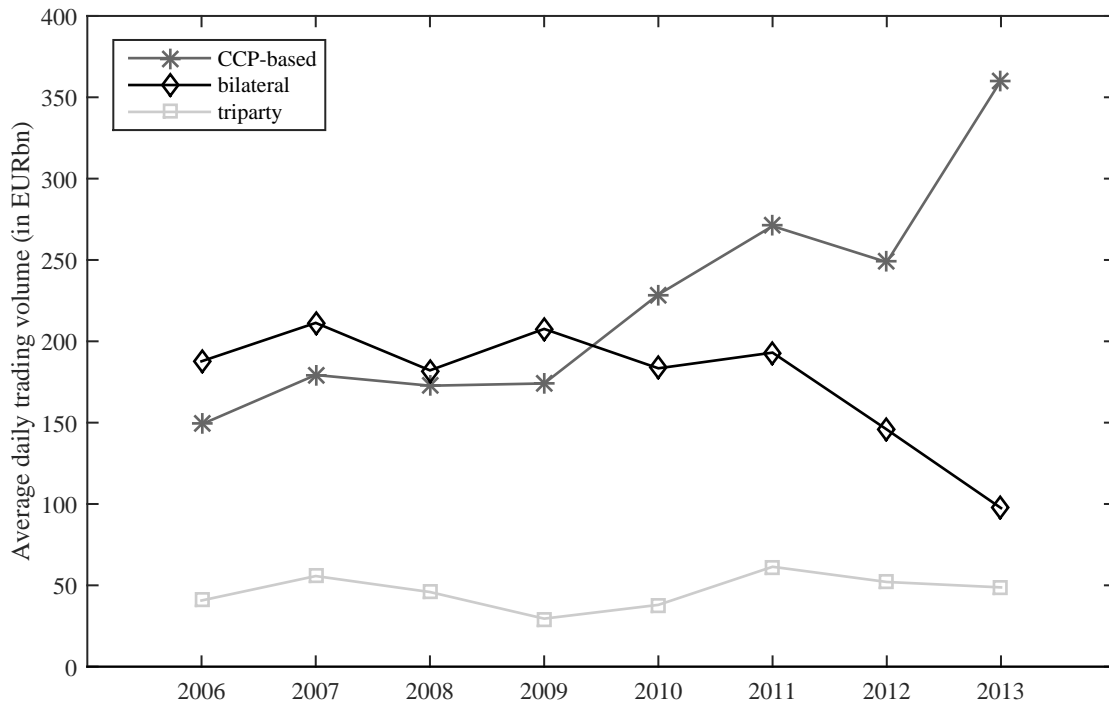


Figure 7. Average daily trading volume of the euro interbank repo market. The figure shows double-counted average daily trading volume of CCP-based, bilateral, and triparty repos in the interbank repo market based on annual data from the European Central Bank (2012, 2013). These volumes are extracted using the total borrowing and lending volumes of the 172 banks participating in the ECB Money Market Study 2012 (European Central Bank, 2012), the indexed borrowing and lending volume development of the constant panel of banks from 2003 to 2013 in European Central Bank (2013), and the shares of the different types of repos published in European Central Bank (2013). Total repo volume is computed as the sum of borrowing and lending volume. The CCP-based volume from 2006 to 2008 is not reported by the ECB. We approximate CCP-based volume during those years by using the sum of 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), scaled by the ratio of this volume and the total CCP-based volume reported by the European Central Bank (2012) for 2009.

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}	\widehat{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}	\widehat{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}	\widehat{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^{ld} 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^{ld}	VOL_t^{ld}	$AVGTERM_t$	S_t^{ld}	VOL_t^{ld}	$AVGTERM_t$
const.	0.571 *** (0.151)	0.042 (0.555)	3.154 (3.156)	0.046 (0.037)	0.199 (0.242)	4.971 *** (0.840)
trend		0.003 *** (0.001)			0.005 *** (0.001)	
S_{t-1}^{ld}	-0.046 (0.260)	0.465 (0.910)	-1.065 (5.450)	0.625 *** (0.083)	0.228 (0.261)	-4.010 *** (1.338)
$AVGTERM_{t-1}$	-0.002 (0.004)	-0.032 *** (0.012)	0.016 (0.081)	-0.001 (0.002)	-0.031 *** (0.011)	0.306 *** (0.058)
VOL_{t-1}^{ld}	-0.031 (0.030)	0.446 *** (0.113)	-1.223* (0.704)	-0.001 (0.015)	0.264 *** (0.068)	-0.911 *** (0.334)
$VOL_{t-1}^{ld} * DUM_{t-1}^{EL>300}$				-0.032* (0.019)		
VOL_{t-1}^{EONIA}		-0.033 (0.021)			-0.083 *** (0.031)	
$CISS_{t-1}$	0.046 (0.075)	0.558 *** (0.224)	4.569 *** (1.675)	0.043 (0.038)	0.708 *** (0.180)	-0.055 (0.897)
EL_{t-1}	-0.709 (0.726)	0.508 (1.519)	-13.429 (11.819)	-0.301 *** (0.116)	-0.757* (0.425)	-3.443 (3.024)
$EL_{t-1} * DUM_{t-1}^{EL>300}$				0.245 *** (0.091)	-0.343 (0.317)	3.823 (2.441)
HCR_{t-1}				0.153* (0.090)	0.458 (0.490)	2.119 (1.465)
EMC_{t-1}	0.039 (0.047)	0.234 (0.211)	-0.016 (1.684)	0.048 (0.059)	-0.094 (0.202)	-0.435 (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 (0.036)	-0.609 *** (0.150)	3.171 ** (1.356)
trend		0.002 *** (0.001)	
$S_{t-1}^{ext,1d}$	0.599 *** (0.086)	-0.113 (0.108)	-2.130 (2.922)
$AVGTERM_{t-1}^{ext}$	-0.001 (0.001)	0.000 (0.003)	0.150* (0.085)
$VOL_{t-1}^{ext,1d}$	0.021 (0.030)	0.672 *** (0.079)	-0.382 (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 ** (0.038)	0.287 *** (0.088)	-2.723* (1.472)
EL_{t-1}	-0.394 *** (0.129)	-0.046 (0.262)	7.993 (7.327)
$EL_{t-1} * DUM_{t-1}^{EL>300}$	0.324 *** (0.097)	-0.032 (0.187)	-5.172 (5.685)
HCR_{t-1}^{ext}	0.143 (0.096)	0.236* (0.138)	1.045 (2.157)
EMC_{t-1}	0.044 (0.078)	-0.024 (0.080)	1.996 (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 (0.086)	64.400 *** (15.890)	-0.001 (0.133)	36.478 *** (6.152)	0.014 (0.061)	24.473 *** (10.250)
trend		0.030 (0.028)		0.098 *** (0.020)		0.033 (0.022)
S_{t-1}^{1d}	0.614 *** (0.059)	-1.214 (6.160)	0.597 *** (0.062)	-10.113 *** (3.621)	0.602 *** (0.070)	-5.826 (5.915)
VOL_{t-1}^{RFR}	0.001 (0.001)	0.437 *** (0.069)	0.002* (0.001)	0.210 *** (0.085)	0.002 *** (0.001)	0.388 *** (0.075)
$VOL_{t-1}^{GC,1d} * DUM_{t-1}^{EL>300}$	-0.002 *** (0.000)		-0.003 *** (0.001)		-0.001 *** (0.001)	
VOL_{t-1}^{EONIA}		-1.451* (0.742)		-1.127 *** (0.378)		-1.258* (0.642)
$CISS_{t-1}$	0.000 (0.034)	5.852 *** (1.920)	0.057 ** (0.026)	9.008 *** (2.951)	0.059 ** (0.027)	-11.920 *** (4.423)
EL_{t-1}	-0.544 *** (0.106)	-19.221 ** (9.303)	-0.408 *** (0.110)	-12.628 *** (5.066)	-0.461 *** (0.113)	-29.587 ** (12.311)
$EL_{t-1} * DUM_{t-1}^{EL>300}$	0.515 *** (0.104)	10.724* (5.573)	0.378 *** (0.110)	7.054* (4.220)	0.390 *** (0.105)	19.152 ** (9.588)
HCR_{t-1}	-0.104 (0.127)	31.437 (22.745)	0.212 (0.162)	39.761 *** (9.628)	-0.026 (0.129)	-21.784 (15.501)
EMC_{t-1}	-0.042 (0.039)	-0.036 (5.689)	-0.037 (0.038)	1.985 (2.672)	0.030 (0.044)	-2.370 (3.871)
Adj. - R^2	0.783	0.393	0.747	0.708	0.757	0.491

Table 5
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), *CMW* for Copeland, Martin, and Walker (2014), and *A et al.* for Agueci et al. (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 and n/a stands for not available.

	Euro interbank repo market							U.S. repo market				
	Eurex Repo		<i>This paper</i> BrokerTec and MTS			Bilateral	Triparty	<i>GM</i>	<i>KNO</i>	<i>CMW</i>	<i>A et al.</i>	
	ECB	ECB EXTended	Germany	France	Italy							
Type of repos												
CCP-based	✓	✓	✓	✓	✓					(✓) ²⁹	✓	
Bilateral						✓		✓				
Triparty							✓		✓	✓		
Infrastructure												
Anonymous trading	✓	✓	✓	✓	✓					(✓)	✓	
Daily unwind									✓	✓	✓	
Integrated reusability of collateral for CB operations	✓											
Pooling of repo trades	✓	✓										
Third party collateral management	✓	✓					✓		✓	✓	✓	
Collateral												
Very safe	✓		✓						✓		✓	
Safe		✓		✓					✓		✓	
Intermediate					✓	✓	✓	✓		✓		
Risky						✓	✓	✓		✓		
Development during crisis												
Volume	+	+	+	+	=	–	–	n/a	–	–	–	n/a
Spread	=	+	=	+	+	n/a	n/a	+	=	+	n/a	n/a
Maturity	+	–	n/a	n/a	n/a	n/a	n/a	n/a	–	–	n/a	n/a
Haircuts	=	=	n/a	n/a	n/a	n/a	n/a	+	=	+	=	n/a
Sample												
Period			2006–2013					2007–2009	2007–2010	2008–2010	2011–2012	
Frequency	intradaily, daily, weekly		daily, weekly			annually		weekly	quarterly	daily	daily	

²⁹The sample investigated by Copeland, Martin, and Walker (2014) includes anonymous, CCP-based GCF repos. However, the majority of the repos investigated in their paper are neither CCP-based nor anonymous.