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Stressed interbank markets: evidence from the European financial and sovereign debt crisis

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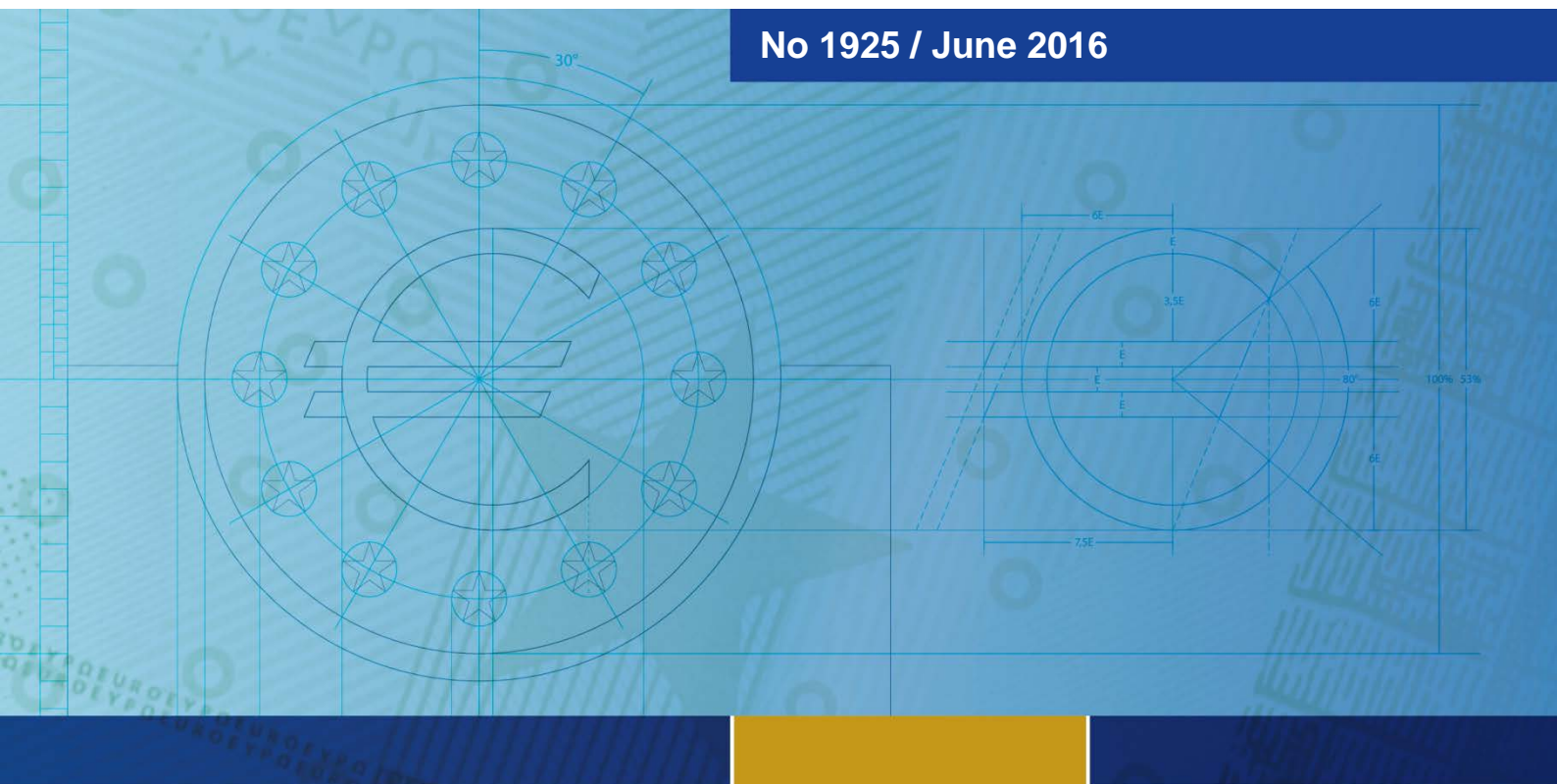
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Stressed interbank markets: evidence from the European financial and sovereign debt crisis

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Abstract

This paper documents stress in the unsecured overnight interbank market in the euro area over the course of the financial and sovereign debt crisis in Europe. We find that stress i) leads some banks to borrow in the market at rates that are higher than the rate of the marginal lending facility of the ECB, ii) leads to less cross-border transactions and contributes to the fragmentation of the euro area money market. A triple-difference estimate shows that the borrowing of banks in the periphery from banks in the core almost disappears in the second half of 2011. Domestic borrowing, however, replaces the loss of cross-border borrowing. Our findings document the severe malfunctioning of the market for liquidity caused by asymmetric information problems in crisis times. We exploit euro area payments data to construct a novel dataset of interbank lending and borrowing. We verify the validity of our approach using the post-trading structure MID, maintained at Banco de España. Based on our results, we conclude that MID is a very high quality source of Spanish interbank market data for research and policy purposes.

JEL Classification: G01, G21, E58, F36

Keywords: Interbank markets, financial crisis, European sovereign debt crisis, payment systems, Furfine algorithm

Non-Technical Summary

Interbank markets play an important role in the implementation and transmission of monetary policy. Banks receive liquidity in the form of central bank money in a central bank's open market operations (against collateral in the form of other financial assets). Central bank money is then traded (unsecured) in the market and receives a price. The price in the overnight market is the first short-term interest rate that is established after the policy rate. In the United States, this is the Federal Funds rate. In Europe, it is the EONIA rate. If the interbank market malfunctions, then the normally tight link between the policy rate and short-term interest rates may break.

A challenge, present even in normal times, is that interbank markets are over-the-counter. Transactions and the resulting volumes and interest rates are currently not available in a single place. Both the Federal Funds and the EONIA rate are, for example, rates reported by a group of banks. In crisis times, there is no guarantee that this group of banks is representative of the entire market.

To overcome this challenge, we employ a new version of the Furfine-type algorithm that relies as little as possible on screening for “plausible” interest rates. We apply our version of the algorithm to TARGET2 payments data. Most existing versions of the algorithm assess the plausibility of two payments forming an interbank loan on the basis of the implied interest rate (calculated from the difference between the outgoing and the returning payment). Usually, the implied interest rate must be within an interval. Rates outside this interval are found implausible and the conclusion is that the two payments do not reflect an underlying interbank loan. But what is a reasonable interest rate interval, especially in crisis times when we see record highs for all kinds of financial prices?

Not relying on an interest rate corridor allows us to document a striking feature of the interbank market in crisis. Banks are willing to borrow at interest rates above the rate they would have to pay at the marginal lending facility of the ECB. We validate the

results of the Furfine algorithm using the MID database maintained by Banco de España. MID is a post-trading platform that records unsecured interbank loans among Spanish credit institutions (after counterparties negotiate the terms). We find a high accuracy of the Furfine algorithm, as it identifies correctly around 94 % of all individual loans. These results highlight both the reliability of the Furfine algorithm and the quality of MID for both policy and research purposes.

By reconstructing the entire European interbank market with the Furfine algorithm, we document several new dimensions of market malfunctioning. We find that stress i) leads banks to borrow in the market at rates that are higher than the rate of the marginal lending facility of the ECB and ii) leads to less cross-border transactions and more fragmentation of the euro area money market. These findings document the severe malfunctioning of the market for liquidity caused by asymmetric information problems in crisis times. None of these findings could have been documented in the United States, as unlike the United States, Europe is not a single country. While maybe absent in normal times, the sovereign debt crisis brought differences across European countries to the fore. With a triple-difference estimate, we show that in fact the borrowing of banks in the periphery from banks in the core almost disappears in the second half of 2011. Domestic borrowing, however, replaces the loss of cross-border borrowing in the interbank market.

Introduction

This paper documents stress in the euro area unsecured overnight interbank market over the course of the financial and sovereign debt crisis in Europe. Documenting a possible malfunction of interbank markets is important and challenging at the same time.

Interbank markets play a key role in the liquidity management of banks. It is the place where liquidity imbalances are smoothed out. Should the market malfunction, then banks either have to insure themselves by holding precautionary liquidity reserves, or they may have to liquidate other assets, or they must default on whatever liability that caused the need for liquidity. All three options are costly.

Interbank markets also play an important role in the implementation and transmission of monetary policy. Banks receive liquidity in the form of central bank money in a central bank's open market operations (against collateral in the form of other financial assets). Central bank money is then traded (unsecured) in the market and receives a price. The price in the overnight market is the first short-term interest rate that is established after the policy rate. In the United States, this is the Federal Funds rate. In Europe, it is the EONIA rate. If the interbank market malfunctions, then the normally tight link between the policy rate and short-term interest rates may break.

The first challenge, present even in normal times, is that this market for liquidity is over-the-counter. Transactions and the resulting volumes and interest rates are currently not available in a single place.¹ Both the Federal Funds and the EONIA rate are, for example, rates reported by a group of banks. In crisis times, there is no guarantee that this group of banks is representative of the entire market.

The second challenge is that the malfunctioning of the overnight market for central bank money may take subtle forms. In an influential study, Afonso, Kovner and Schoar

¹ The ECB Money Market Statistical Regulation (MMSR) will as of mid-2016 collect transaction-by-transaction data from a sample of EU reporting agents covering the secured, unsecured, foreign exchange swap and euro overnight index swap money market segments.

(2011) document the malfunctioning of this market in the United States. Transaction volumes dropped temporarily and interest rates started to reflect the risk of borrowers.

By looking at the European interbank market, we document new dimensions of market malfunctioning. We find that stress i) leads banks to borrow in the market at rates that are higher than the rate of the marginal lending facility of the ECB and ii) leads to less cross-border transactions and more fragmentation of the euro area money market. These findings document the severe malfunctioning of the market for liquidity caused by asymmetric information problems in crisis times.

A tripe-difference set-up confirms these findings. The borrowing of banks in the periphery from banks in the core almost disappears in the second half of 2011. Domestic borrowing, however, replaces the loss of cross-border borrowing.

None of these findings could have been documented in the United States. First, unlike the United States, Europe is not a single country. While maybe absent in normal times, the sovereign debt crisis brought differences across European countries to the fore. Moreover, if there are informational frictions in the market (e.g., on borrower quality), then one would expect these to affect in particular transactions across countries (Freixas and Holthausen (2005)).

We employ a new version of a Furfine-type algorithm that relies as little as possible on screening for “plausible” interest rates. Most existing versions of the algorithm assess the plausibility of two payments forming an interbank loan on the basis of the implied interest rate (calculated from the difference between the outgoing and the returning payment). Usually, the implied interest rate must be within an interval. Rates outside this interval are found implausible and the conclusion is that the two payments do not reflect an underlying interbank loan. But what is a reasonable interest rate interval, especially in crisis times when we see record highs for all kinds of financial prices?

Not relying on an interest rate corridor allows us to document a striking feature of

interbank market in crisis. Banks are willing to borrow at interest rates above the rate they would have to pay at the marginal lending facility of the ECB.

Our version of the Furfine algorithm does not rely on a tight interest rate interval. Instead, we exploit institutional features inherent in a payment message such as account numbers, transactions IDs and the fact that banks normally quote rates only as multiples of basis points to determine whether two payments reasonably result from an interbank loan. A key feature of our study is that we check the validity of our approach using the official universe of overnight unsecured transactions in Spain.² This allows us to establish whether our algorithm misses true interbank loans and whether it constructs interbank loans that do not exist in reality.

We proceed as follows. Section 1 discusses related literature. Section 2 presents the institutional background of the euro area money market. Section 3 presents data and the validation of the Furfine algorithm. Section 4 explains our measures of stress and fragmentation. Section 5 contains our triple-difference analysis. Section 6 concludes.

1. Literature Review

Afonso, Kovner and Schoar (2011) show empirically how after the Lehman bankruptcy negotiated terms among counterparties on the federal funds market in the U.S. incorporated information on borrower's characteristics. They find that worse performing banks receive less unsecured funding and face higher rates than healthier banks do. Also, they document how banks with lower profitability accessed funding from the Fed's discount window more often, as they could presumably not obtain unsecured funding in the market. Afonso, Kovner and Schoar (2011) conclude that counterparty risk played a key role during the 2008 financial crisis. Acharya and Merrouche (2010) find that participants in the U.K. interbank market increased their demand for liquidity

² Transactions for tomorrow next and spot next are not included.

following the BNP Paribas announcement on the 9th of August 2007 of the suspension in valuations for three money market funds due to exposures to U.S. subprime mortgage losses. This increase in demand of interbank market funding caused increases in rates for liquidity in both unsecured and secured money markets in the U.K. Acharya and Merrouche (2010) find an important contagion channel from riskier banks to other market participants.

Hartmann, Manna and Manzanares (2001) were among the first to empirically investigate euro area money market integration after the start of the EMU. They do not find important cross-border differences in overnight rates, which results in homogeneous interest rates across banks from member states. Gaspar and Farinha (2008) find that Portuguese banks rapidly experienced convergence in money market rates with the adoption of the euro. They show evidence of an increase in cross-border activity for Portuguese banks, which reflects their integration with other financial markets. More recent studies at the euro area examine the 2008 financial crisis effects in interbank markets. Angelini, Nobili and Picillo (2011) use e-MID to show empirically that only after August 2007, the Italian domestic interbank market became sensitive to bank-specific characteristics. Banks with lower credit rating or that hold less capital face higher rates in the unsecured market. Brunetti, Di Filippo and Harris (2011) examine, also with e-MID data, whether central bank interventions improved liquidity in the interbank market. They find that more uncertainty derived from the public injections of liquidity in the market in the form of market volatility and higher spreads. According to their findings, asymmetric information is not mitigated by ECB interventions. Arciero et al. (2016) also apply a (different implementation of the) Furfine algorithm to TARGET2 data. The authors find an important reduction in overall volumes since the start of the financial crisis in 2008.

Several studies have explored the functioning of the interbank market and its main

characteristics on the theoretical front. Freixas and Holthausen (2005) study interbank markets in an international context. They find that in an economy with unsecured markets peer monitoring plays a key role in lending decisions. This leads to an efficient outcome as money is transferred to the most efficient projects. Asymmetric information about borrower risk therefore plays a key role in their interbank market model. Heider, Hoerova and Holthausen (2015) analyze the effects of asymmetric information and counterparty credit risk on interbank market functioning. They show that when the information asymmetry about counterparty risk is large, interbank market trade can break down and banks may hoard liquidity to self-insure against liquidity shocks.

2. Background on the euro area interbank market since 2008

The euro area money market survey conducted by the European Central Bank on a yearly basis since 1999 presents main developments in euro area money markets, both on a secured and unsecured basis. The survey currently consists of a panel of 149 banks (Sep. 2015 figures) where statistics on money market activity are collected for all banks through their respective National Central Banks (NCBs) inside the European System of Central Banks (ESCB). In the last edition of the survey in September 2015, the ECB money market survey points to a drop in overall money market turnover of 12% year-on-year. The decline is particularly evident for both secured and unsecured markets. The highest turnover in the unsecured market occurs for maturities up to one week or less. In particular, the overnight market remains the largest contributor to the unsecured segment with over 90% of share in the market. The last issue of the ECB money market survey also presents statistics on the secured market, which represents the largest segment in the survey (close to 30% of the cumulative quarterly turnover). An important finding on the secured money market is that declines in volumes for the secured market did not materialize for those centrally cleared during 2015 (representing 72% of all bilateral repo

transactions). This highlights the importance of central clearing as it provides insurance against counterparty risk (see e.g. Biais, Heider and Hoerova, 2012). While granular information on the unsecured money market can come from TARGET2 by means of a standard Furfine algorithm, such information for the secured market cannot. Information on the secured market remains a small “terra incognita” in TARGET2.³ This is, as once a CCP clears a repo transaction, disentangling the lending and borrowing leg represents a challenge due to netting in payments - and thus making it impossible to identify them in TARGET2 payments.

Reconstructing the unsecured segment of the euro area money market with TARGET2 data provides a rich source of granular interbank market information.⁴ Results from this study highlight the reliability of using a Furfine algorithm to examine the unsecured money market (both in a positive and negative interest rate environment). We check for robustness with the Spanish post-trading structure MID.

Overall, the main developments in the euro area money market shown in this study coincide with those from the ECB money market survey, as well as those from the EONIA panel banks. Figure 1 (top) shows the total monthly unsecured overnight volume in TARGET2. Overall, there is a strong downward trend in trading especially after the outbreak of the global financial crisis in 2008 compared to mid-2014 levels (from around 2.5 trillion EUR in 2008 to 0.5 trillion EUR in 2014). This reduction in trading occurs for all types of trading (both on behalf of clients and of the banks themselves). At the Spanish domestic level, MID also shows a continuous fall in turnover (see Figure 2 - top). An in depth analysis of the overnight unsecured money market using TARGET2 data provides important insights into the monetary policy transmission mechanism in the

³ Based on TARGET2 data, the application of the methodology used for the unsecured market to the secured segment would not be feasible.

⁴ See Box 3 in Issue 6 / 2015, ECB Economic Bulletin “The usefulness of TARGET2 transaction data for the analysis of the unsecured overnight money market”. https://www.ecb.europa.eu/pub/pdf/other/eb201506_focus03.en.pdf

euro area. Figure 1 (bottom) shows the weighted average interest rate paid in the euro area overnight market since 2008. The pass-through of the monetary policy rates to the overnight market is evident – such as after the Eurosystem switch from variable to fixed-rate full allotment tender procedure in October 2008. Also, stress periods show up markedly in the overnight market. This is for instance the case during mid-2010 and end-2011 – shortly before the ECB conducts its first 3-year longer-term refinancing operation (LTRO).

3. Stress in the interbank market

The ECB deposit facility and marginal lending facility provide in theory a floor and ceiling for the overnight market respectively. This is, as banks can deposit funds overnight at the central bank and earn remuneration (so they would not have an incentive to receive less in the private market than what they can earn at the ECB). At the same time, banks can receive overnight funding at the central bank by paying the rate set at the marginal lending facility (against the presentation of financially sound collateral). Again, a bank would not have an incentive to pay a higher rate in the private market than what they would have to pay at the ECB.⁵ Therefore, in a rational and well-functioning market, there should be no money market abnormalities (rates either below the deposit facility rate or above the marginal lending facility rate). But, does this rationale hold during severe stress times?

Figure 3 and 4 report the total number of overnight loans (and volume) identified with an interest rate at or above the ECB marginal lending facility rate each month since 2008 – together with two financial stress indices. The Composite Indicator of Systemic Stress (CISS) measures the financial system as a whole by integrating measures of stress

⁵ Here it is important to note that central bank overnight liquidity is only against the presentation of enough and financially sound eligible collateral. Moreover, an access to MLF could have the stigma of not being able to find funding in the market.

in stock, bond, money, foreign exchange and banking markets, while the Composite Indicator of Systemic Sovereign Stress (SovCISS) focuses on stress in sovereign bond markets exclusively).⁶ The main novel features of the CISS and SovCISS frameworks is that they apply basic portfolio theory to aggregate individual stress measures into composite stress indicators - which involves the computation of time-varying cross correlations between individual stress measures (for each sub-indexes). Both indicators measure stress from 0 (no stress) to 1 (high stress). The SovCISS indicator focuses in particular on government bond markets (changing default risk expectations, risk aversion, liquidity risk and uncertainty) for the euro area.⁷ It is worth noting how the CISS shows markedly a higher stress during 2008 than in end-2011 – whereas the SovCISS is the other way around. This highlights already the different nature of the crisis in 2008 (more financial banking and widespread), compared to that of 2011 (more sovereign nature).

Banks trading at a rate at or above MLF markedly coincides with severe stress in both CISS and SovCISS – and especially during two periods: post-Lehman bankruptcy in October 2008 and the intensification of the European sovereign debt crisis in November and December 2011. In the case of late-2011, the algorithm identifies up to 15% of total monthly transactions that equal or surpass the MLF rate (Figure 3).

The period in late-2011 also coincides with important political news in the euro area that impaired capital markets more generally.⁸ The two composite systemic stress indicators show 2008 and end-2011 as the two most significant periods of banking stress – which exactly coincide with activity at or above MLF in interbank markets. It is in particular during end-2011 that sovereign tensions materialize for Italy in particular (10-

⁶ The basic idea of the SovCISS is that the level of bond market stress is not exclusively determined by the level of country spreads vis-à-vis a “risk-free” instrument but also depends on current and anticipated liquidity and volatility conditions both at the short and the long end of the yield curve. See Garcia-de-Andoain and Kremer (2016) for details.

⁷ Data on the CISS and the SovCISS can be downloaded via the ECB Statistical Data Warehouse: <http://sdw.ecb.europa.eu/browse.do?node=9551138>.

⁸ A detailed description of the news can be found on Table 4 in the appendix.

year benchmark bond yield reaches a historical maximum on November 25th 2011 at 7.288 % - see Figure 8). The high 10-year bond yield of Italy during 2011 fully coincides with the high rates that Italian banks faced for unsecured liquidity at the time (see Table 2).

Tensions in the secured and unsecured money market in Italy were closely interrelated at the height of the sovereign debt crisis. In November 2011 there was a significant increase in margin calls by an Italian CCP - 12 times more than the monthly average during 2011. As CCP-cleared transactions play a major role for the secured market in Italy, the increase in margin requirements is a sign of funding problems and counterparty risk concerns in this market segment too.⁹

However, interbank market stress (at least in the unsecured segment) came to a halt exactly after the introduction of the 1st 3-year LTRO on December 2011.

Cross-border share as a measure of fragmentation

Severe downturn patterns in cross-border activity acutely depict market fragmentation as suggested by Freixas and Holthausen (2005).¹⁰ This effect is not so clear on overall volumes (Figure 1 - top). Figure 5 shows the cross-border share of overnight lending in the euro area. Since the overnight market is the most immediate source of liquidity for banks (and also the last market resort) we could expect banks to curtail liquidity on a cross-border basis if problems arise because they may need the liquidity for themselves instead. According to Figure 5, this is clearly the case. A negative trend particularly emerges after Lehman's bankruptcy on September 15th 2008 as well as after the ruling out to a debt restructuring by Greece on May 2nd 2011.

⁹ The importance of CCPs for the functioning of the bond and hence the secured market stems from the risk mitigation tools a CCP has to lower counterparty risk (for more details on the increase in margin requirements in Italy in November 2011, see IMF, 2013, and also Corradin and Rodriguez-Moreno, 2015).

¹⁰ See Chart A, Box 1 in Chapter 1 of the Financial Integration Report, European Central Bank, 2016. <https://www.ecb.europa.eu/pub/pdf/other/financialintegrationineurope201604.en.pdf>

Although both shocks play out differently in the market (Lehman shock more abrupt; Greek shock more gradual), there is a clear reversal in the overnight market cross-border share following these two market events.

4. Using a Furfine algorithm to identify market money market stress

Our version of the Furfine algorithm to TARGET2 payments data

Our sample consists of unsecured overnight loans in the euro area. We use a Furfine-type algorithm that extracts payments transactions in the TARGET2 system and uses them to construct overnight loans. The appendix describes in detail the methodological aspects of the algorithm. One of the main characteristics of this implementation is that little restrictions ex-ante on possible rates bank transact at in the overnight market are considered. We inspect overnight activity above the ECB corridor, and relate this activity to economic and political events impacting bank's country of residence. Our methodology identifies high stress events which fully coincide with systemic stress indicators for widespread financial market stress. In particular, we find that banks pay an overly high price for overnight funding during late 2011. This stress only comes to a halt after the ECB conducts its 1st 3-year LTRO operation on December 22nd 2011.

Euro area overnight market statistics

Table 1 reports summary statistics for interest rate, loan size (mill EUR), loan volume (bn EUR), total number of transactions and activity at or above the MLF rate for all transactions. In addition, Table 2 reports the same information for transactions on behalf of banks inside the same group exclusively. Overall, banks are grouped into four categories according to their geographical location: stressed (Greece, Ireland, and Portugal), Spain, Italy and non-stressed countries (remaining countries with access to TARGET2). We present statistics for Spain and Italy separately as both countries deserve special attention due to their large domestic interbank markets (MID and e-MID

respectively). Spanish and Italian banks pay overall rates which are closer to non-stressed countries than to stressed-jurisdictions. In addition, Italian and Spanish banks pay very similar rates throughout our sample. However, average loan size in Spain is much larger than in Italy, while overall loan volumes are higher in Italy on average. Banks in non-stressed countries pay on average 253 basis points less than banks located in stressed countries. Activity at or above the MLF is particularly significant for Italian banks (as well as for Greek, Irish and Portuguese banks). For Spanish banks, this activity above the ECB corridor occurs to a lesser extent.¹¹

The validation of our Furfine algorithm

Importantly, we validate the results of the Furfine algorithm using the MID database maintained by Banco de España. MID is a post-trading platform that records unsecured interbank loans among Spanish credit institutions (after counterparties negotiate the terms). The universe of overnight transactions in Spain allows testing the accuracy of our Furfine-type algorithm (when applied to TARGET2 data) because the large majority of MID loans settle in TARGET2 on an individual, i.e. payment basis. We apply the Furfine algorithm to TARGET2 transactions and compare the results for Spanish banks directly to the MID database in Spain. Finally, we restrict our comparison to extra-group loans only. For this, we use the SWIFT Bank Directory Plus together with information on mergers and acquisitions since 2008. We do this in order to sort out of the database intra-group loans. The results of the validation exercise confirm the usefulness of a Furfine type algorithm for the analysis of the unsecured overnight money market with payments data. Figure 2 presents the validation result for total overnight volume (top) and weighted overnight rate (bottom) in MID compared to TARGET2. The correlation of both series is over 99% in the two cases. It is worth noting that the validation shows high accuracy throughout the sample. This highlights the adaptability of our methodology to all types of

¹¹ Further analysis reveals how the largest share of activity above the MLF rate occurs around Lehman and late-2011.

market functioning.

We conduct our validation exercise for the following fields: outgoing and repayment date of the loan, Bank Identifier Code (BIC) of sender and receiver and amount outgoing and repayment of the loan. A match occurs only when all six categories coincide in both databases. If a repayment varies for 1 cent, it triggers an error automatically. For the years 2008, 2009, 2010, 2011, 2012, 2013, 2014 and 2015, 79,434 extra-group loans officially appear in MID for overnight maturity (loans initiated on a Friday are returned on a Monday are also included in this category). The Furfine algorithm identifies correctly 74,490 individual loans (93.78 %). Error type I or false positives are 762 (1.01%). Error type II or false negatives amount to 4,944 (6.22 %). We now turn to describe in detail both error types. It is worth noting that the validation exercise yields the same positive results for both positive and negative interest rate environments (both cases close to 94 %, see Figure 2 - bottom).¹²

Type I error (false positives) correspond to 1.01 % of the sample. The application of a Furfine algorithm to reconstruct the unsecured market incorporates assumptions on interest rate plausibility, therefore type I error is normal. We identify 762 loans wrongly categorized as overnight, and these relate to both longer term maturities and instances where the algorithm paired two transactions as money market related when in fact they were not.

Type II error corresponds to loans the Furfine algorithm cannot find but are included in the official MID database. This error occurs for 6.22 % of the sample. There are several causes for this source of error. Among these are: non-round outgoing amounts; set up of the MID post-trading structure that aggregates payments for efficiency purposes when two or more repayments come back within 30 minutes within same institutions; loans with a principal amount lower than the algorithm threshold of 1 million EUR, loans

¹² See also Abildgren et al. (2015) and Rainone and Vacirca (2016) for an investigation of Furfine-type algorithms in zero and negative interest rate environments.

at zero percent interest rate and loans in MID that do not settle in TARGET2. Transacting credit institutions that are indirect participants of the same direct participant are included in this category - as the direct participant internalizes payments. Thus MID does not send these transactions to TARGET2 as in reality no movement of funds occurs for these entities in the books at Banco de España.

Errors from non-round outgoing payments account for 0.9 % of all loans in the official MID universe. One of the most critical assumptions of the Furfine algorithm is that outgoing amounts must be in round lots of 100,000 EUR. Therefore, if the first leg of a loan does not end in at least five zeros, the algorithm will not search for it.

The second cause of Type II error is inherent to the MID efficient set up of the post-trading structure. If payments in MID occur within the same 30 minutes among the same credit institutions, MID aggregates and nets them out. The Furfine algorithm follows a one-to-one matching methodology, therefore cannot include these types of payments. According to internal payment statistics in Banco de España, approx. 5 % of overnight loans in MID are of this type. This specificity does not however apply to the euro area data as a whole. This aggregation and netting of payments is only inherent to MID's post-trading structure – for liquidity efficiency purposes.

The third possible source of type II error lies in the search threshold of the Furfine algorithm, as the methodology does not search for loans with a nominal amount of less than 1 million EUR. 118 loans in MID (or 0.15 %) fall in this category.

The fourth source of type II error occurs when an overnight loan carries a zero percent interest rate. Our methodology does not search for overnight loans when both amount outgoing and repayment are the same. Other studies already document this methodological constraint (see. Abildgren et al. 2015). We prefer to ignore zero-rate transactions rather than model their occurrence based on bilateral trade formation in over-the-counter markets (as in Rainone and Vacirca 2016). Overall, this source of error is

small (345 loans or 0.4% in the MID universe). Zero-interest loans appear to be rare and hence, we do not see any impact on the overall volume when ignoring them (see Figure 2 - top).

A final source of Type II error is that some transactions in MID do not settle in TARGET2, therefore the algorithm does not search for them. This source of error occurs also for other studies such as Alfonso et al. (2011) which misses Fed fund loans that do not go through Fedwire Funds.

5. Counterparty risk - difference in difference analysis

We examine the functioning of the unsecured interbank market during the sovereign debt crisis. Specifically, we ask whether banks in the periphery of the euro area found it more difficult to borrow in the interbank market because their risk increased. Was it the case that during the sovereign debt crisis lenders feared counterparty risk when transacting with borrowers in the periphery?

To answer this question, we must first define a setting in which we hope to identify the impact of counterparty risk on the interbank market. Even though the sovereign debt crisis and the availability of data on interbank transactions are obvious prerequisites for finding an appropriate setting, more is needed to obtain a “natural experiment”. This is particularly challenging, as the sovereign debt crisis had several phases involving different countries at different moments in time.

Our natural experiment focuses on Italian and German interbank transactions from 1st January 2011 until 1st December 2011. We focus on the period of the first eleven months of 2011 because during this period, the sovereign debt crisis erupted in full force. We focus on banks located in Germany and Italy because both countries are large and central to the sovereign debt crisis. Italy is the main country in the periphery of the euro area

where concerns about fiscal sustainability loomed high. The concerns about the fiscal sustainability of a country go hand-in-hand with concerns about the risk of banks located in that country. This interplay between sovereign and bank risk is a key feature of the European sovereign debt crisis (see Acharya et al., 2014). Hence, the risk of Italian borrowers in the interbank market increased as the risk of the Italian sovereign intensified. In contrast, Germany is the main country in the core of the euro area, which was not exposed to concerns about fiscal sustainability.

Figure 8 illustrates the setting of our natural experiment. It shows the 10-year sovereign bond yields of Germany (blue - right-hand scale) and Italy (red - left-hand scale) from January 1st 2008 until March 30th 2015 respectively. We focus on the period from 1st January 2011 until 1st of December 2011 (bright area) and compare the behavior of German and Italian banks before and after 1st June 2011 (green line). The period from 1st January until 1st June 2011 is one of relative calm. The sovereign bond yields of Germany and Italy are flat (and identical after adjusting for the different level through the choice of the different y-axes). After 1st June 2011, the yields of Italian government bonds increase dramatically relative to the yields of German government bonds. Hence, we define the period after 1st June as the crisis period for banks in Italy.

We start the analysis on 1st January 2011 because there is an increase of sovereign bond yields in the second half of 2010. This indicates an increase in sovereign stress in both the periphery and the core of the euro area. Moreover, we exclude earlier periods (prior to mid-2010) because they are far from the start of the crisis and potentially subject to other developments (e.g., the events in Greece). We end the analysis on 1st December because the ECB announced the 3-year Longer-Term Refinancing Operations (3-year LTROs) on 8th December 2011. The announcement and the actual conduct of the 3-year LTROs at the end of December 2011 and the end of February 2012 was a massive intervention that put a halt on the negative developments in the euro area interbank

market.

We want to examine whether the crisis in the periphery led to an increase in the counterparty risk for Italian banks, impairing their access to overnight unsecured interbank market funds. A first attempt to examine the issue is to compare the borrowing of Italian banks before and after 1st June 2011. But this comparison can be misleading because something else could have been going on that affects all borrowers in the euro area and not just Italian ones. For example, the ECB started to decrease interest rates in mid-2011 after having increased rates in the first half of 2011. In addition, on May 2011, Greece ruled out a restructuring of their debt, worsening cross-border relationships in the market (see Figure 5).

In order to rule out such a time trend for the entire euro area, we use borrowers in the core (Germany) as a control group. The sovereign risk of core countries does not increase in mid-2011, yet banks in core countries were affected by euro area developments such as interest rate changes or a spillover from events in Greece.

Figure 9 illustrates the difference-in-difference approach. The figure shows the transaction volume of borrowers in the periphery (Italy) and borrowers in the core (Germany) over time. Interestingly, there is no obvious impact of the crisis on the borrowing by banks in the periphery (the treatment group). There is also no obvious impact on the borrowing by banks in the core (the control group). Hence, there is no difference between the treatment and control group (first difference) in how much each of their borrowing changes before and after 1st June 2011 (second difference).

The formal difference-in-difference estimate is given by the following specification:

$$y_{jt} = \alpha_j + a_t + \delta D_{jt} + \varepsilon_{jt}, \quad (1)$$

where $j \in (C, P)$ denotes whether the borrower is in the core or in the periphery, t denotes time (week), α_j is the core/periphery fixed effect, a_t is the time fixed effect, and

y_{jt} is the transaction volume for all borrowers in the core or the periphery in week t . The dummy D_{jt} is one for borrowers in the periphery after 1st June 2011 and zero otherwise. The coefficient δ measures the treatment effect: how much does the crisis change the transaction volume of borrowers in the periphery relative to that of borrowers in the core?

Not surprisingly, the difference-in-difference estimate is not significant (Table 5, Column 1). The point estimate of 0.201 also is inconsistent with counterparty risk. It indicates that once the crisis erupts, banks in the periphery borrowed EUR 0.2bn more relative to banks in the core.

There are two reasons why the difference-in-difference comparison cannot identify the role of counterparty risk. First, banks in the periphery borrow both from banks in the periphery and from banks in the core. Possibly, domestic and cross-border interbank transactions react differently to counterparty risk. Transacting across borders should be more sensitive to counterparty risk because of information asymmetries and legal issues. Italian banks may know more about the true risk of other Italian counterparties - more than German banks do (see Freixas and Holthausen, 2005). Italian banks may also find it easier than German banks to discipline other Italian banks and to ensure loan repayment (e.g., through formal legal or informal channels).

Second, some other factor than the crisis itself may affect borrowers in the periphery. That is, borrowers in the core may not be a good control group because they are not exposed to this factor. For example, borrowers in the periphery may react to deteriorating economic conditions in the periphery. Or they may react to policies by peripheral governments that coincide with the crisis. Alternatively, borrowers, i.e., cash-poor banks, in the periphery may be able to rely on cash-rich banks also in the periphery to provide funding even though counterparty risk has gone up.

For these reasons, we use a more narrow definition of the treatment group. Treated banks are now borrowers in the periphery (whose lenders are in the core). This way, we

focus on those cross-border transactions for which counterparty risk matters most. The risk of the borrower increases because he is located in the periphery, while the risk of the lender does not change because she is located in the core.

With such a narrower definition of the treatment group, we can also use a different control group. Instead of borrowers in the core, we now can use borrowers in the periphery whose lenders are also in the periphery. This “within borrower-in-periphery” comparison controls for any factors that coincide with the crisis and specifically affect borrowers in the periphery.

Figure 10 illustrates this refined difference-in-difference approach. The first difference is the transaction volume between periphery borrowers and core lenders (in red) before and after 1st June 2011. There is a clear drop after the crisis. The second difference compares this drop to what happens to the transaction volume when borrowers and lenders are both in the periphery (in light blue). While the control group of domestic transactions in the periphery shares the slight decline in the first half of 2011 with the treatment group, the volume of domestic transactions in the periphery actually increases somewhat once the crisis occurs. According to this counterfactual, the transaction volume between borrowers in the periphery and lenders in the core would have increased slightly had there not been the crisis. But instead, the transaction volume dropped and remained at a very low level.

To find the new difference-in-difference, we estimate specification (1) using only transactions with borrowers in the periphery. Now $j \in (C, P)$ denotes whether the lender is in the core or in the periphery, t denotes time (week), α_j is the core/periphery fixed effect, α_t is the time fixed effect, and y_{jt} is the transaction volume for all peripheral borrowers with lenders in the core or the periphery in week t . The dummy D_{jt} is one for peripheral borrowers with core lenders after 1st June 2011 and zero otherwise. The coefficient δ measures the treatment effect: how much does the crisis change the

transaction volume between borrowers in the periphery and lenders in the core relative to the transaction volume between borrowers in the periphery and lenders in the periphery?

This new difference-in-difference estimate is statistically significant and economically meaningful (Table 5, Column 2). Once the crisis occurs, the transaction volume between peripheral borrowers and core lenders drops by EUR 1.012 bn relative to the transaction volume between peripheral borrowers and peripheral lenders.

But the new difference-in-difference still can be misleading. It is biased when factors (other than the increase in counterparty risk of peripheral borrowers) affect lenders in the core relative to lenders in the periphery. For example, lenders in the periphery could react to the funding problems of peripheral borrowers and lend more relative to lenders in the core.

In order to control for such confounding lender-effects, we add a second control group (i.e., a third difference to difference-in-difference set-up). The second control group consists of transactions between lenders in the core and borrowers in the core. While the first control group addresses factors affecting all borrowers in the periphery (relative to borrowers in the core), the second control group addresses factors affecting all lenders in the core (relative to lenders in the periphery). That is, we add a third difference (within core-lenders) to the difference-in-difference set-up (within peripheral-borrowers).

Figure 10 illustrates the triple-difference approach. The second control group consists of transactions between core lenders and core borrowers (in dark blue). It controls for factors that affect core lenders and peripheral lenders differentially. While the first control group (periphery lending to the periphery) shows an increase in the transaction volume once the crisis occurs, the second control group (core lending to the core) shows a decrease in the transaction volume. Hence, the difference-in-difference effect (within peripheral borrowers) likely is too large because peripheral banks seem to increase

lending while core banks reduce lending.

To find the triple-difference, we estimate the following specification:

$$y_{ijt} = \alpha_i + \alpha_j + a_t + \alpha_{ij} + a_{it} + a_{jt} + \delta D_{ijt} + \varepsilon_{ijt}, \quad (2)$$

where $i \in (C, P)$ denotes whether the lender is in the core or in the periphery, $j \in (C, P)$ denotes whether the borrower is in the core or in the periphery, t denotes time (week), α_i is the lender (core/periphery) fixed effect, α_j is the borrower (core/periphery) fixed effect, α_t is the time fixed effect, α_{ij} is the lender-borrower fixed effect, a_{it} is the lender-time fixed effect, a_{jt} is the borrower-time fixed effect and y_{ijt} is the transaction volume between lenders (in the core or the periphery) and borrowers (in the core or the periphery) in week t . The dummy D_{ijt} is one for borrowers in the periphery whose lenders are in the core after 1st June 2011 and zero otherwise. The coefficient δ measures the treatment effect: how much does the crisis change the transaction volume of borrowers in the periphery whose lenders are in the core relative to i) borrowers in the periphery whose lenders are in the periphery and ii) borrowers in the core whose lenders are in the core?

The triple-difference estimate is statistically significant (at the 5% level) and economically relevant. Once the crisis occurs, banks in the periphery borrow EUR 0.730 bn less from lenders in the core after controlling for other factors that affect either peripheral borrowers or core lenders. Relative to a pre-crisis transaction volume of EUR 0.923 between borrowers in the periphery and lender in the core, the drop is considerable (79%).

Relative to the difference-in-difference estimate (1.012) the triple-difference estimate is 28% smaller. This is in line with our discussion of the graphical evidence (Figure 10). The comparison within periphery borrowers (and across lenders in the periphery and in the core) needs to be adjusted for the different change in lending by banks in the core

(they decrease lending) and by banks in the periphery (they increase lending).

To sum up, the sovereign debt crisis in the periphery of the euro area increases the counterparty risk of banks in the periphery that borrow from banks in the core. This type of cross-border lending almost disappears in the second half of 2011. There is, however, no overall impact on the borrowing of banks in the periphery. Banks in the periphery receive more funding from other banks in the periphery.

6. Conclusion

This paper shows evidence of malfunctioning in the euro area overnight unsecured money market under high stress resulting from asymmetric information problems. This leads to lower cross-border activity and to more trading at rates outside the ECB interest rate corridor. We develop in this study a version of the Furfine algorithm that reconstructs the overnight unsecured money market. We then use the post-trading structure in Spain (MID) to corroborate our findings. With our application of the Furfine algorithm, we are able to identify accurately turmoil events in the financial system, such as the Lehman bankruptcy or the intensification of the European sovereign debt crisis. These findings coincide with early warning indicators on sovereign systemic stress as well as market events. With a triple-difference estimate we show that the borrowing of banks in the periphery from banks in the core almost disappears in the second half of 2011. In addition, an important conclusion from our study is that the MID post-trading structure maintained by Banco de España provides a high quality source of domestic interbank money market data. This source is of great value for both policy and research analysis.

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Appendix A: Our implementation of the Furfine algorithm

We use a similar algorithm than the one developed by Craig Furfine in 1999 in order to construct unsecured overnight loans from transaction level data in TARGET2. Since the development of the algorithm in 1999, several studies have followed Furfine's methodology to examine unsecured money markets in U.S., Switzerland, Portugal, Netherlands, U.K. or the Euro area. The algorithm used in this study follows five steps – which we explain below.

Step 1: Filter TARGET2 data

We filter each monthly production file on the TARGET2 simulator for interbank and ancillary system transactions larger or equal than EUR 1,000,000.¹³ In the case of ancillary systems, we select MID and e-MID transactions only (Spanish and Italian interbank market domestic platforms, respectively).

Step 2: Core implementation

We identify transactions among participants in TARGET2 where on one day there is a payment ending in at least five zeros and the next day a slightly larger amount is returned (i.e. any “loan” with a zero rate is not identified). We calculate the interest rate on the loan as the difference between outgoing and repayment amount. We narrow at first the search of interest rates up to ten times the order of magnitude of the ECB marginal lending facility rate (i.e. if the MLF rate is 1.5%, the algorithm would search annualized interest rates up to 15%). We however refine at a later stage the maximum annualized interest rate, based on the number of transactions occurring above the MLF rate and relating these to particular events occurring in the respective host country. In order to determine the final cut off for overnight interest rates, we plot the distribution of overnight rates above the MLF rate (in basis points). As observed in Figures 6 and 7,

¹³ Each month of data contains around 7 million transactions. We consider interbank and ancillary system transactions only which have a 1.2 and 3.2 transaction class respectively in TARGET2.

there is little activity at a spread above 75 basis points over the MLF. We therefore finally set the final cut-off for overnight rates at 100 basis points above the MLF rate set by the European Central Bank.¹⁴

Step 3: Cross-check validity of matches

We also check that participants in each leg of the loan (send or receive) – settle the transactions from the same TARGET2 account in both legs.

We check that the participants involved in the loan send and return payments on behalf of the same participant. For this check, we use the available fields in TARGET2 that allow for correspondent lending and borrowing to be identified (originator and beneficiary).

We examine the annualized interest rate of the loan in detail to determine whether the rate is a multiple of half a basis point up to the fourth decimal. For instance, an interest rate of 0.3518000 would not satisfy the requirement, since rounded to four decimals (0.3519) is not multiple of half a basis point. On the other hand, 0.3514999 would, as 0.3515 satisfies the requirement.

Step 4: Discard central bank accounts and consolidate banking groups

We identify the BICs for all central bank accounts and exclude them from the dataset. We consolidate banking groups using the SWIFT Bank Directory Plus, official TARGET2 directory (which includes participant's information), ECB internal sources and internet searches. This is in order to accurately account for banking group changes throughout the financial and European sovereign crisis.

Step 5: Drop identified intra-group transactions

We use the constructed banking group's consolidation to identify transactions between participants of the same banking group. As final step, we exclude them from the dataset. This approach is consistent with other studies such as Afonso, Kovner and

¹⁴ In addition, we inspect after each month the identified number of loans above 100 basis points – which is minimal.

Schoar (2011) which do not consider loans involving institutions from the same bank holding company.

Appendix B: MID post-trading structure in Spain

MID is the Spanish interbank money market post-trading structure. Banco de España runs this automated system that matches, registers, clears (bilateral netting previous to the settlement) and settles on TARGET2. MID settles operations between market participants. Participants connect to MID through SWIFT or VPN. Operations settled through MID are performed via Ancillary System ESPBESMMMID, so they can be easily identified on TARGET2. The first sweep is sent at 10:00 and afterwards every 30 minutes sweeps are generated and sent automatically to the SSP until 18:00.

Main rules:

- Credit institutions can take part in the system.
- Once the operation is matched by both counterparties, it is unchangeable.
- The loan is booked in the accounts of both credit institutions in the SSP.
- The reimbursement is automatically done at the deadline by the application itself.

The amount refunded is the sum of the loan amount plus its interest.

- There is no minimum amount to be settled.
- There is no rule of increments, all possibilities are allowed (even 1 euro).
- It is possible to renew a former loan.
- Roll-overs are very common. These occur where the same institutions transact

with each other in multiple occasions during a short span of time. In these cases, MID nets the operations directly in order to maximize liquidity efficiency. This means that for these specific loans, the settlement inside TARGET2 differs from that in MID. Roll-overs occur for around 5% of volume of operations and 2% of value.

- If intra-group operations occur, as there is a bilateral compensation at the level of the same account holder, the operations would be recorded in MID but there would be no settlement in TARGET2.

- It is normal for the participant to use a broker agency to trade the operations.
- Biggest part of operations are in over-night deposits (82% have 1 day maturity).
- Banco de España publishes, on a daily basis, value settled and interest rates

(maximum, minimum and medium of each session rounded to two digits).

Importance of the market:

- High volume negotiated among credit institutions.
- Interest rates are used as a reference for other operations performed among credit

institutions, or among credit institutions and their customers, such is the case of the MIBOR.

Appendix C: Variable Definitions

Interest rate (percent) is the annualized interest rate as identified in the overnight money market database.

Loan size (mill EUR) is the total amount of an overnight loan.

Loan volume (bn EUR) is the sum of overnight turnover aggregated for banks located in stressed countries (GR, IE and PT), Spain, Italy and banks located in non-stressed countries (all remaining countries with access to TARGET2).

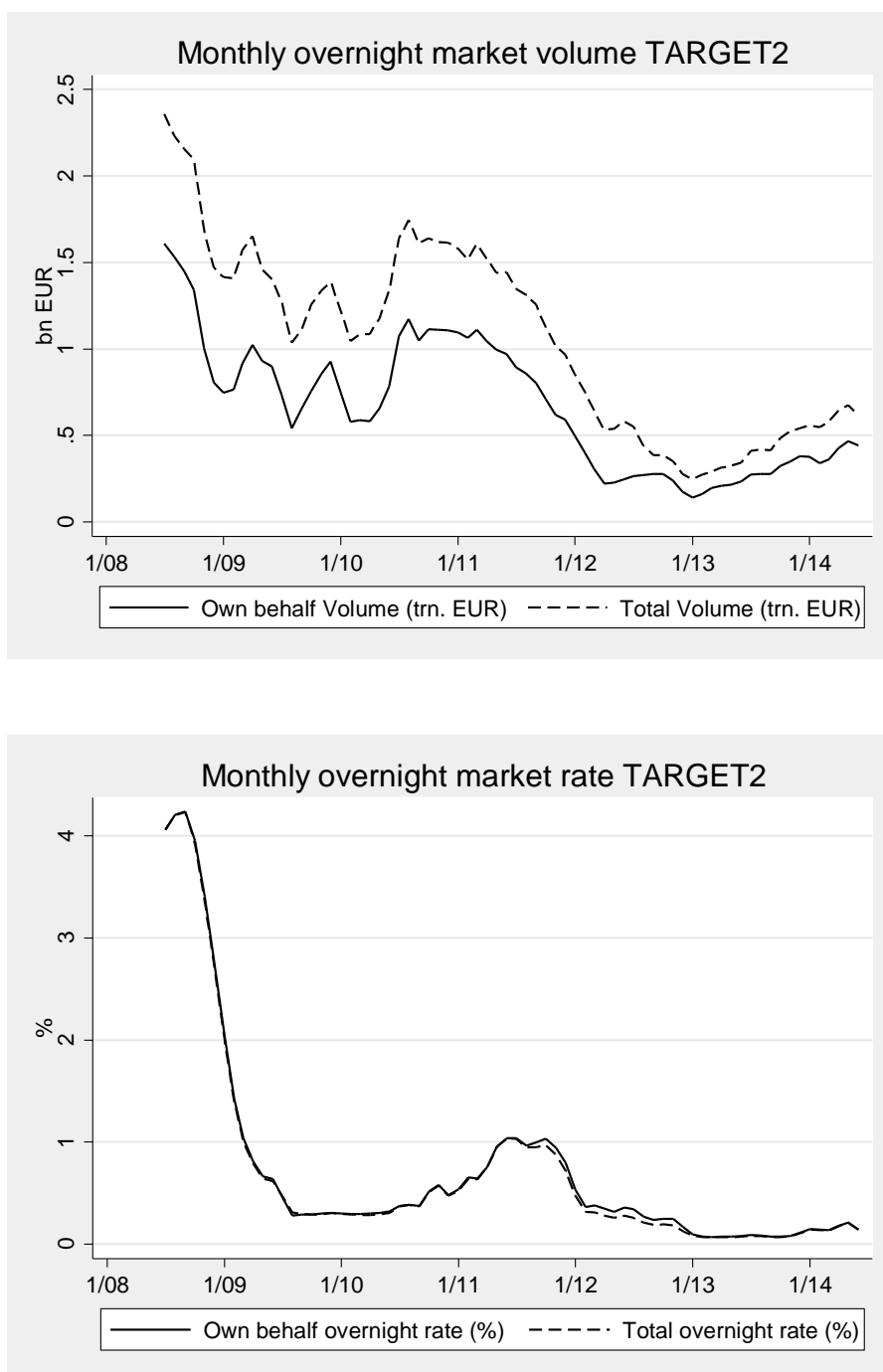
Total number of transactions is the total number of overnight loans.

Total number of transactions at or above MLF rate is the total number of overnight loans with an annualized interest rate equal or higher than the ECB marginal lending facility rate.

Stressed countries refer to banks located in GR, IE and PT.

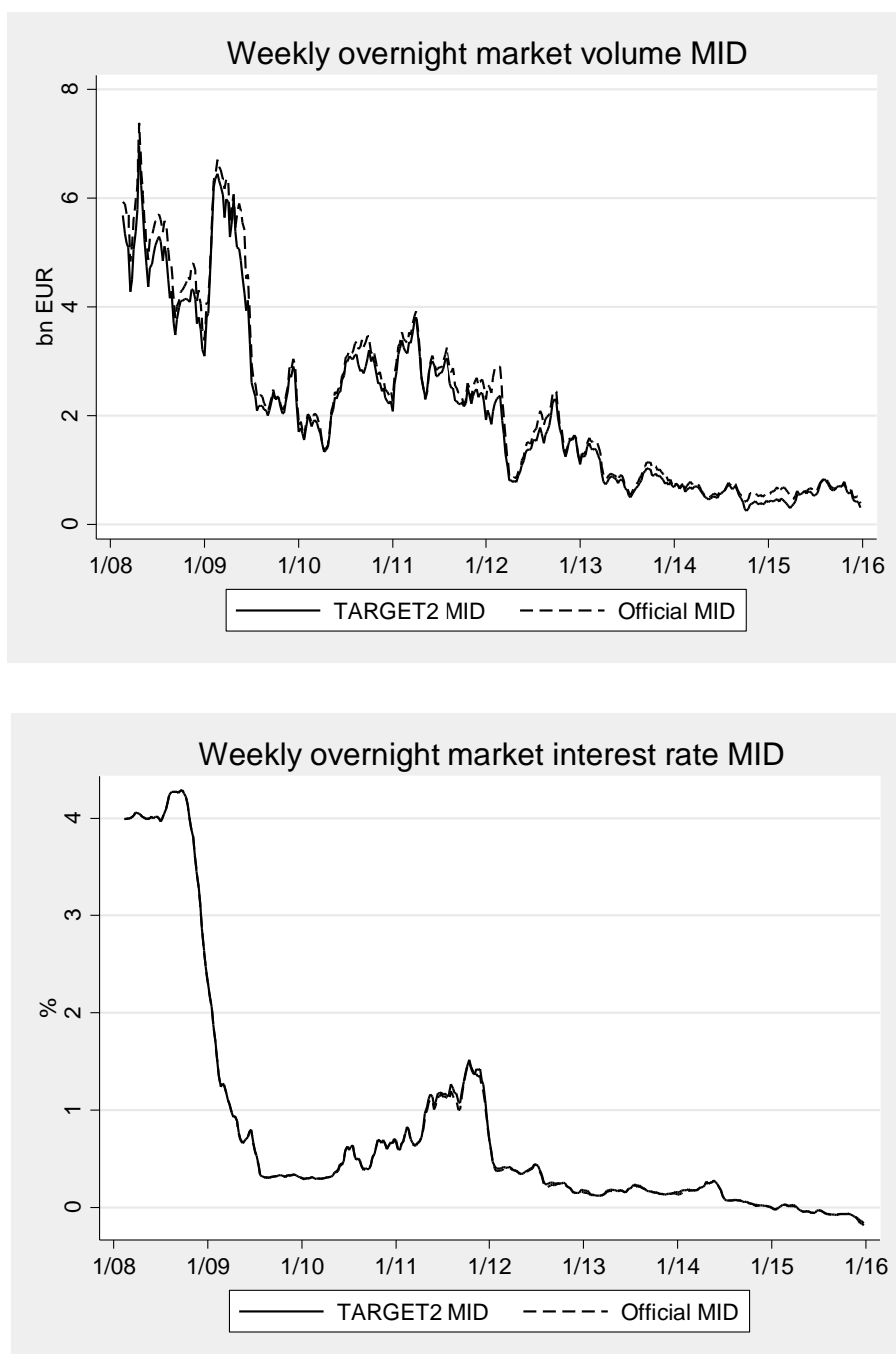
Non-stressed countries refer to banks located in all countries except GR, IE, PT, IT and ES.

Figure 1: TARGET2 overnight unsecured volume and interest rate (own behalf and total)



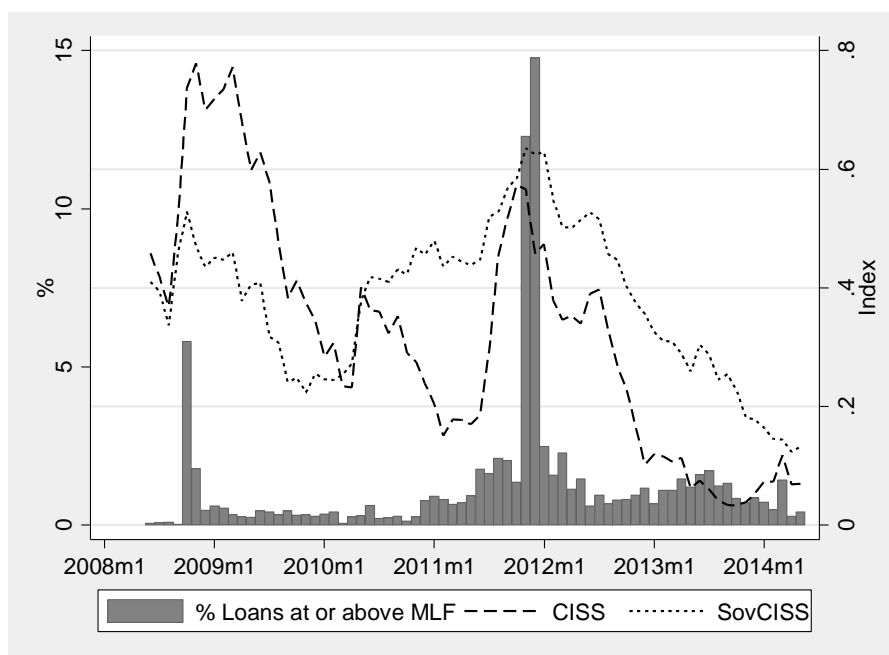
Notes: Monthly unsecured overnight in trillion EUR (top) and monthly unsecured overnight rate in percent (bottom). 1-month moving average. The series include all type of loans (dotted line) and only negotiated by banks on behalf of clients inside their banking group (solid line).

Figure 2: Validation results TARGET2 and MID



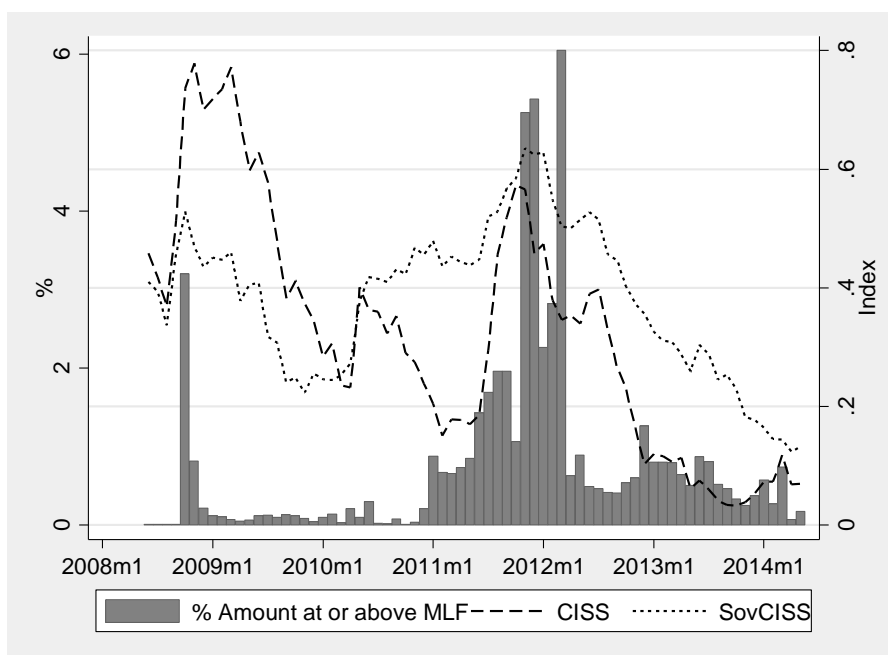
Notes: Weekly overnight market volume in MID and TARGET2 (top) and weekly weighted average overnight interest rate in MID and TARGET2 (bottom). Overnight rate weighted by total volume. TARGET2 MID contains the results of applying the Furfine algorithm to the transactions sent by MID to TARGET2. 4-week moving average.

Figure 3: Overnight market loans at or above MLF and Composite Indicators of Systemic Stress



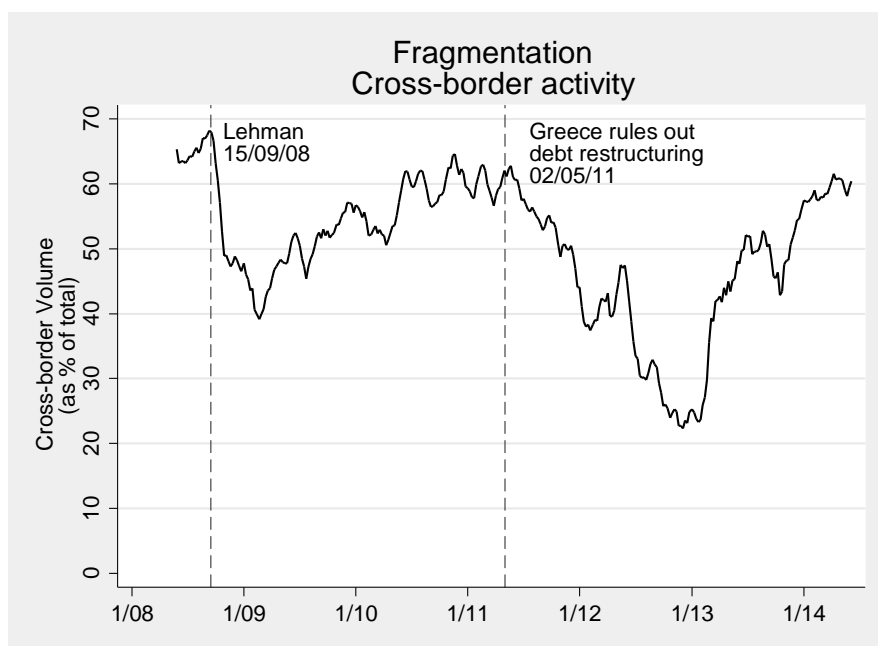
Notes: The percentage of monthly overnight loans at or above the MLF rate is shown in the left-hand axis. The series excludes loans negotiated by banks on behalf of clients outside their banking group. The Composite Indicator of Systemic Stress (CISS) and Composite Indicator of Systemic Sovereign Stress (SovCISS) are shown on the right-hand axis. The CISS measures stress in the financial system as a whole, while the SovCISS only aggregates measures of stress in the sovereign bond markets of 11 euro area countries. See Holló, Kremer and Lo Duca (2012) and Garcia-de-Andoain and Kremer (2016) for details.

Figure 4: Overnight market volume at or above MLF and Composite Indicators of Systemic Stress



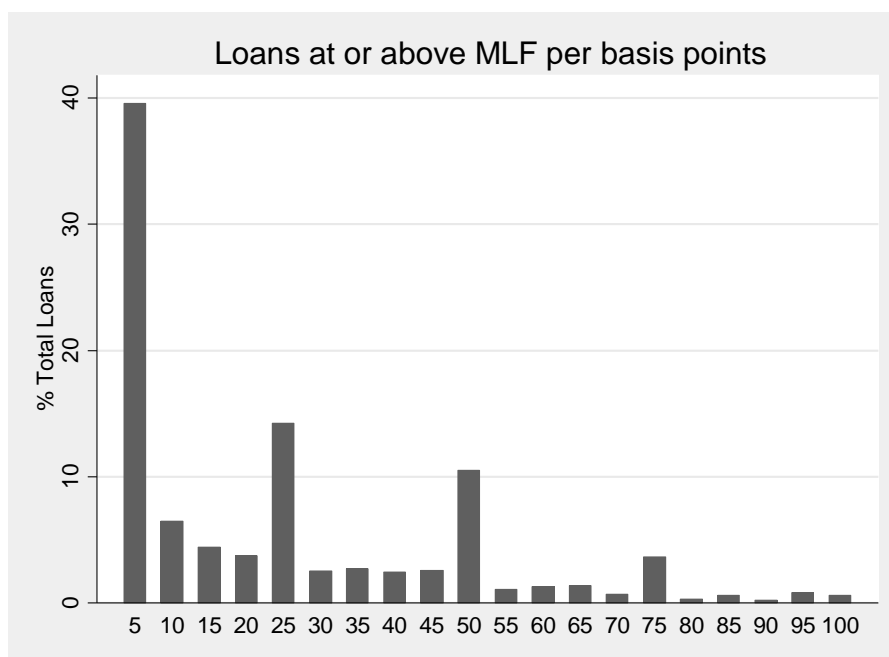
Notes: The percentage of monthly overnight volume at or above the MLF rate is shown in the left-hand axis. The series excludes loans negotiated by banks on behalf of clients outside their banking group. The Composite Indicator of Systemic Stress (CISS) and Composite Indicator of Systemic Sovereign Stress (SovCISS) are shown on the right-hand axis. The CISS measures stress in the financial system as a whole, while the SovCISS only aggregates measures of stress in the sovereign bond markets of 11 euro area countries. See Holló, Kremer and Lo Duca (2012) and Garcia-de-Andoain and Kremer (2016) for details.

Figure 5: Cross-border share fragmentation in the overnight market



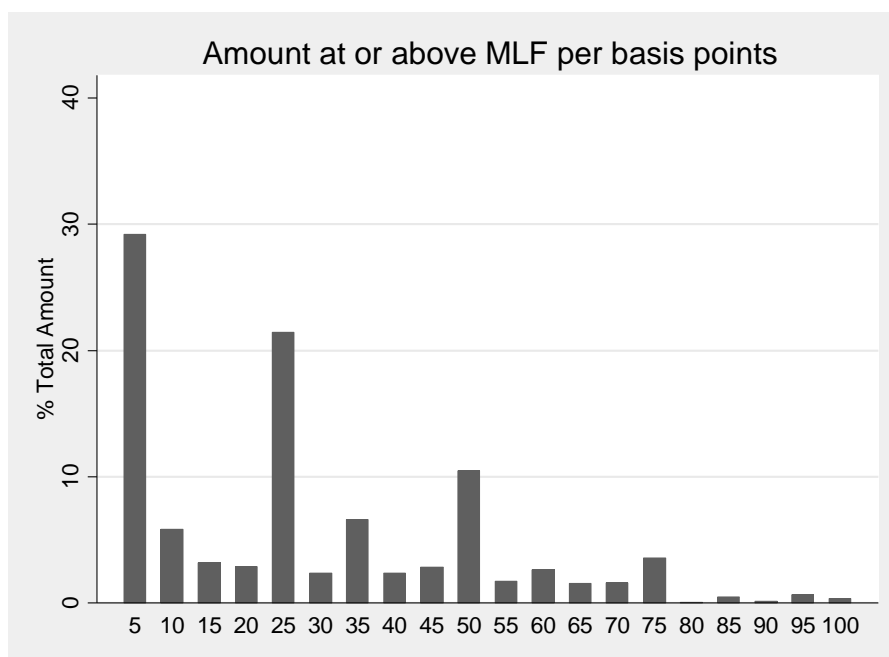
Notes: Weekly cross-border share of the overnight market (as a % of total volume). Two events lines (dotted vertical line) show the Lehman bankruptcy on September 15th 2008 and Greece ruling out a debt restructuring on May 2nd 2011. The series excludes loans negotiated by banks on behalf of clients outside their banking group. 4-week moving average.

Figure 6: Number of overnight loans at or above MLF per 5-basis points



Notes: Total overnight loans at or above MLF (as % of total at or above MLF) per 5-basis point buckets. The series excludes loans negotiated by banks on behalf of clients outside their banking group.

Figure 7: Volume overnight loans above MLF per 5-basis points



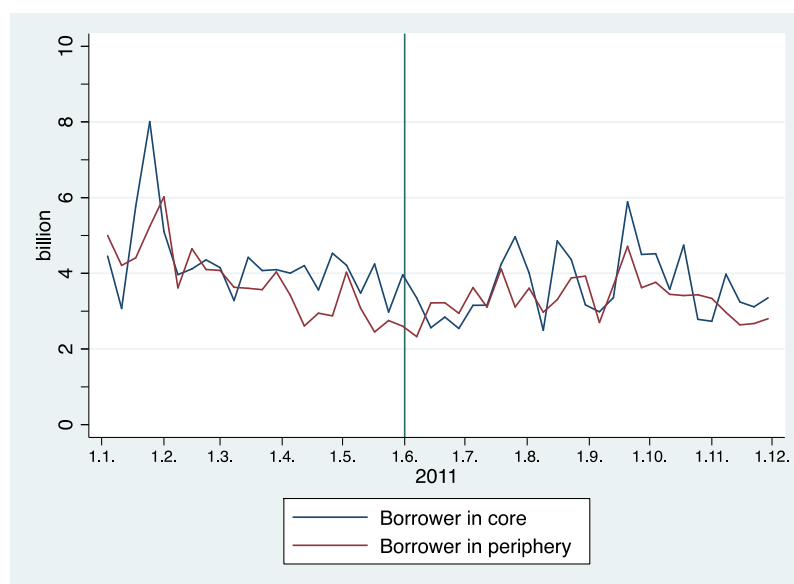
Notes: Volume overnight loans above MLF (as % of total volume above MLF) per 5-basis point buckets. The series excludes loans negotiated by banks on behalf of clients outside their banking group.

Figure 8: Sample period for the difference-in-difference analysis



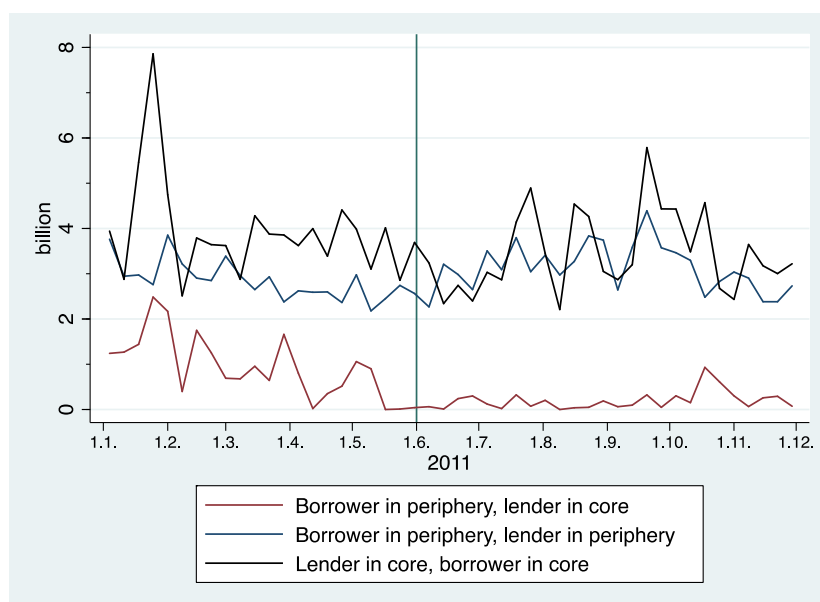
Notes: The figure shows the sample period for the difference-in-difference analysis. The analysis starts on 1st January 2011 and ends on 1st December 2011. The treatment occurs on 1st June 2011. The figure shows the yields on the 10-year government bonds of Germany (blue, right-hand scale) and Italy (red, left-hand scale).

Figure 9: Difference-in-difference – borrowers in periphery vs. borrowers in core



Notes: The figure compares the transaction volumes in billions when the borrowing bank is in the periphery (Italy; treatment group, in red) and when it is in the core (Germany; control group, in blue).

Figure 10: Triple difference – borrowers in periphery and lenders in the core



Notes: The figure compares the transaction volumes in billions when the borrowing bank is in the periphery (Italy) and the lending bank is in the core (Germany). This is the treatment group (in red). The first control group consists of borrowers and lenders in the periphery (in blue). Comparing the treatment group to this first control group is the within-borrower comparison. It takes care of other factors affecting all borrowers in the periphery. But the problem is that lenders in the periphery (used in the within-borrower comparison) may behave differently from lenders in the core. The second control group takes care of this confounding factor. It consists of lenders and borrowers in the core (in dark blue). Comparing the within-borrower comparison to this second control group takes care of the different behaviour of lenders in the periphery relative to lenders in the core.

Table 1: Summary Statistics (all transactions)

	mean	sd	percentile		
			25th	50th	75th
Interest rate					
Overall	1.107	1.335	0.270	0.520	1.100
in non-stressed countries	1.094	1.348	0.260	0.500	1.090
in stressed countries	1.347	1.383	0.330	0.750	2.000
in Spain	1.106	1.211	0.300	0.700	1.150
in Italy	1.100	1.308	0.280	0.520	1.150
Loan size (mill. EUR)					
overall	79.228	160.612	10.000	25.000	80.000
in non-stressed countries	105.281	187.004	15.000	42.000	100.000
in stressed countries	58.684	83.866	12.500	30.000	70.000
in Spain	81.189	176.350	17.000	36.000	80.000
in Italy	29.224	73.120	5.000	10.000	25.000
Loan volume (bn EUR)					
overall	49.766	26.689	25.201	50.431	70.774
in non-stressed countries	38.118	21.278	19.402	37.258	54.222
in stressed countries	2.266	1.729	0.671	1.791	3.677
in Spain	4.270	2.566	1.815	4.357	6.034
in Italy	5.111	3.230	2.211	4.705	7.155
Number of transactions					
overall	969,839				
in non-stressed countries	559,014				
in stressed countries	59,622				
in Spain	81,245				
in Italy	269,958				

Notes: mean, standard deviation, 25th percentile, median and 75th percentile for, interest rate, loan size (mill. EUR) and loan volume (bn EUR). Interest rate is weighted by total volume. Non-stressed countries are all countries except GR, IE, PT, ES and IT. Stressed countries are GR, IE and PT. Statistics shown for time period: 2nd June 2008 – 10th June 2014.

Table 2: Summary Statistics (own-behalf transactions on both sides)

	mean	sd	percentile		
			25th	50th	75th
Interest rate					
Overall	1.145	1.358	0.280	0.550	1.150
in non-stressed countries	1.135	1.383	0.270	0.530	1.100
in stressed countries	1.349	1.363	0.340	0.800	2.000
in Spain	1.137	1.234	0.300	0.730	1.220
in Italy	1.121	1.319	0.290	0.550	1.200
Loan size (mill. EUR)					
overall	89.814	180.500	10.000	30.000	100.000
in non-stressed countries	153.668	233.839	25.000	75.000	180.000
in stressed countries	65.049	90.197	15.000	31.750	85.000
in Spain	76.783	173.539	18.000	35.000	75.000
in Italy	29.899	77.401	5.000	10.000	25.000
Loan volume (bn EUR)					
overall	31.335	18.480	14.394	28.662	44.502
in non-stressed countries	21.989	14.599	9.746	19.619	31.926
in stressed countries	1.684	1.280	0.535	1.295	2.704
in Spain	3.740	2.318	1.622	3.592	5.305
in Italy	3.923	2.507	1.763	3.420	5.512
Number of transactions					
overall	538,688				
in non-stressed countries	220,936				
in stressed countries	39,978				
in Spain	75,194				
in Italy	202,580				
Transactions at or above MLF					
overall	6,290				
in non-stressed countries	365				
in stressed-countries	2,235				
in Spain	1,164				
in Italy	1,717				

Notes: mean, standard deviation, 25th percentile, median and 75th percentile for, interest rate, loan size (mill. EUR) and loan volume (bn EUR). Interest rate is weighted by total volume. Non-stressed countries are all countries except GR, IE, PT, ES and IT. Stressed countries are GR, IE and PT. Statistics shown for time period: 2nd June 2008 – 10th June 2014. Statistics exclude loans negotiated by banks on behalf of clients outside their banking group.

Table 3: Validation results

	Number of loans	Error rate
True positive	74,490	
False negative (Type II error)	4,944	6.22%
MID loans (true positive + false negative)	79,434	
False positive (Type I error)	762	1.01%
Loans found by algorithm (true positive + false positive)	75,252	

Notes: Validation results of identified overnight loans in TARGET2 and the official MID post-trading structure. True positive reflects a successful match, Type II error reflects loans missed by the algorithm and Type I error presents loans that are incorrectly identified by the algorithm as overnight maturity. Error rate percentages derive with respect to the total number of overnight loans in MID.

Table 4: Events

Date	Description
Sep. 15 th 2008	Lehman bankruptcy
Apr. 23 rd 2010	Greece seeks financial support
May. 10 th 2010	ECB introduces Security Markets Programme
Nov. 21 st 2010	Ireland seeks financial support
Apr. 6 th 2011	Portugal request activation of aid mechanism
May. 2 nd 2011	Greece rules out debt restructuring
Nov. 1 st 2011	Greece announces referendum on Eurozone debt deal (withdrawn the next day)
Nov. 12 th 2011	Berlusconi resigns as Italy's prime minister
Nov. 16 th 2011	Monti becomes Italy's new prime minister forming a technocrat government
Nov. 20 th 2011	General elections in Spain
Dec. 8 th 2011	ECB announces measures to support bank lending and money market activity
Dec. 22 nd 2011	First ECB 3-year Long-Term Refinancing Operation (LTRO)
Mar. 1 st 2012	Second ECB 3-year Long-Term Refinancing Operation (LTRO)
Jun. 27 th 2012	Cyprus requests financial support
Jul. 20 th 2012	Eurogroup grants financial assistance to Spain's banking sector
Sep. 6 th 2012	ECB announces technical features of Outright Monetary Transactions

Notes: Date and description of economic and political news during the financial and European sovereign debt crisis.

Table 5: Difference-in-difference(-in-difference) regressions

	<i>Dep. var.: Transaction volume</i>		
	DD	DD	DDD
	Borrower in periphery	Borrower in periphery and lender in core	Borrower in periphery and lender in core
	vs.	vs.	vs.
	borrower in core	borrower in periphery and lender in periphery	borrower in periphery and lender in periphery
			vs.
			lender in core and borrower in core
	(1)	(2)	(3)
Borrower_Peri*Crisis	0.201		
	0.251		
Borrower_Peri-Lender_Core*Crisis		-1.012***	
		0.185	
Borrower_Peri-Lender_Core*Crisis			-0.730**
			0.326
Time FE	Y	Y	Y
Core/Periphery FE	Y		
Borrower (Core/Periphery) FE		Y	Y
Lender (Core/Periphery) FE			Y
Lender - Borrower (C/P-C/P) FE			Y
Borrower (C/P) - Time FE			Y
Lender (C/P) - Time FE			Y
R^2	79.0%	94.8%	97.0%
No. of countries	2	2	2
No. of observations	96	96	192

Notes: This table examines whether Italian (= periphery) borrowers transact less because of the increased counterparty risk after 1st June 2011 (*Crisis* = 1). The dependent variable is the per-week average of the daily trading volume. The first column compares Italian (periphery) borrowers (*Borrower_Peri* = 1) to German (core) borrowers (*Borrower_Peri* = 0). There is no distinction between cross-border and domestic lending. Hence column 1 only has time fixed effects and a country (= core/periphery) fixed effect. Column 2 compares Italian banks that borrow from German banks (*Borrower_Peri-Lender_Core* = 1) to Italian banks that borrow from Italian banks. This is a comparison within peripheral borrowers (hence the borrower fixed effect). The interaction term in columns 1 and 2 is a difference-in-difference estimator. Column 3 compares Italian banks that borrow from German banks (*Borrower_Peri-Lender_Core* = 1) to Italian banks that borrow from Italian banks and German banks that lend to German banks. The interaction term now is a triple difference estimator (with borrower, lender and time fixed effects as well as their interactions: borrower-lender, borrower-time and lender-time). ***, **, and * denote statistical significance at the 1%, 5%, and 10% level, respectively. Standard errors are robust to heteroscedasticity.

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