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HOW TO MEASURE THE UNSECURED MONEY MARKET? THE EUROSYSTEM'S IMPLEMENTATION AND VALIDATION USING TARGET2 DATA

by Luca Arciero*, Ronald Heijmans**, Richard Heuver**, Marco Massarenti***, Cristina Picillo* and Francesco Vacirca****

Abstract

This paper develops a methodology, based on Furfine (1999), for identifying unsecured interbank money market loans from the transaction data of the most important euro payment processing system TARGET2, for maturities ranging from one day (overnight) up to three months. The implementation has been verified with (i) interbank money market transactions executed on the e-MID Italian electronic trading platform and (ii) aggregated reporting by the EONIA panel banks. The Type2 (false negative) error for the best performing algorithm setup is 0.92%. We find aggregated interest rates very close to the EONIA but observe a high degree of heterogeneity across countries and market participants. The different stages of the global financial crisis and of the sovereign debt crises are clearly revealed in the interbank money market by significant drops in turnover. The results focus on three levels: euro-area, country group and country (Italy and the Netherlands).

JEL Classification: E42, E44, E58, G01.
Keywords: euro interbank money market, Furfine, TARGET2, financial stability, EONIA.

Contents

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1 Introduction[1]

An efficient interbank money market is essential for the stability of the financial system and plays a critical role in the transmission of monetary policy. After the failure of Lehman Brothers in the fall of 2008, banks became increasingly reluctant to lend liquidity to each other, due to higher perceived counterparty risk (Heider et al., 2009). To compensate for this increased uncertainty, lenders demanded higher credit risk premia or high quality collateral (ECB, 2010). At the same time, liquidity-short banks were reluctant to ask for interbank deposits to avoid being perceived as illiquid, the so-called stigma effect (Cappelletti et al., 2011). In many cases banks stopped lending to their counterparties and preferred to use the European Central Bank's (ECB) overnight deposit facility to store their surplus liquidity. This resulted in a significant decrease in the turnover on the unsecured interbank money market and a large increase in the ECB's overnight deposit facility. Furthermore, interbank money market trading shifted from the unsecured market to the secured market (ECB, 2012a,b; Cappelletti et al., 2011), where the interposition of the central counterparty mitigates risks. Following the contagion of the sovereign debt crisis among some European countries, the segmentation of the interbank money market increased significantly. Banks located in Greece, Ireland, Italy, Portugal and Spain faced a rise in sovereign risk premia while cross-border liquidity flows to these countries declined (BIS, 2012).

In response to the crisis the Eurosystem introduced unconventional monetary policy measures to ease the strains in several markets, such as the interbank money market, strains that hampered the smooth transmission of monetary policy impulses. (ECB, 2010; van Riet, 2010).[2] The effect of these actions and especially of the switch to fixed-rate full-allotment monetary policy tenders was that banks no longer need to rely on each other to fund their liquidity needs (ECB, 2012a). Liquidity-short banks can always obtain the desired amount of liquidity from regular ECB monetary policy operations, against collateral in the form of a wide range of eligible assets. Liquidity-rich banks can always deposit excess amounts at the ECB's overnight deposit facility instead of lending it to a market counterparty, as long as they accept the implicit opportunity cost.

To evaluate the efficiency of the transmission of the (unconventional) monetary policy impulses, it is essential to have reliable and complete information on the interbank money market. Normally, however, central banks, including the ECB, have to rely on partial information. In the Eurosystem this information derives from the following sources: (i) reporting by the major banks in the euro area on their overnight lending rates and volumes (which make up the Euro OverNight Index Average, EONIA); (ii) data on individual exchanges on the e-MID Italian electronic trading platform ; (iii)

[1] We thank Ron Berndsen, Hans Brits and Matti Hellqvist for reviews of early versions of the paper and the colleagues at the ECB who worked together in the early stage of the money market project: Carlos Garcia de Andoain Hidalgo, Florian Heider, Joanna McLafferty, Patrick Papsdorf and Sara Testi. We are also grateful for their comments to participants at the 2nd CPSS workshop on payment monitoring indicators (BIS) and the first joint Financial Stability Committee-Payment and Settlement Systems Committee workshop (ECB). The views expressed in this paper are those of the authors and do not necessarily represent those of Banca d'Italia, De Nederlandsche Bank or ECB. All errors and/or omissions are ours.

[2] Unconventional monetary policy measures included: fixed-rate full-allotment since October 2008; swap agreements with other Central Banks (e.g. the Fed and the SNB); extension of the collateral framework; extension of the duration of refinancing operations (e.g. year tenders starting July 2009 and 3-year tenders starting December 2011); the introduction of the Covered Bond Purchase Programme (May 2009), the Securities Market Programme (May 2010) and of Outright Monetary Transactions (September 2012).

data on individual trades on the MID Spanish domestic market; and (iv) data on domestic and cross-border lending and borrowing for Greek banks.[3] EONIA panel data refer only to the aggregated daily overnight transactions of the major money market actors in the euro area; e-MID data account for less than 20% of overall interbank transactions in the euro area and, especially since mid-2011, are mainly representative of Italian banks. Similarly, MID and Greek data mainly reflect the Spanish and Greek interbank markets. The residual over-the-counter (OTC) money market transactions are not directly available to the Eurosystem. However, the majority of these transactions will be settled in the most important euro large value payment system (LVPS), TARGET2.

The main research question of this paper is, therefore, how to identify euro-area unsecured interbank loans with maturities ranging from one day up to one year using payment data from TARGET2. To find loan-refund combinations from LVPS data, we employ and expand the method put forward by Furfine (1999). He developed an algorithm to identify interbank loans for the US money market, using Fedwire data. This algorithm assumes a round value transferred from bank A to bank B at time t and the same value plus an amount based on a plausible interest rate from bank B to bank A at time $t+1$. The minimum value of a payment was set equal to \$ 1 million with increments of \$ 100,000. The interest rate is considered plausible if it lies within 50 basis points above or below the federal funds rate. Demiralp et al. (2004) extended the algorithm to capture smaller loans and excluded any transaction whose interest rate did not correspond to a market quote for interest rates in units of 1/32 percentage points or in whole basis points.

Subsequently, several authors have applied Furfine's method to payment data from several payment systems. Millard and Polenghi (2004) applied Furfine's algorithm to British LVPS (CHAPS) data, using a threshold of £1 million. Hendry and Kamhi (2007), studying the Canadian Large Value Transfer System (LVTS), followed the approach of Demiralp et al. (2004) by including only interest rates in units of half a basis point. Akram and Christophersen (2010) implemented an algorithm for the Norwegian market. They accepted that some money market trades could occur at rates below the overnight deposit rate, which is usually the lower bound of the interest rates traded in the market, since at that rate banks can turn to their central bank to deposit their excess liquidity as long as they have access to central bank's standing facility . The authors argued that foreign banks which do not have access to Norges Bank's overnight deposit facilities may in fact lend their excess liquidity in Norwegian krones even at rates below the deposit rate.

The aforementioned papers have in common that they focus solely on the overnight money market. Heijmans et al. (2010) and Guggenheim et al. (2010) implemented an algorithm for maturities up to one year for the Dutch and Swiss markets respectively. The main difference between the two papers is the way longer-term loans are matched. Guggenheim et al. (2010) start by identifying one-day loans. When a loan-refund match has been found, the two payments that have been matched are excluded from the search for the following maturity. Conversely, Heijmans et al. (2010) do not exclude any loan-refund candidates when looking at longer maturities. Thus, the same payment may be matched

[3] In addition to each of the four sources only giving partial information on the money market, there are also restrictions on the availability of the data for confidentiality reasons: individual EONIA data are available only to the European Banking Federation (EBF) and to the ECB for monetary policy purposes, e-MID data are available only to Banca d'Italia in its financial markets' supervisory function and correspondingly MID and Greek data are available only to Banco de España and to the Bank of Greece respectively.

with different refunds and vice versa. Multiple matches may arise both within the same maturity and between different maturities. The alternative candidates stemming from these multiple matches are then selected according to the most plausible match. This approach avoids the *a priori* matching imposed by the order in which the algorithm processes the payments.

Following a similar approach, we enhance the algorithm to reduce the uncertainty of the results. Moreover, with respect to other works, the results have been validated against two external data sources: (i) aggregated EONIA panel contributions and (ii) e-MID transaction-level data. To the best of our knowledge, this is the most comprehensive validation exercise yet carried out for Furfine implementation. The validation enables us to quantify the Type 2 (false negative) and Type 3 (mismatch) errors. Further, it shows that our algorithm's performance is satisfactory, particularly in the overnight segment. This result is in sharp contrast with the recent paper by Armantier and Copeland (2012) assessing the quality of Furfine's algorithm implemented at the Federal Reserve Bank of New York against a dataset of bilateral transactions between two large US dealers. They find very discouraging results, namely average Type 1 and Type 2 errors equal to 81% and 23% respectively between 2007 and 2011. In addition, they argue that these errors may not diminish if the algorithm's output is aggregated. This confirms the validity of our implementation and underscores that a "plain-vanilla" version of the Furfine algorithm without a deep knowledge of the underlying data and technical details of the system may produce misleading and potentially spurious results. This study also aims at providing the Eurosystem with a database of euro-area money market transactions for monetary policy, financial stability and research purposes. First analysis using the database developed in the basis of this methodology are forthcoming (Snellman et al. (2013) and Abbassi et al. (2013)).

The outline of this paper is straightforward. Section 2 presents the data used in our analysis. Section 3 describes the algorithm, while its validation against e-MID and EONIA panel data is provided in Section 4. That section also describes the level of uncertainty of the algorithm and presents the most suitable corridor for the euro money market. Section 5 provides some descriptive analysis of the euro-area interbank money market. Finally, Section 6 concludes and makes some policy recommendations.

2 Data

The data sources we use for this paper are (i) payments settled in TARGET2, the main euro-area LVPS;[4] (ii) individual interbank loans settled on the e-MID Italian electronic money market trading platform; and (iii) aggregate reporting by the banks participating in the EONIA panel.

2.1 TARGET2

TARGET2, Trans European Real-time Gross settlement Express Transfer, is the Eurosystem real time gross settlement system (RTGS) for euro-denominated large value payments in central bank money. Currently, all euro-area countries and six non-euro-area countries are connected to TARGET2.[5] The system processes the transactions of roughly 4,500 credit and other financial institutions which meet the access criteria, directly or indirectly. As TARGET2 is an RTGS system, each transaction is settled immediately (real time), individually (gross) and irrevocably. Besides transactions between (in)direct participants and transactions related to monetary policy implementation, it is also used for the settlement of many other ancillary systems (Kokkola, 2010). For the purposes of this paper, two important systems which settle in TARGET2 are the Italian e-MID and the Spanish MID, i.e. the only trading platforms for unsecured money market transactions operating in the euro area (see Section 2.2).

Every transaction in TARGET2 involves two participants (mainly banks) and/or one (domestic) or two (cross-border) national central banks (NCBs). The list of participants comprises mainly euro-area credit institutions and several large non-euro-area banks (notably located in the UK and the US). Each account of every participant is assigned to an NCB. Although banks are free to choose a reference central bank in the Eurosystem, most banks choose the central bank of the country where their headquarters are located and opt for two or more reference central banks only as specific business needs arise. For non-euro-area participants, the location of branches and/or subsidiaries has determined the choice of reference central bank. This is important and should be kept in mind when studying domestic and cross-border developments in the euro interbank money market.

Money market transactions may also be settled through EURO1, the second euro LVPS system, which is a privately owned payment system for domestic and cross-border payments in commercial bank money. The system has 65 participating (mainly large) euro-area banks. Although banks participating in this system can settle interbank money market loans in EURO1, the majority of money market transactions are assumed to be settled in TARGET2, where daily turnover is close to € 3,000 billion whereas in EURO1 it is less than € 250 billion euros.[6]

[4] Access to transaction-level data and the establishment of the TARGET2 Simulation Project is based on a decision by the Governing Council from 29 July 2010, (ECB/2010/9). See http://www.ecb.int/ecb/legal/pdf/l_21120100812en00450047.pdf. In particular, access to and use of transaction-level data is limited to a small group of designated staff members from the National Central Banks (NCBs) and the European Central Bank (ECB) for oversight and operational purposes, i.e. the Group of Authorised Overseers (GAO) and the Group of Users from the Operational side (GUO).

[5] The six non euro area countries are Bulgaria, Denmark, Latvia, Lithuania, Poland and Romania (status at the end of October 2012).

[6] https://www.ebaclearing.eu/Statistics-on-EURO1%2fSTEP1-N=E1_Statistics-L=EN.aspx.

2.2 e-MID

The electronic Mercato Interbancario dei Depositi, e-MID, is a privately owned electronic money market system for interbank loans, created in 1990 as a joint initiative of the Italian banking community and Banca d'Italia. Money market trades that are executed on this platform do not differ significantly from OTC transactions, as e-MID offers three different trading options: (i) the Multilateral Trading facility, where orders entered by participants are visible to the entire market and are binding *vis-à-vis* other participants; (ii) the Request for Quote facility, where banks can trade with a restricted group of counterparties; and (iii) the Direct Order dealing option, where banks agree bilaterally on money market trades. The two latter trading options closely resemble OTC transactions.

Following the launch of the euro and until the start of the financial crisis, e-MID experienced continuous growth in trading and increasing participation by non-Italian banks. At the beginning of 2007, more than 60% of participants were non-Italian institutions from 19 countries. In that year, e-MID accounted for 20% of the overall interbank transactions in Europe (ECB, 2012b). As of August 2007, and especially in the aftermath of the collapse of Lehman Brothers, the daily average turnover declined, most likely as a result of higher perceived counterparty risk and a potential stigma effect for banks having to disclose their liquidity needs on a transparent electronic platform like e-MID (Cappelletti et al., 2011). Starting in 2008, cross-border flows also decreased significantly. Nevertheless, according to Monticini and Ravazzolo (2011), in 2008 e-MID was still representative for the euro-area money market as a whole, since loans involving at least one non-Italian counterparty accounted for 42% of the total turnover and foreign participants accounted for 42% of the total number of active traders (179). Although the share of non-Italian trading fell to 20% in 2009 and to 10% in 2010, market conditions on e-MID remained anchored to the euro-area money market as witnessed by the low spread between the overnight interest rate traded on e-MID and the EONIA rate. Thus, e-MID can be regarded as a benchmark of the euro area money market and a suitable support in validating Furfine's algorithm, especially at the beginning of the period considered and for the overnight maturity.[7]

Unlike one-day transactions, longer-term maturities traded on e-MID have been quite rare since the outbreak of the crisis. Therefore, the extension to the entire data set of the validation results for these maturities is less straightforward. The e-MID market shifted towards shorter-term maturities in the aftermath of the sub-prime crisis. From June 2008, one-day transactions (overnight, tomorrow-next, spot-next) accounted for more than 90% of total transactions. Until mid-2009 loans with maturity up to 3 months (excluding one-day transactions) represented 5% of the overall turnover. Although infrequent, longer e-MID trades are the only readily available source of individual money market transactions which can be used to assess the goodness of fit of the Furfine-like algorithm in the euro area at longer maturities.

[7] Only since the contagion of the sovereign debt crisis in Italy (August 2011) has the market become mainly Italian and the spread between the EONIA and e-MID rates widened, reflecting increased national segmentation of the euro-area money market. Thus, the information content of e-MID loans as a benchmark for the overnight euro-area money market has deteriorated since then (Cappelletti et al., 2011).

2.3 EONIA panel

The EONIA is an effective overnight interest rate computed as the weighted average of all overnight unsecured loans reported by the contributing euro-area panel banks.[8] Soon after the closing of the day trade phase in TARGET2, each panel bank sends the ECB the sum of all lending transactions carried out during the business day and the corresponding weighted average rate. EONIA rate and aggregated turnover are publicly available at the ECB website and are provided by several data providers.

Panel banks have to exclude certain lending transactions from their report: loans to counterparties belonging to the same banking group (intra-group), money market transactions settled on behalf of customers as well as tomorrow-next and spot-next transactions, the latter not being agreed on the reporting business day.

The EONIA panel includes banks in EU countries participating in the euro from the beginning, banks in EU countries not participating in the euro from the beginning and large international banks in non-EU countries but with important euro-area operations. The banks contributing to the EONIA rate are the same as those in the EURIBOR panel and all hold an RTGS account in TARGET2.

[8] In October 2012 the EONIA panel consisted of 43 banks. The list of current panel banks can be found at http://www.euribor-ebf.eu/euribor-eonia-org/panel-banks.html.

3 The algorithm setup

Our implementation of the unsecured interbank loan identification algorithm in the euro area using TARGET2 payments data is characterised by the following elements: (i) the input data, (ii) the loan value and increment, (iii) the areas of interest rate plausibility, (iv) a further criterion for plausible interest rates, (v) the procedure for dealing with multiple matches and finally (vi) the identification of the maximum reliable duration. This section concludes by summarising the implementation of the algorithm. See the Annex for a more formal description of the algorithm setup.

3.1 TARGET2 data

As we are interested in identifying unsecured loans settled in TARGET2 between commercial banks in the euro area, our input dataset is composed solely of bank-to-bank (interbank) transactions.[9] Starting from the total TARGET2 database, interbank transactions are identified excluding payments from or to accounts belonging to central banks and national treasury accounts. In addition, we exclude transactions from and to accounts belonging to the same legal entity. Some banks (and groups of banks) have more than one account in TARGET2 (with one central bank for administrative reasons and/or across several central banks within the euro area): we deem it admissible to consider them together because usually these accounts are controlled by the credit institution's head office. As we want to assess the overall money market transactions in the euro area, executed both over-the-counter and electronically, we also include ancillary system transactions stemming from e-MID (Italy) and MID (Spain) electronic money market platforms. Transactions from all other ancillary systems in the euro area are discarded. Finally, we need to point out that, due to data unavailability, the matches are based on the TARGET2 settlement banks and not on the originators and final beneficiaries of the transactions. This may introduce substantial noise into analyses at bank level. The TARGET2 data we use in this paper go from 1°June 2008 to 30 June 2012.

3.2 Loan and increment values

In the seminal version of the algorithm, Furfine (1999) adopts \$ 1 million as the minimum loan value and a fixed increment of \$ 100,000 for the US federal funds market. Demiralp et al. (2004) also describe the US market using \$ 50,000 as the lower bound and increment. Heijmans et al. (2010), investigating the Dutch part of the euro-area market, used € 100,000 as the minimum loan and increment value. Guggenheim et al. (2010) used a minimum loan value of SFR 500,000 and an increment of SFR 100,000 for the Swiss market. All the papers available in the literature adopted minimum loan values ranging between 50,000 and 1 million of the local currency unit, with increments ranging of between 50,000 and 100,000 units. Nevertheless, none of the papers provided hard evidence to support their choices.

To choose the optimal setup for the euro-area a two-phased approach was adopted. First, a survey was conducted among the euro area central banks to assess national practices in the euro-denominated

[9] The algorithm can be used to analyse customer payments as well: these are excluded from our input dataset as the focus of the present work is on the interbank money market, not lending and borrowing activity involving customers.

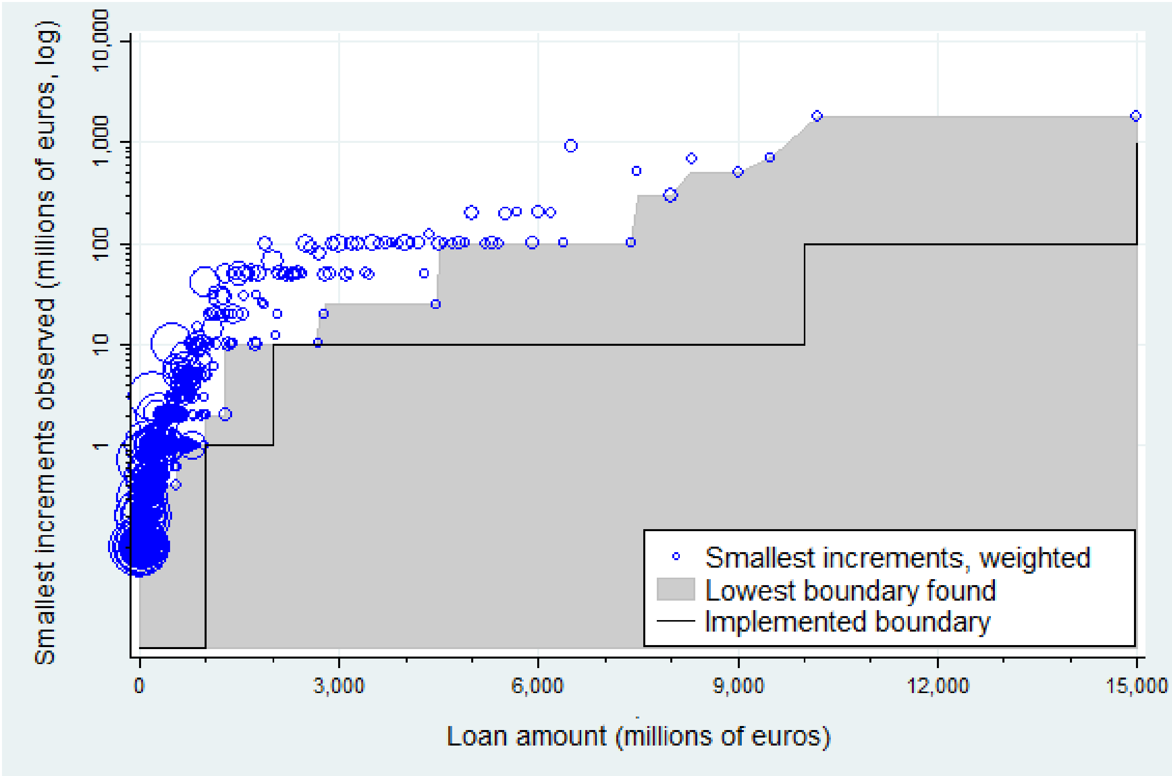

Figure 1: Observed smallest increments to the next higher loan amount.

money market.[10] The survey revealed (i) that the minimum loan value is € 1 million with increments ranging from 10,000 to several million euros, depending on the loan size, (ii) that payment splitting (which would make it almost impossible to identify individual money market transactions) almost never occurs and (iii) that roll-overs (automatic renewal of loans) are frequent in certain euro-area countries.[11] In addition, the e-MID database confirms that € 1 million is a good choice as minimum loan value, although the platform does allow smaller trades under specific conditions.[12]

The analysis of the number of unique matches obtained by imposing a minimum increment threshold of € 10,000 shows that setting increments according to the amounts of loans is the optimal strategy: increments that are too low could lead to an increase in false positives, whereas setting thresholds too high would not capture effective money market transactions (false negatives, see Section 4.1). Figure 1 depicts the scatter plot of the increment with respect to the loan amount for all unique matches captured by the algorithm that uses the € 10,000 increment rule. The size of the circles is weighted with the number of identified transactions for a given loan amount and a given increment. The black line, representing the increment threshold below which no unique matches were found, led us to adopt a step function for the minimum increment amount, as follows:

[10] The survey was jointly conducted by the Working Group Oversight (WGO) and the Working Group TARGET2 (WGT2) of the Eurosystem.

[11] This applies in France, Portugal and Spain.

[12] In e-MID, banks are required to quote proposals at least equal to € 1.5 million. Nevertheless, if after being hit by an order that partially covers the proposed quantity, the residual quantity is lower than the minimum amount, the proponent can still negotiate it. e-MID trades below 1 million euros represent only 0.1% of all e-MID transactions by volume.

A. € 10,000 for transactions below € 1 billion;

B. € 1 million for transactions between € 1 billion and 2 billion;

C. € 10 million for transactions between € 2 billion and 10 billion;

D. € 100 million for transactions between € 10 billion and 15 billion;

E. € 1,000 million for transactions greater than € 15 billion.

3.3 Areas of plausibility

Matching two transactions as being an interbank loan and its refund requires assumptions regarding plausible interest rates. Furfine (1999) uses a corridor of 50 basis points below the 11:00 a.m. brokered federal funds rate and 50 basis points above the closing rate. Demiralp et al. (2004) use a corridor of 100 basis points in order to capture loans that potentially differ more noticeably from brokered fed funds trades. They use a minimum interest rate of 1/32. Heijmans et al. (2010) use a corridor of 50 basis points centered on the EONIA or EURIBOR rate (depending on the maturity) for most of the period considered. After the failure of Lehman Brothers, they increase the lower bound to 100 basis points because some banks were able to attract liquidity at unusually low interest rates. Guggenheim et al. (2010) set the corridor at 15 basis points around the respective LIBOR rate for most of the days. On days of high volatility, they use a band width that is a function of the intraday volatility.

To find the optimal area of plausibility for the euro area, we investigate five different corridors. The first plausibility area (ECB0) is equal to the ECB corridor of marginal lending and overnight deposit rates. However, evidence from the literature and from the e-MID data show that rates both below the deposit rate and above the marginal lending rate do occur.[13] Therefore, a second plausibility area widens the ECB corridor by 25 basis points below and above (ECB25). However, the ECB corridor represents a benchmark for overnight money market transactions but not for longer term ones. Better reference rates for longer term money market transactions might therefore be derived from the EURIBOR yield curve. Therefore, we also investigate corridors around the EONIA rate for overnight transactions and around EURIBOR for maturities starting from 5 days. Unlike the ECB key policy rate, which is the centre of the first type of plausibility areas, EURIBOR is not an actual rate but only a quoted one, which means that effective longer-term maturities may depart significantly from the relative fixing. Like Furfine (1999), we choose to set a corridor around this reference rate of 25 basis points (EONIA25), 50 basis points (EONIA50) and 100 basis points (EONIA100).

3.4 Plausible interest rates

The corridor approach excludes implausibly high and low interest rates but may still match payments that yield implausibly complicated interest rates. Anecdotal evidence collected from market operators

[13] Banks may borrow at rates higher than the ECB marginal lending rate if, e.g., they lack collateral to guarantee their overdraft; banks may also borrow and lend at rates outside the ECB corridor if they do not have access to the Eurosystem standing facilities.

and the e-MID minimum rate tick rule suggests that banks do not agree on interest rates that are not rounded to a particular number of decimals.

Demiralp et al. (2004) were the first to employ this additional interest rate criterion: they filtered out any repayments that did not imply an interest rate in units of 1/32 percentage points or in whole basis points. Similarly, we only include matched transactions with implied interest rates of multiples of half a basis point, i.e. the third decimal must be either 0 or 5. In other words, a returning payment that leads to a 4.345% rate is included in the output dataset, whereas one resulting in a 4.343% rate is not considered a plausible match and therefore discarded. Treasurers at several commercial banks have confirmed this hypothesis.[14]

3.5 Multiple matches

The algorithm described so far matches all transactions that represent possible loan advances with all payments that qualify as potential repayments. As a consequence, a single transaction can be matched with several other payments (multiple matches or collisions). Two different types of multiple match can occur: (i) intra-day and (ii) inter-day. The first case occurs when one or more potential reimbursements match with one or more transactions on the same day. In this case the wrong choice of match may lead to an error in the estimated rate if the amounts of the reimbursements differ. The second case occurs when one or more reimbursements on different days match with one or more loan advances; in this case the error affects both the maturity and the rate. Obviously, the two can also occur simultaneously.

In the case of an intra-day maturity collision, the choice of match is made randomly since the first implied interest rate is assessed to be as plausible as the second one. In the case of an inter-day maturity collision, we choose the most plausible duration according to the observed frequency of the maturities of uniquely matched TARGET2 loans (see Figure 2). The chart shows that where an identified loan advance matches two opposite transactions, one six and the other seven days later, our rule will consider it as a seven day maturity loan. In most cases, maturities counted in whole weeks and months occur more frequently than any of the adjacent maturities.

3.6 Maximum reliable duration

The longer the loan maturity, the larger the area of plausibility is in an absolute sense. Where the corridor is wider, it is more likely that a matched loan-refund combination is in fact a pair of two unrelated transactions. In other words, the amount of noise (falsely identified loans) will increase with maturity. Figure 3 shows schematically the increase of the stochastic error with increasing maturity whereas Figure 4 shows the distribution for 16 different maturities of all unique loans found by our algorithm. As the stochastic error becomes larger, the algorithm becomes less reliable. The validation exercise of Section 4.2 confirms this. Therefore, we assume that our algorithm is the most reliable for identified TARGET2 loans up to three months.

[14] In this paper we have implemented only the 360-day year convention for rate calculation. However, we have found evidence that some trades (in some parts of the Eurosystem), follow the 365-day year convention. This is probably due to the British banks holding TARGET2 accounts since the United Kingdom follows the 365-day convention.

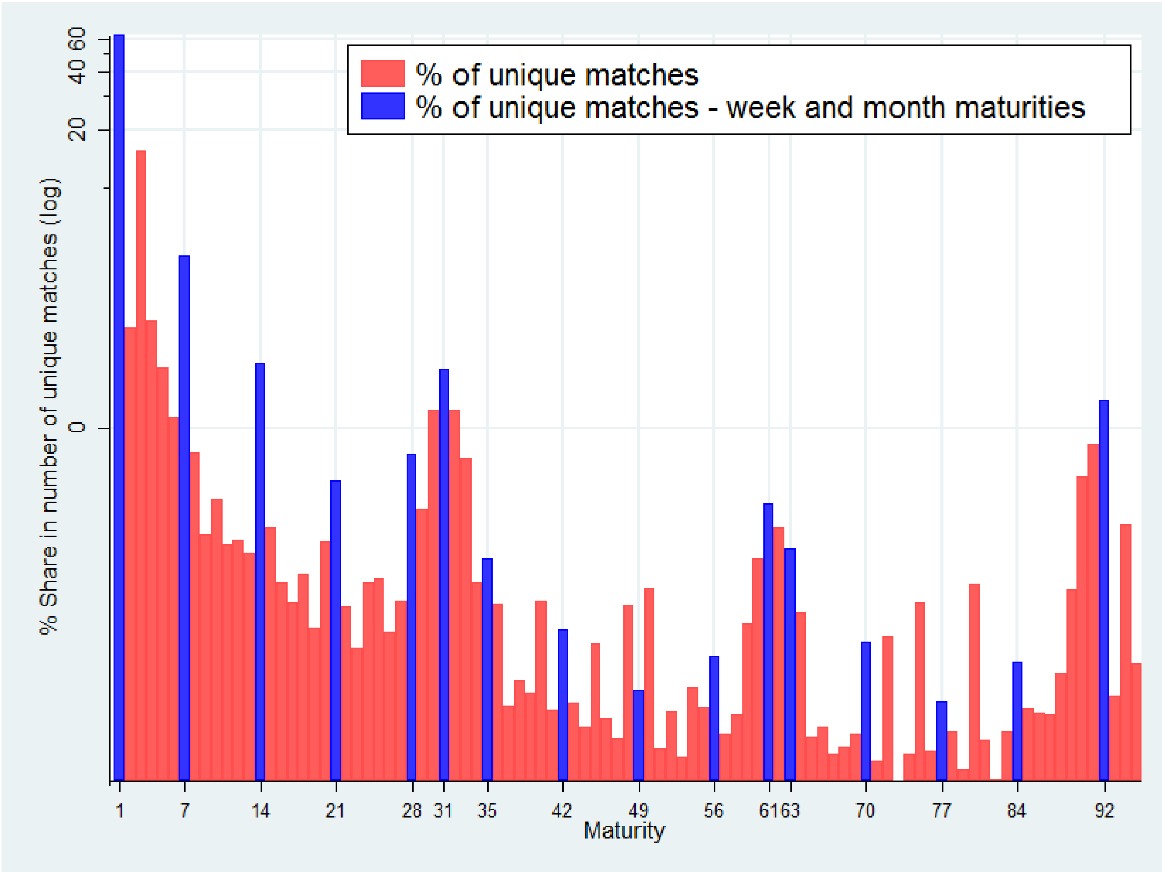

Figure 2: Observed frequency of maturity of all unique matches.

3.7 Summary of the algorithm

The elements of the algorithm are the following:

A. Input:

   a. Interbank payments (MT202) and selected ancillary system transactions (e-MID and MID)

   b. Only transactions between different BICs (no liquidity transfers).

B. Loan and increment:

   a. The minimum loan value is € 1 million.

   b. The loan increment follows the following criteria:

      i. € 10,000 for transactions below € 1 billion;

      ii. € 1 million for transactions between € 1 billion and € 2 billion;

      iii. € 10 million for transactions between € 2 billion and € 10 billion;

      iv. € 100 million for transactions between € 10 billion and € 15 billion;

      v. € 1,000 million for transactions greater than € 15 billion.

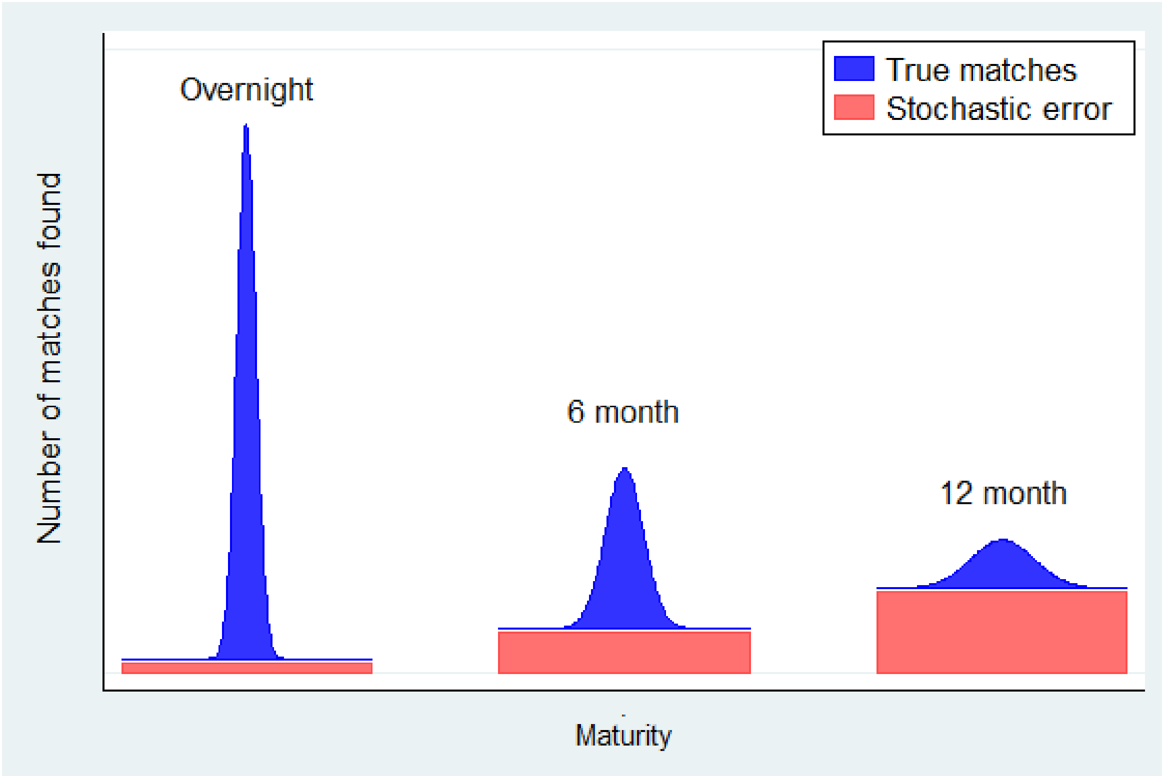

Figure 3: Type 1 error: schematic overview of the increasing stochastic error for longer maturities.

C. Plausible corridors are centered either on EONIA/EURIBOR rates or on ECB standing facilities corridor rates. In the first case, the EONIA rate is used for loans up to 4 days and the corresponding closest EURIBOR for loans of 5 days or longer.

D. Interest rates must be multiples of half a basis point, i.e. the third decimal digit must be either 0 or 5.

E. Multiple matches: the most plausible duration is chosen on the basis of extra-group loans based on the SWIFT BIC directory information. For this purpose the field Parent BIC code is considered to consolidate group accounts.

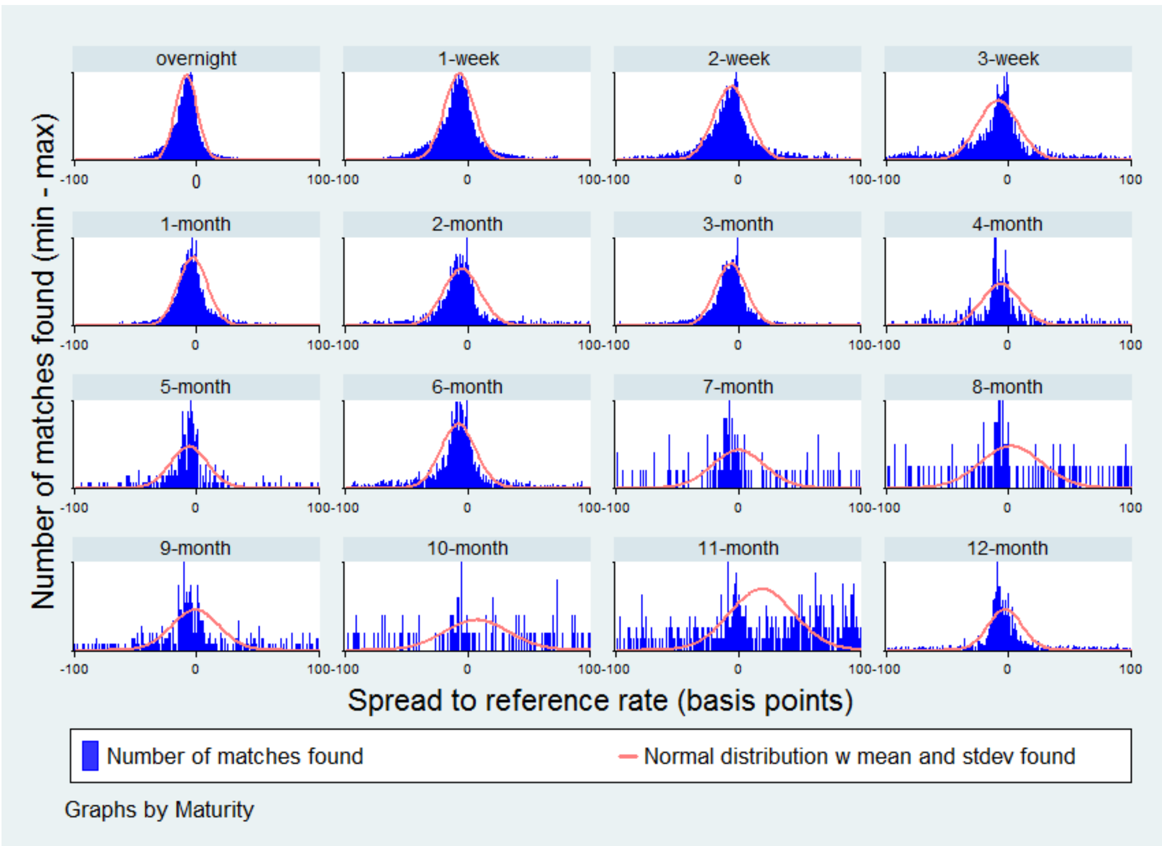

Figure 4: Type 1 error: Frequency of spreads with respect to the reference rate at increasing maturities. The red line represents the fitted normal distribution using the mean and standard deviation of the sample.

4 Validation

To evaluate the robustness of the algorithm and to choose the best performing corridor, the TARGET2 loans identified were validated against external sources of money market transactions which represent a subset of the total market. For this purpose, e-MID transaction-level data and aggregated EONIA data were used. This section describes the outcome of the validation of the algorithm. Section 4.1 explains the three different types of uncertainties inherent in the algorithm. Sections 4.2 and 4.3 present the validation of the algorithm with e-MID and EONIA data, respectively.

4.1 Uncertainties in the algorithm

The algorithm described above is not free of errors as it identifies money market transactions simply by matching two payments given certain boundary conditions. The algorithm does not "know" whether the coupled payments really represent a money market loan, or whether the two payments refer to the same money market exchange or stem from two different money market transactions. In the estimated database three different types of error may occur:

A. a Type 1, or false positive, error occurs when the algorithm identifies a money market transaction which in fact is not composed of a loan and a repayment, but of two unrelated payments. This error can typically occur if the corridor is too wide, because the larger the corridor, the higher the probability that two random transactions will match as a loan-refund combination. This happens especially when matching longer maturities for which the plausibility area is wider in absolute terms.

B. a Type 2, or false negative, error occurs when the algorithm fails to identify a money market transaction. This can happen for the following reasons: (i) the transaction is not present in the TARGET2 initial dataset, for example because the money market exchange was not settled in TARGET2, but in EURO1 or on commercial bank accounts; and (ii) the algorithm is not able to find the transaction, because the loan does not satisfy the conditions embedded in the parameters of the algorithm. This is particularly likely to happen, (a) if the interest rate of the exchange lies outside the corridor (if the algorithm looks for loans with an interest rate between 1% and 2%, it will fail to pick up money market exchanges executed at 2.1% or 0.95%), (b) if the amount of the loan transaction does not respect the increment rule or (c) if the implied rate is not a multiple of half a basis point.

C. a Type 3 error relates to so-called "wrong matches". These can occur when the real loan is not considered plausible (e.g. because it falls outside the corridor) or when there are multiple matches. In the latter case, two types of multiple match can be distinguished. First, a loan can be matched with several repayments executed on the same day, i.e. a loan transaction at $t = D$ may match with more than one plausible refund payments on $t = D + x$. Since only one of these has to be randomly selected, the algorithm may choose a wrong one thus impairing the statistics on the executed rates. The second kind of multiple match occurs if the algorithm couples a loan with several repayments executed on different days: this happens when a loan at $t = D$ has a plausible refund at $t = D + x$ but also at $t = D + y$. As the algorithm will select one, according to the unique matches duration probabilities described in Section 3.5, it may select the wrong match, discarding the correct one. The wrong matches are directly connected to false positive errors and can be considered as a subset thereof, i.e., each wrong match is connected to a false negative transaction but not vice versa.

The increase of wrong matches may be because in a wider corridor the algorithm is more likely to find multiple matches, including the correct one. If the corridor is too narrow, the algorithm finds a smaller number of multiple matches, possibly missing the correct one: here the false negative error rate may be higher. On the other hand the wider the corridor, the more likely it is that the dataset will include false positives, which however will be difficult to estimate or even to approximate. The choice of corridor width is therefore a compromise between the false negative and estimated false positive error rates.[15] The trade-off between false negatives and false positives is amplified for longer maturities for which the overlap between the corridors of subsequent maturities increases with the maturity and, accordingly, the probability of "collision" (see Section 3.5).[16]

4.2 Comparison with e-MID

The validation with e-MID data of the TARGET2 loans identified employed two different strategies, given the two different settlement procedures in e-MID, (i) automatic settlement and (ii) manual settlement. The first strategy is applied to trades settled automatically. This typically occurs when both counterparties have joined the automated facility that allows the e-MID electronic platform to send the deal directly to TARGET2. The transactions submitted automatically by e-MID to TARGET2 are identified in the TARGET2 database with a code which allows the unique matching of the originating transaction and the reimbursement of a single e-MID deal. However, not all e-MID participants have joined the automated facility and when one counterparty of a money market contract has not, the deal must be sent to TARGET2 directly by the participants (manual settlement). Such e-MID transactions do not allow straightforward matching of the loan and the connected repayment. In this case the validation process has to rely on e-MID nominative individual transactions collected by Banca d'Italia for supervisory purposes.

4.2.1 Validation of e-MID trades settled exclusively with the automatic settlement facility

The automatic settlement facility is used by all Italian banks, whereas most non-Italian banks do not use this feature; the validation with automatically settled e-MID transactions therefore concentrates on loans between Italian banks. We compare the e-MID labelled loans in the TARGET2 data (settlement date, settlement banks, maturity, amount and rate) to money market transactions identified by our Furfine procedure. The validation shows three different matching possibilities:

[15] Needless to say , increasing the maturity spectrum over which the algorithm is run will increase, *ceteris paribus*, the false positive error rate. This is because each bilateral transaction is matched with a greater number of potential reimbursements, thus increasing the likelihood of spurious matches.

[16] A more detailed discussion of the issue of overlapping maturities is presented in the Annex.

A. a perfect match: a loan with identical settlement date, settlement banks, maturity, amount and rate in TARGET2 and e-MID data.

B. a false negative: a loan in the e-MID data set not found in the Furfine data set, which can either be:

   a. A false negative because the interest rate of the transaction lies outside the assumed corridor; or

   b. A false negative for other reasons.

C. a wrong match: e-MID transactions identified by the algorithm but with a different rate and/or duration.

Table 1 presents the results for the different corridors on maturities between 1 and 370 calendar days for all automatically-settled e-MID transactions from June 2008 up to and including June 2012 with a size exceeding € 1 million.[17] For each corridor, false negative and wrong match rates (Type 2 and Type 3 errors) with respect to the total number of e-MID automatic transactions are given. The outcome shows that the algorithms searching over the corridors ECB25 (overall error rate 0.92%) and EONIA100 (overall error rate 1.96%) yield better results than the implementations based on other corridors. In terms of traded amounts (not reported in Table 1), the false negative rate is always below 0.015% for all five corridors. Nevertheless, as the corridor width for ECB25 and EONIA100 is quite large in both cases, most of the unidentified transactions are due to the fact that the rate is outside the plausible corridor. Increasing the corridor width improves the Type 3 (wrong match) error rate which is a special kind of false negative error.

Figure 5 shows the time series of the false negative rates for different maturities. The evolution of the false negative error rate over time shows that both the ECB25 and the EONIA100 corridors work remarkably well between 2008 and 2010 and in 2012 (error rate below 0.6%). However, during 2011 the error rate increases significantly (to 7.8% for EONIA100 and to 2.75% for ECB25). This could be due to the high rates agreed by Italian banks in the second half of the year, during the Italian sovereign debt crisis until the ECB's first three-year long-term refinancing operation.

4.2.2 Validation of automatically and manually settled e-MID trades based on e-MID archive data

Apart from e-MID loans that are settled automatically, there are two other options: (i) loans between two counterparties that are not settled in TARGET2 because they are settled through the same settlement bank (on-us transactions) and (ii) loans that are settled in TARGET2 but involve at least one e-MID participant that has not joined the automated settlement. Comparing the Furfine-identified transactions with the e-MID archive data provides important insights on both these categories which cannot be inferred from automatically settled e-MID loans in the TARGET2 database. The second

[17] The extension of the maturity to 370 calendar days is designed to capture one-year money market exchanges whose effective duration is longer than 365 days because of intervening weekend days and holidays that shift the repayment date.

Table 1: First validation method (e-MID transactions with amount > € 1 million). Error rates are in terms of number of transactions.

	Total automatically settled e-MID trades (A)	Matched transactions (B)	Validation rate (C=B/A)	False negatives rate (interest rate out of range) (D)	False negatives rate (other reasons) (E)	Total false negatives rate (F=D+E)	A component of total false negatives: Wrong matched (G=γF)
ECB0	222,568	211,613	95.08%	2.76%	2.16%	4.92%	0.47%
ECB25	222,568	220,513	99.08%	0.68%	0.25%	0.92%	0.26%
EONIA25	222,568	194,464	87.37%	12.53%	0.10%	12.63%	1.08%
EONIA50	222,568	212,436	95.45%	4.46%	0.10%	4.55%	1.08%
EONIA100	222,568	218,201	98.04%	1.81%	0.15%	1.96%	0.73%

validation method is carried out separately for loans between Italian banks and for loans involving at least one foreign counterparty.

On the one hand, on the automatic settlement platform, used directly or through a settlement agent by virtually all Italian banks, the error rates of the validation exercise should be interpreted as a mix of:

A. the algorithm's inability to identify real trades from the settlement data;

B. the difficulty of matching the TARGET2 loan identified with the correct e-MID trade because it has been settled indirectly (through a correspondent banking relationship) since settlement banks are not recorded in the e-MID archives (Type 2);

C. an identification failure due to the fact that two banks trading on e-MID settle their obligations through the same TARGET2 direct participant (*on-us* transactions) (Type 3).

Compared with to the previous validation method, the last two sources of uncertainty yield a slightly lower validation rate for Italian participants. This is not due to the algorithm, which is the same under both methods. The uncertainties could be removed if we had detailed information about the original sender and beneficiary across the TARGET2 data.

On the other hand, when it comes to deals involving non-Italian participants, there is an additional error factor related to the different market practices trading banks may choose to adopt. In fact, while market players cannot affect the settlement of their automatically settled e-MID trades, TARGET2 loans involving at least one non-Italian bank do not necessarily match the traded quantity exactly. Banks may, for example, not settle their money market transactions on a gross basis exchanging a unique loan amount and a unique repayment ("1-to-1 basis"), as inferred from anecdotal evidence, but may split their obligations into several chunks, e.g. by repaying the principal and the interest separately. Furthermore, market operators may offset some intermediate payments against each other in the event of a roll-over, a market practice that the money market survey suggests is used infrequently.

As the first validation method already pointed to the superiority of the ECB25 and EONIA100 corridors, the second validation methodology focuses directly on them: the results are shown in Table

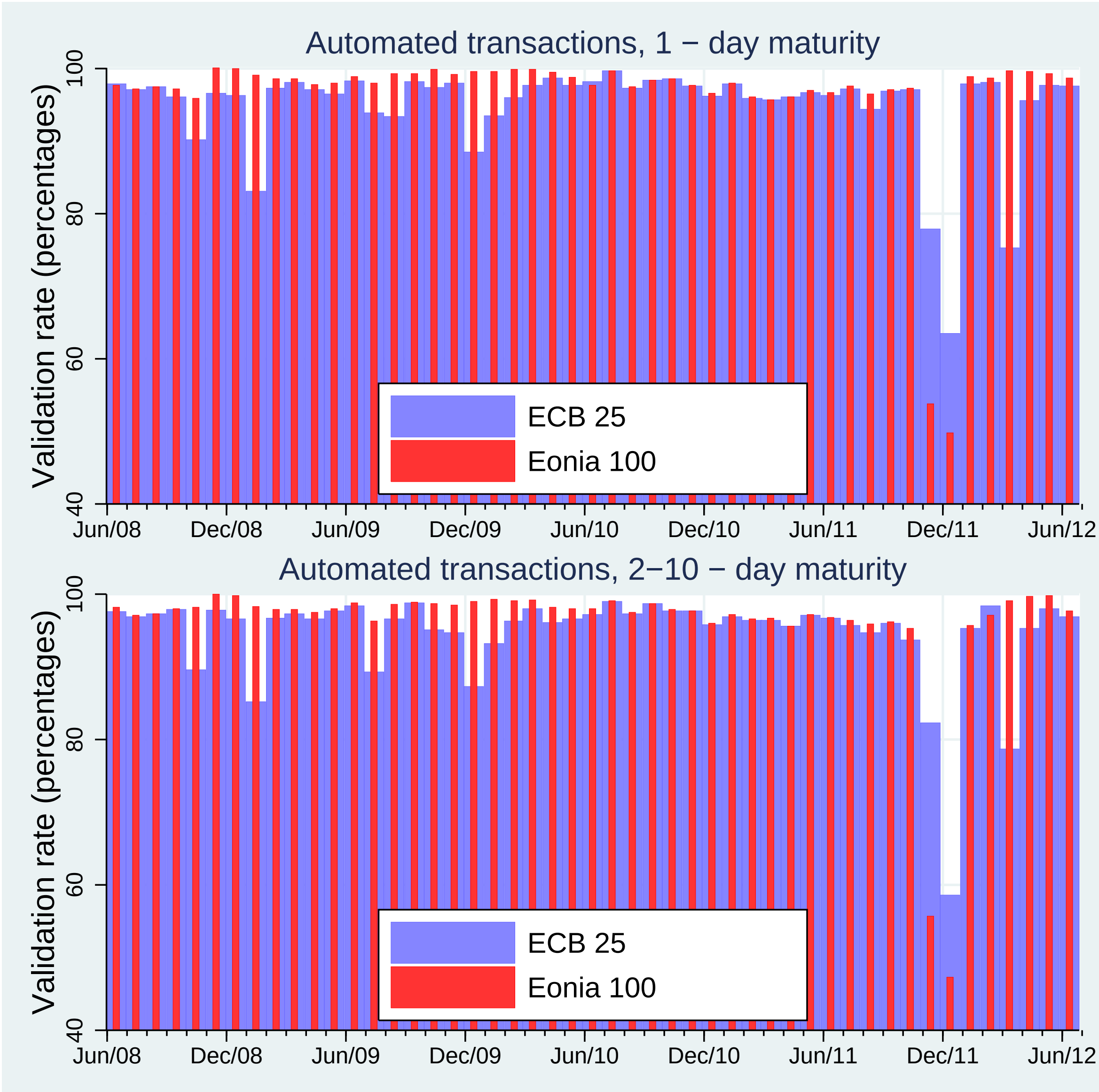

Figure 5: Results of the e-MID validation for automatically settled loans.

2. A first by-product of the second validation approach is a measure of the proportion of *"on-us"* transactions in total unsecured money market trading, which yields reassuring results. According to the e-MID data, only a small proportion, around 3%, of trades carried out between domestic counterparties are not settled in central bank money and thus escape detection because they are not included in the payment data. More specifically, the proportion of internalised transactions in total money market trades executed between Italian counterparties seems relatively low, across all maturities, with higher maturities exhibiting higher ratios.[18] The proportion of *"on-us"* transactions appears 10 times smaller in the case of cross-border money market deals, around 0.3%, again with higher maturities exhibiting higher ratios. Bearing in mind the caveats due to the lower representativeness of the sam-

[18] It is worth mentioning that the *"on-us"* rates could be improved if future analysis aimed at detecting *who settles for whom* in TARGET2, especially for foreign participants. This analysis could also shed light on the settlement practices followed by the market and help to improve the accuracy of the algorithm.

ple of e-MID cross-border transactions compared with OTC transactions executed in the euro area, this result is not surprising as we expect small and medium-sized banks to be less likely to establish correspondent relationships across national borders.

The comparison between our estimated Furfine dataset and the e-MID original archives enables us to quantify the ratio of unmatched transactions to total e-MID loans (Type 2 error rate), which, as expected, is lower for those carried out between Italian counterparties than for loans involving at least one non-Italian bank, thanks to the availability of a richer data set.[19]

At the domestic level, the proportion of unmatched transactions is relatively small (2.7% for the ECB25 corridor and 3.7% for the EONIA100 corridor), but increases quite substantially with rising maturities. The two corridors perform differently across the maturity range: for short maturities (up to one month) the ECB25 corridor exhibits slightly better validation rates; the opposite holds for longer maturities, in fact the error rate of the ECB25 corridor peaks at 29% for domestic deals with maturities longer than 3 months, whereas the error rate of the EONIA100 corridor never exceeds 20%. For money market deals executed on a cross-border basis, the validation rates exhibit a similar pattern but they are lower across the entire range of maturities for both corridors. While for domestic transactions the error rates are negligible throughout the whole reference period, except for the dramatic fall recorded in late 2011 due to the Italian sovereign debt crisis, the evolution of the error rates for cross-border transactions appears more erratic, with validation rates dropping below 80% on several occasions.[20]

[19] In the ECB25 corridor the overall type 2 error rate for trades between Italian banks is 2.7% while that for trades involving at least one non-Italian participant is 8.6%. In the EONIA 100 corridor the percentages are very similar (3.7% and 8.2%, respectively).

[20] The time series analysis is carried out only on the most liquid maturities.

Table 2: Second validation methodology. Error rates are in terms of number of transactions.

	Maturity	Total	Total e-MID trades with amount > €1 million (A)	on-us (B)	Total e-MID trades without on-us transactions (C=A-B=D+E+F)	Matched (D)	False negatives because interest rate is out of range (E)	False negatives for other reasons (F)	Validation rate (D/C)	False negatives error rate (E+F)/C
ECB 25	all maturities	226,439	226,162	7,158	219,004	213,011	1,522	4,471	97.3%	2.7%
	1 day	166,552	166,325	4,736	161,589	158,193	602	2,794	97.9%	2.1%
domestic	2-10 days	52,735	52,692	2,014	50,678	49,216	287	1,175	97.1%	2.9%
	11-33 days	5,185	5,179	305	4,874	4,239	267	368	87%	13%
	34-94 days	1,621	1,620	79	1,541	1,134	292	115	73.6%	26.4%
	94-370 days	346	346	24	322	229	74	19	71.1%	28.9%
	all maturities	11,516	11,515	38	11,477	10,490	4	987	91.4%	8.6%
	1 day	8,898	8,897	16	8,881	8,169	1	712	92%	8%
foreign	2-10 days	2,427	2,427	11	2,416	2,177	0	239	90.1%	9.9%
	11-33 days	163	163	2	161	131	2	30	81.4%	19.9%
	34-94 days	21	21	9	12	8	0	4	66.7%	33.3%
	94-370 days	7	7	0	7	5	1	2	71.4%	42.9%
EONIA 100	all maturities	226,439	226,162	7,158	219,004	210,928	4,057	4,019	96.3%	3.7%
	1 day	166,552	166,325	4,736	161,589	156,253	2,708	2,628	96.7%	3.3%
domestic	2-10 days	52,735	52,692	2,014	50,678	48,756	894	1,028	96.2%	3.8%
	11-33 days	5,185	5,179	305	4,874	4,323	290	261	88.7%	11.3%
	34-94 days	1,621	1,620	79	1,541	1,306	146	89	84.8%	15.2%
	94-370 days	346	346	24	322	290	19	13	90.1%	9.9%
	all maturities	11,516	11,515	38	11,477	10,547	16	930	91.9%	8.2%
	1 day	8,898	8,897	16	8,881	8,191	15	690	92.2%	7.9%
foreign	2-10 days	2,427	2,427	11	2,416	2,209	0	207	91.4%	8.6%
	11-33 days	163	163	2	161	133	1	28	82.6%	18%
	34-94 days	21	21	9	12	8	0	4	66.7%	33.3%
	94-370 days	7	7	0	7	6	0	1	85.7%	14.3%

4.3 Comparison with EONIA

Despite its granularity and the availability of longer-term money market transactions in the e-MID data, which allows transaction-by-transaction cross-checking, the analysis somehow lacks a euro-wide context since from the start of the crisis, e-MID data have been concentrated on money market trades between Italian participants. The need for validation against more euro-wide representative data calls for a cross-check with EONIA data as well. As already noted, every bank in the EONIA panel reports daily (i) the aggregate volume and (ii) the corresponding weighted average rate of lending transactions made on its own behalf. The use of the EONIA data set provides valuable reference material for the euro-area market going beyond and complementing the e-MID validation. The results reported in the following are based on the comparison between the overnight interbank loans identified using the Furfine algorithm for the EONIA panel banks and the actual daily EONIA aggregate reported values and rates. The validation considers a dynamic panel reflecting the changing composition of the reporting banks in the sample under analysis.

The results of the comparison are reassuring. We start by looking at the difference between the total value reported and the total value identified with the Furfine algorithm. Figure 7 shows the reported and identified turnovers for the EONIA panel banks using the EONIA100 corridor. The two series show similar trends, with the identified turnover ranging from 98% to 250% (the 1st and 3rd quartiles are 120% and 160%, respectively) of the reported turnover. This does not imply that the EONIA is not valid. In fact, there are several reasons for the differences in the two series:

A. Identified volumes can be larger than reported by the EONIA data due to:

   a. Possible over-identification;

   b. Tomorrow-next and spot-next transactions, not reported in the EONIA data;

   c. Rollovers, not reported in the EONIA data unless both parties are actively involved in the issue of a new contract;

   d. Intra-group transactions, excluded in the EONIA reporting but not always possible to distinguish and discard in the TARGET2 dataset;

   e. Transactions concluded on behalf of clients;

B. Identified volumes can be lower than the reported EONIA due to:

   a. Transactions settled outside TARGET2, e.g. on the accounts of a commercial bank (correspondent banking);

   b. Loans settled via another payment system such as EURO1.

For example, we found that some banks were very active in the tomorrow-next and spot-next markets. In other cases, we identified regular lending to other banks, but deeper analysis showed that the sending and/or receiving bank was not always the beneficiary but was acting on behalf of another bank. Such transactions introduce a bias in the implied rate and an upward bias in the volume estimation. Finally, one bank reporting in the EONIA panel opened an account in TARGET2 only a

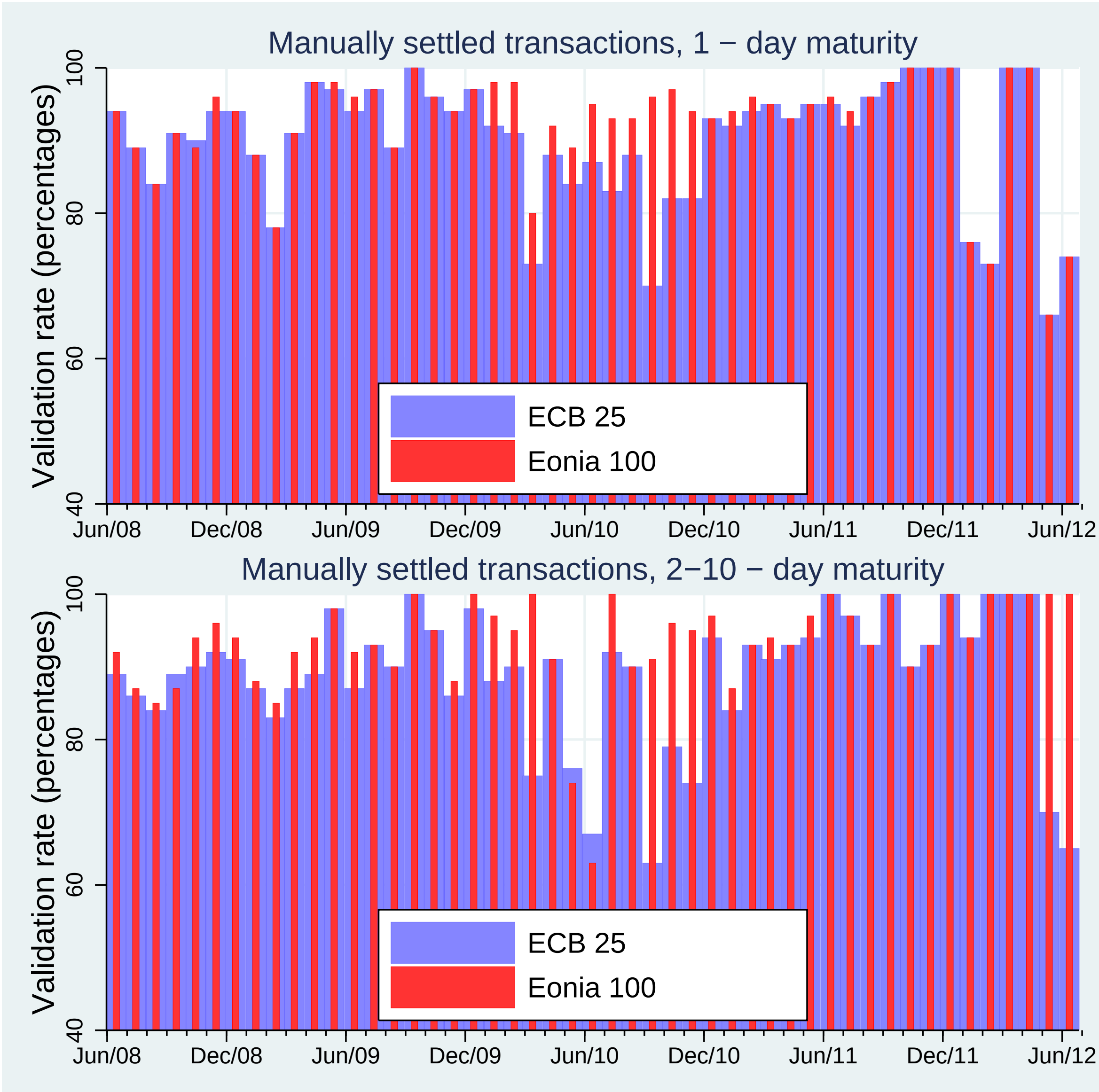

Figure 6: Results of the e-MID validation for manually settled loans.

few months from the beginning of our sample. The lending transactions of this bank were obviously settled outside TARGET2, either via a different payment system or on its books.

With regard to rates (see Figure 7, bottom panel), the reported and implied rates lie close together. It is reassuring that the interest rate matching spikes occur at the end of a maintenance period, due to the increase in the cost of interbank borrowing. The mean and median spreads are equal to 9 and 8 basis points respectively. Finally, the implied rate is almost always lower than the reported rate and the difference is larger around interest rate decisions. This may be due to unidentified intragroup loans, which usually take place at rates well below the EONIA.

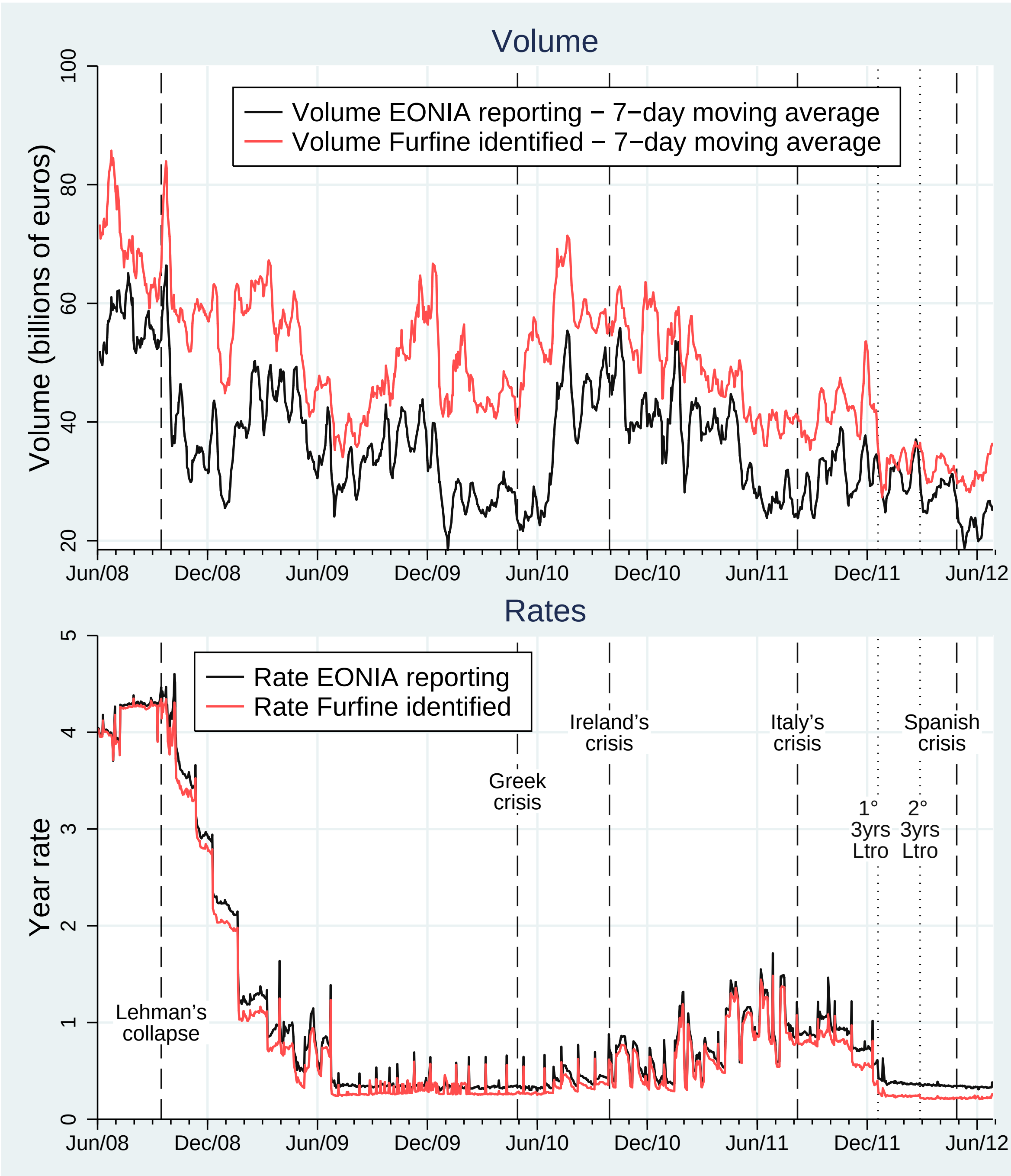

Figure 7: Results of the EONIA cross-check for the EONIA100 corridor

5 The euro-area unsecured money market

This section describes developments in the euro-area interbank money market, since June 2008, based on our algorithm. We focus on three levels: (i) the Eurosystem level, including all banks participating in TARGET2 (ii) the country-group level and (iii) the country level (Italy and the Netherlands).

5.1 Eurosystem level

Figure 8 shows the turnover of the overnight interbank money market.[21] This dropped dramatically by almost 50% after the default of Lehman Brothers, from € 130 billion in June 2008 to € 79 billion in June 2009. It stabilised at around € 75 billion until April 2010. We observe a partial recovery between May 2010 and April 2011 to some € 93 billion followed by another sharp fall after Portugal's request for financial assistance, to an average of € 75 billion between May and November 2011. Turnover decreased again after the two ECB 3-year Longer Term Refinancing Operations (LTRO) in December 2011 and February 2012, falling to € 47 billion, on average, between January and June 2012. Overall, cross-border trades exhibit a more pronounced decreasing trend than domestic trades, except that they were less affected by the ECB's second 3-year tender. This results are in line with the recently published "Euro money market study 2012" ECB (2012a)

The proportion of trades with maturity longer than one day fluctuates between 10% and 17%, but their outstanding amounts range from 87% to 93% of the entire unsecured money market. In other words, in terms of trades overnight loans are the majority, but in terms of outstanding value loans with longer maturity predominate. From a central bank policy point of view both aspects are important, as central banks are interested not only in the smooth circulation of interbank money but also in the amount of liquidity individual banks need to fund themselves. Figure 9 shows the outstanding value of loans with maturity up to three months (top panel) and up to one year (bottom panel).[22] The outstanding amounts of deposits with maturities up to three months exhibit a significant drop after the collapse of Lehman Brothers, falling from an average of € 324 billion in the four months preceding the default to an average of € 273 billion in the four months after it (- 24%). This pattern is clearly visible despite the underestimation of the first three months in the sample. While loans up to three months remained constant until Portugal's request for financial assistance, with the exception of a physiological cyclicality, the longer-term outstanding amounts declined with a constant trend in

[21] In the remaining, the expression "overnight" will be used for one-day exchanges. In fact, the Furfine algorithm cannot distinguish between overnight, tomorrow-next and spot-next transactions, since they are characterized by a time lag of one day between the loan and the refund, even if the trade was agreed on different days (the overnight exchanges was agreed on the very same day of the loan's settlement, the tomorrow-next was agreed on $t-1$ and the spot-next on $t-2$).

[22] It should be noted that it is possible to estimate volumes and outstanding amounts reliably only for the central interval of the time horizon considered, since for some maturities the loans or the refunds are not included in the initial TARGET2 dataset. The shorter the maturity the longer the reliability of the estimated dataset. For example, the estimations of the one-day exchanges will be reliable over the whole time span except for the first and last days of the sample: on the first day it will be impossible to identify the refunds of loans initiated the previous day whereas on the last day the loans will not be matched with their refunds since these are not yet available. Similarly, when considering the one-year maturity, the algorithm neglects all the refunds that are available in the first twelve months and all the loans in the last period of the sample. As a result, the outstanding amounts of money market deposits with maturity between one day and twelve months can be quantified exactly only between June 2009 and June 2011, while the volumes traded will be underestimated only in the final period of the sample.

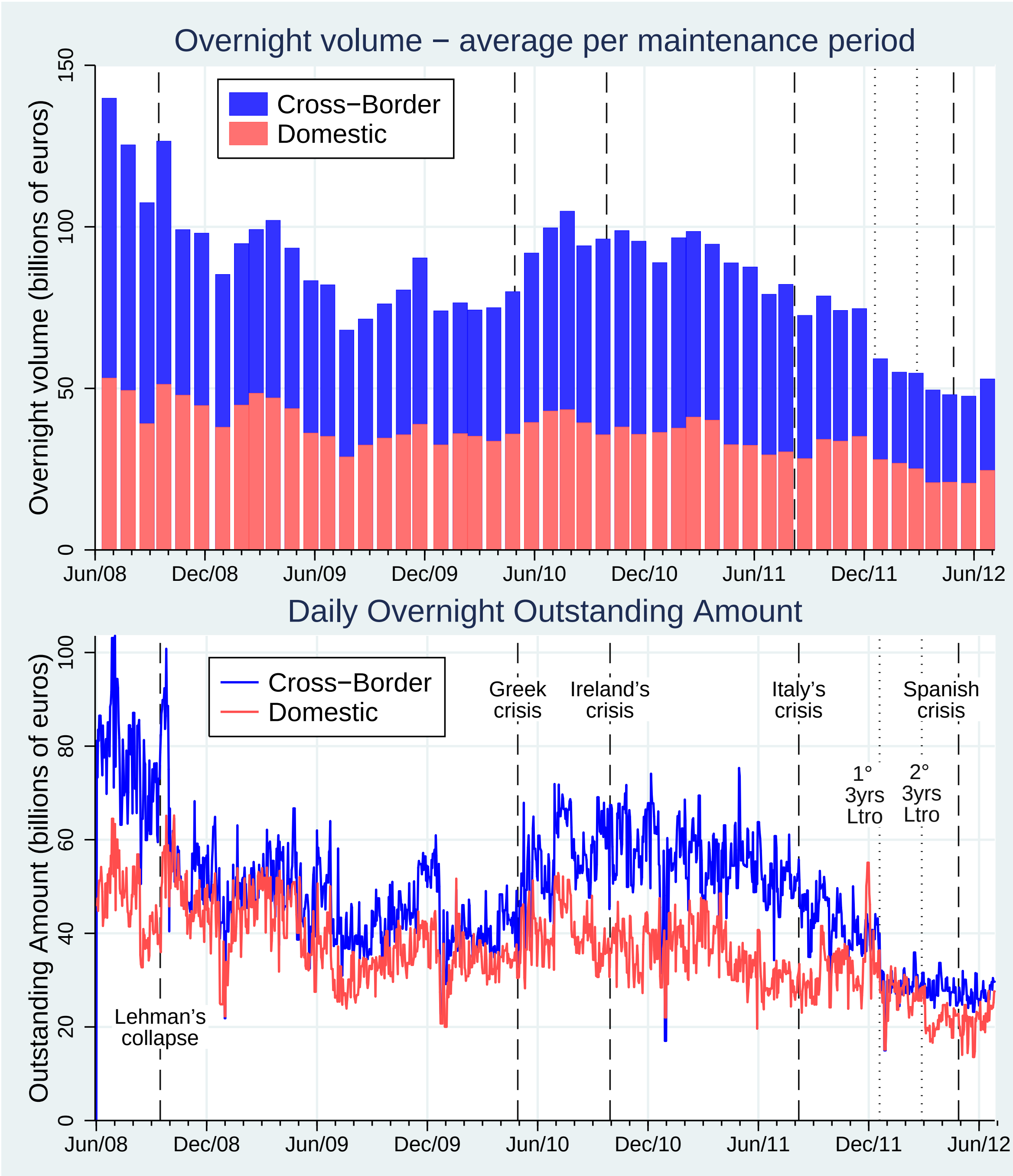

Figure 8: Overnight volumes in the euro area - breakdown into domestic and cross-border components (daily averages per maintenance period and outstanding amounts).

the domestic component partially compensated by a slight increase in the cross-border component (bottom panel of Figure 9).

Figure 10 (bottom panel) depicts the difference between the estimated weighted average overnight interest rate and the EONIA for the domestic and cross-border money market exchanges. Immediately after the collapse of Lehman Brothers, the estimated weighted average overnight rate departed significantly from the European fixing until the summer of 2009, averaging 15 basis points below.

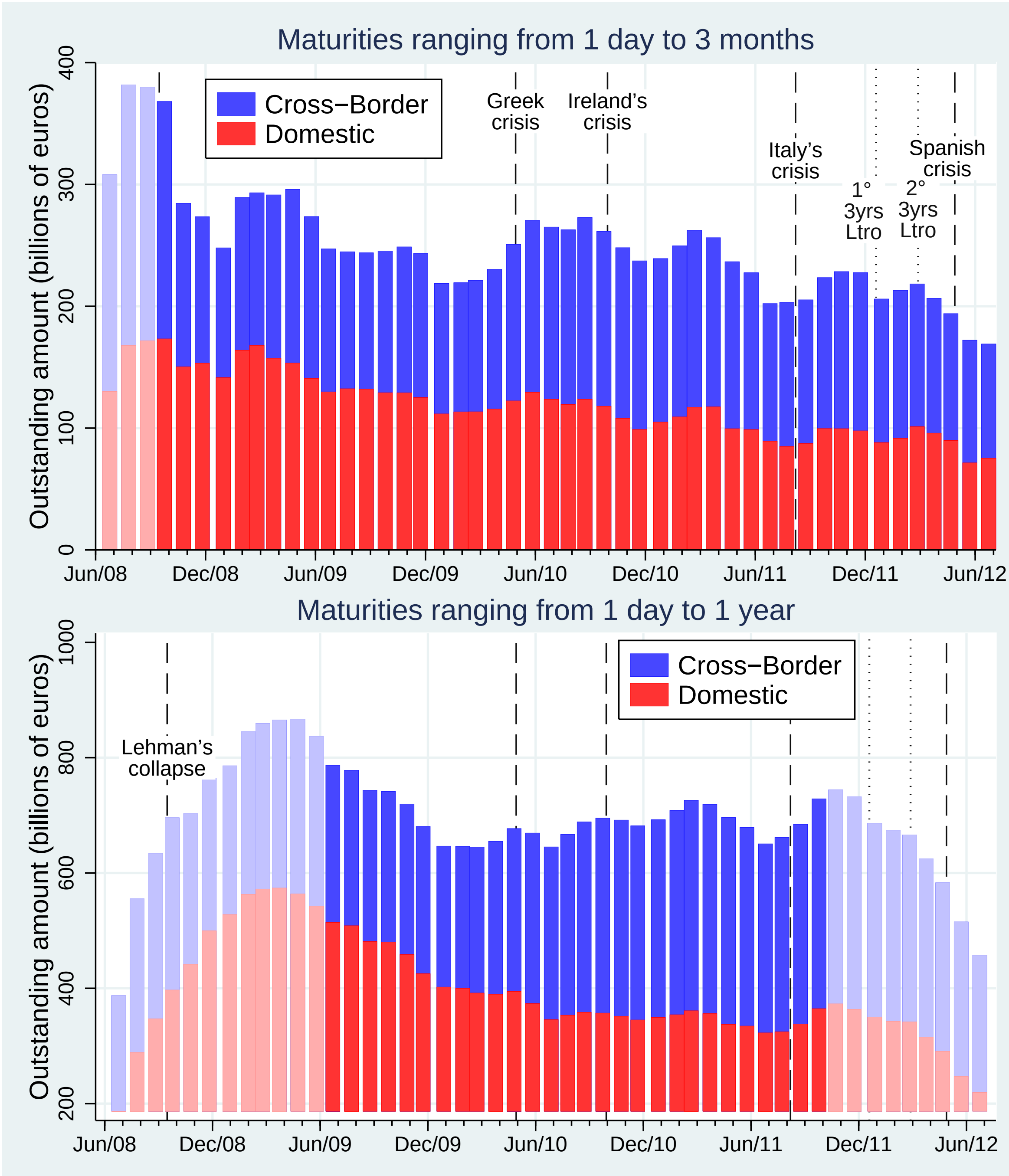

Figure 9: Outstanding amounts of the deposits up to 3 months and up to twelve months, breakdown into domestic and cross-border component (daily averages per maintenance period). Columns presented in transparency refer to the data which are underestimated.

As of mid-2009 the series moved back towards the EONIA rate and remained closely aligned with it until the summer of 2011.

With the deepening of the sovereign debt crisis linked to Italian political events in the second half of 2011, both the domestic and the cross-border rates deviated consistently from the EONIA: they approached the rate on the ECB overnight deposit facility and, after the ECB's second 3-year LTRO

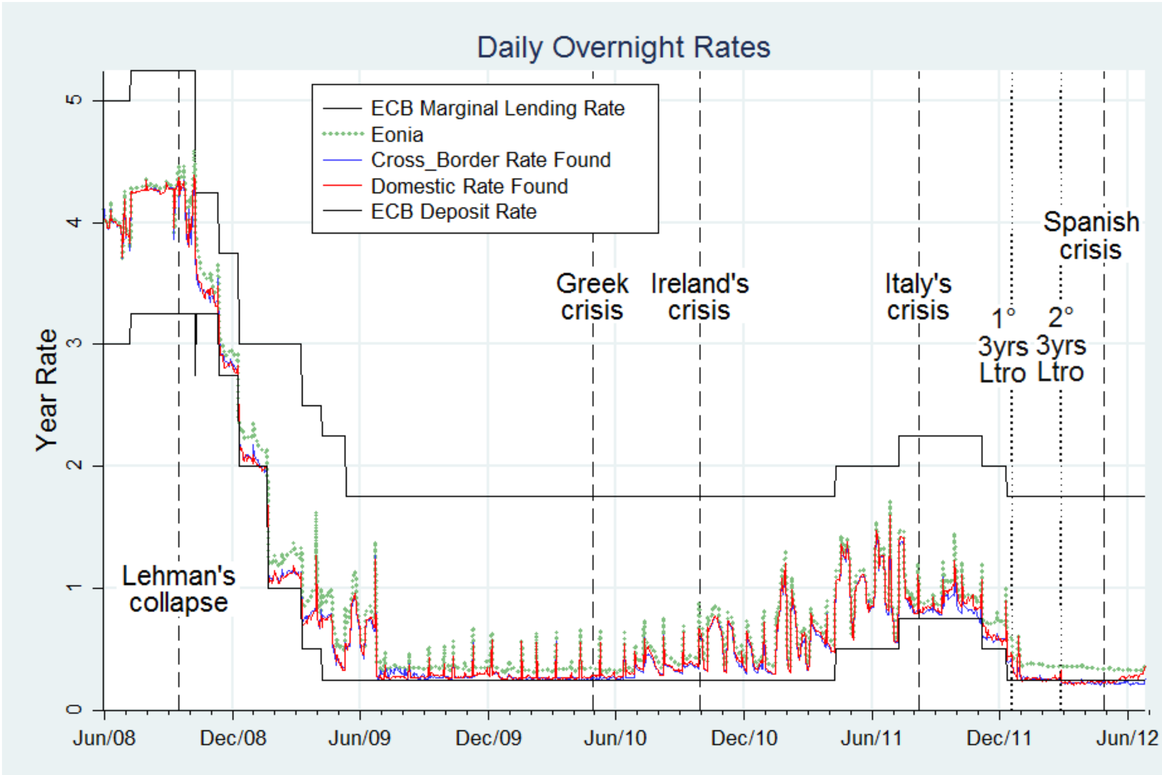

Figure 10: Estimated overnight rates, breakdown in domestic and cross-border.

in late February 2012, they fell below the lower bound of the monetary policy rate corridor, corroborating the results of Akram and Christophersen (2010).[23] The reason why cross-border rates are consistently lower than domestic rates from the second half of 2011 may be that only the best fund-raisers are able to attract liquidity from the European market at lower rates than those paid by the less reliable banks which are forced to refinance themselves at the domestic level. However, the phenomenon cannot be confirmed beyond doubt, since information is only available on the settlement banks, not on the originators and final beneficiaries of the monetary transactions.

5.2 Country-group level

At a more granular level, we compare money market developments between countries less exposed to the sovereign debt tensions (group A countries: Germany, France, the Netherlands, Belgium and Finland) and countries most exposed to them (group B countries), including the programme countries (Greece, Ireland, and Portugal) but also Italy and Spain. The cross-border exchanges of the least exposed countries to sovereign strains recorded the largest and most persistent decline following the collapse of Lehman Brothers through to the summer of 2012, while the one-day deposits exchanged domestically by these countries gradually increased starting from March 2012 (Figure 11, top panel). During the first period this could be due to greater difficulty in evaluating the creditworthiness of foreign borrowers, itself attributable to non-harmonised insolvency frameworks across Europe; since

[23] The cross-border rate deviated from the EONIA rate from the month of August 2011 onwards, the domestic rate from November onwards.

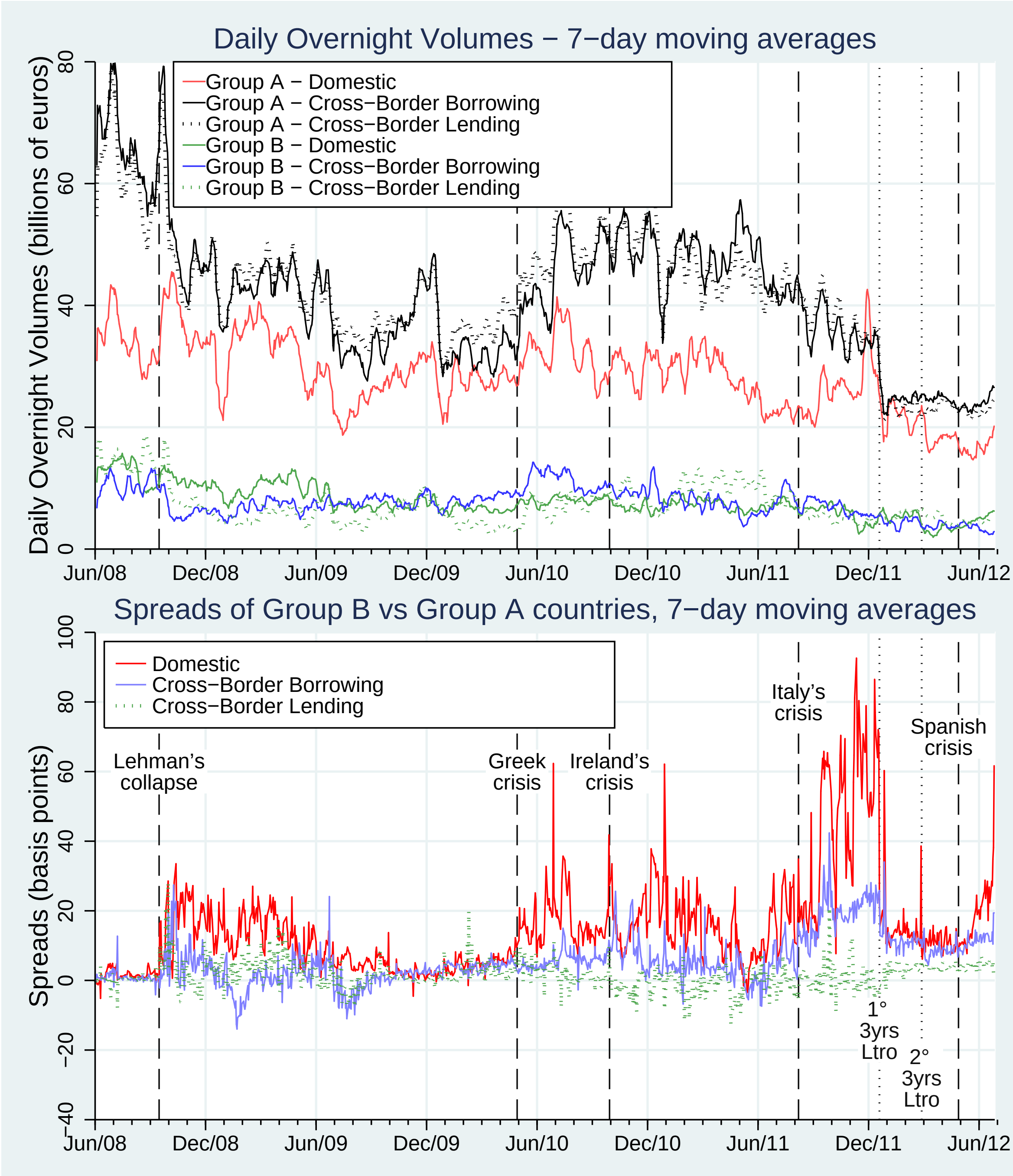

Figure 11: Estimated overnight volumes and spreads, breakdown into group A and group B countries.

the outbreak of the sovereign debt crisis, the reason for the decline in the cross-border exchanges of the countries most exposed to sovereign tensions may lie in distrust of banks located in the such countries. The spread paid by most exposed countries with respect to the EONIA (Figure 11, bottom panel) is higher for domestic deposits than for cross-border ones, presumably due, again, to an adverse selection effect: the few banks of the these countries able to raise funds from abroad were the most creditworthy counterparties in their country, and they were able to negotiate lower interest rates than the other domestic banks, which were forced to tap the domestic money market.

5.3 Country level

We now focus on two countries, Italy and the Netherlands. As regards Italy, it can be seen that the net cross-border position of Italian banks was negative in all the maintenance periods until the one starting in December 2011, just before the first 3-year LTRO, when, presumably, interbank money market fund-raising was further replaced by central bank liquidity (Figure 12). However, the net exposure in the very-short-term maturity range was positive from January 2011 onwards, while it was negative for longer-term maturities. The Italian banking system therefore seems to borrow long-term funds from abroad and to reinvest the surpluses by providing short-term loans to foreign banks.[24]

As for the Netherlands, the story is slightly different (Figure 12). Dutch banks entered the reference period with a positive net cross-border position for both very short and very long maturities. Later, the net position of Dutch banks at the shortest and longest maturities diverged: the Dutch banking system continued to raise liquidity at the very short maturities, until the first 3-year LTRO, when the net cross-border position became virtually balanced. By contrast, from the first 1-year LTRO in June 2009, the net position of Dutch banks at longer maturities became significantly negative, returning to positive values only in the second half of 2011. One notable difference between the Italian and Dutch cross-border position concerns the outstanding amounts of borrowing and lending, which appear significantly higher for the Dutch banking community.

Turning to price conditions, the overnight interest rates offered by Italian lenders to foreign borrowers (cross-border lending) were lower on average been lower than those paid by Italian borrowers to raise liquidity for one day from abroad (cross-border borrowing - Figure 13). All in all, the rates paid by Italian banks were been fairly well aligned with the EONIA rates, with the exception of the summer of 2011, when the Italian sovereign debt crisis led to a sharp increase in the overnight rates paid by Italian banks domestically. This increase quickly reversed after the first 3-year LTRO. Again, the impact of the sovereign debt crisis on the borrowing rates paid by the Italian banking system to non-domestic counterparties was less severe due to probable selection effects, so that only major Italian players continued to borrow from abroad. By contrast, the Dutch banking community turned out to be able to borrow at rates well below the EONIA throughout the period, benefiting from a wider spread during the most severe phase of the sovereign crisis.

[24] This evolution would be in line with the dynamics of the collateralised money market exchanges backed by Italian government bonds executed on the MTS repo Italy electronic platform.

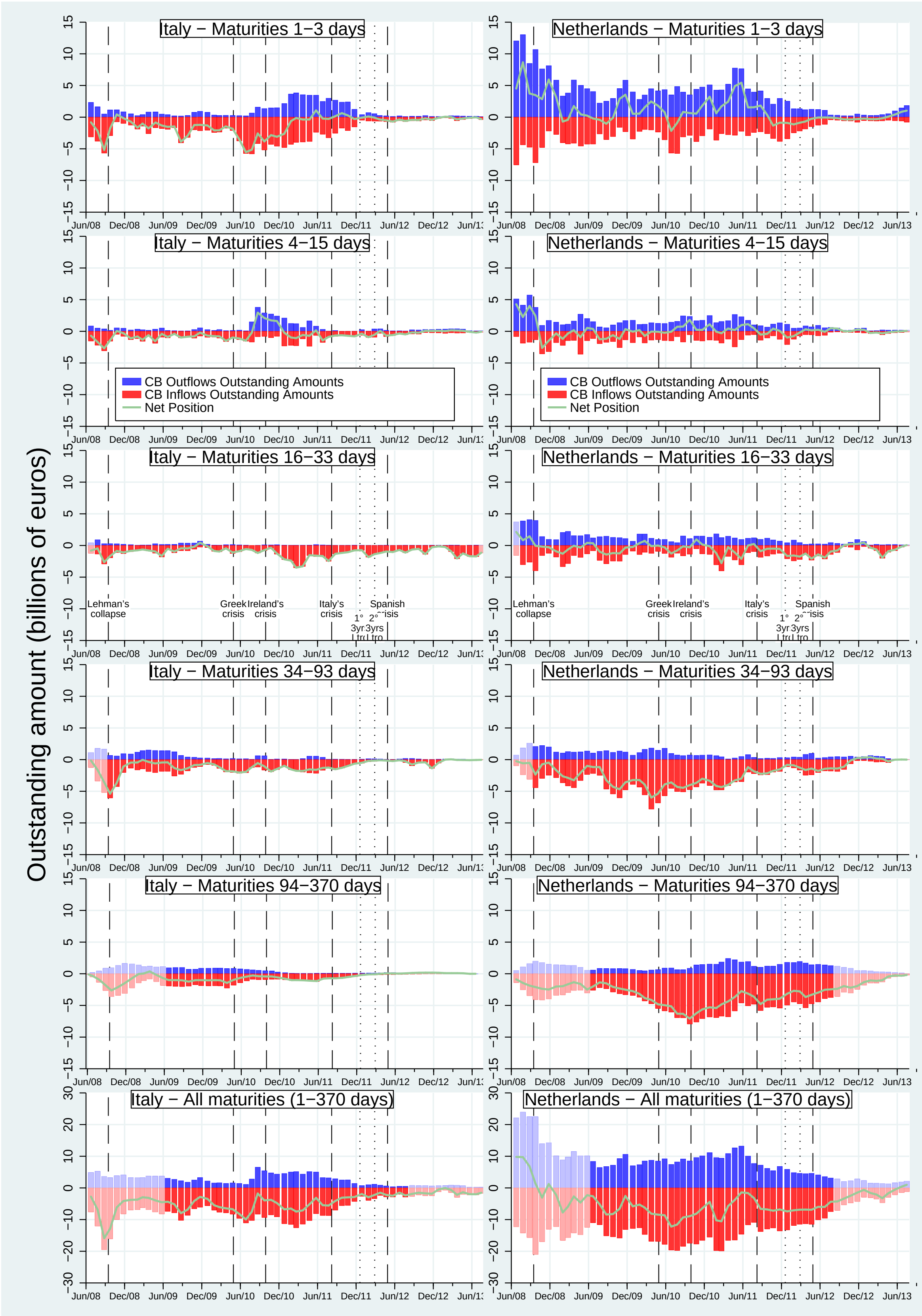

Figure 12: Italian and Dutch cross-border net position (daily averages per maintenance period) - breakdown in different maturities.

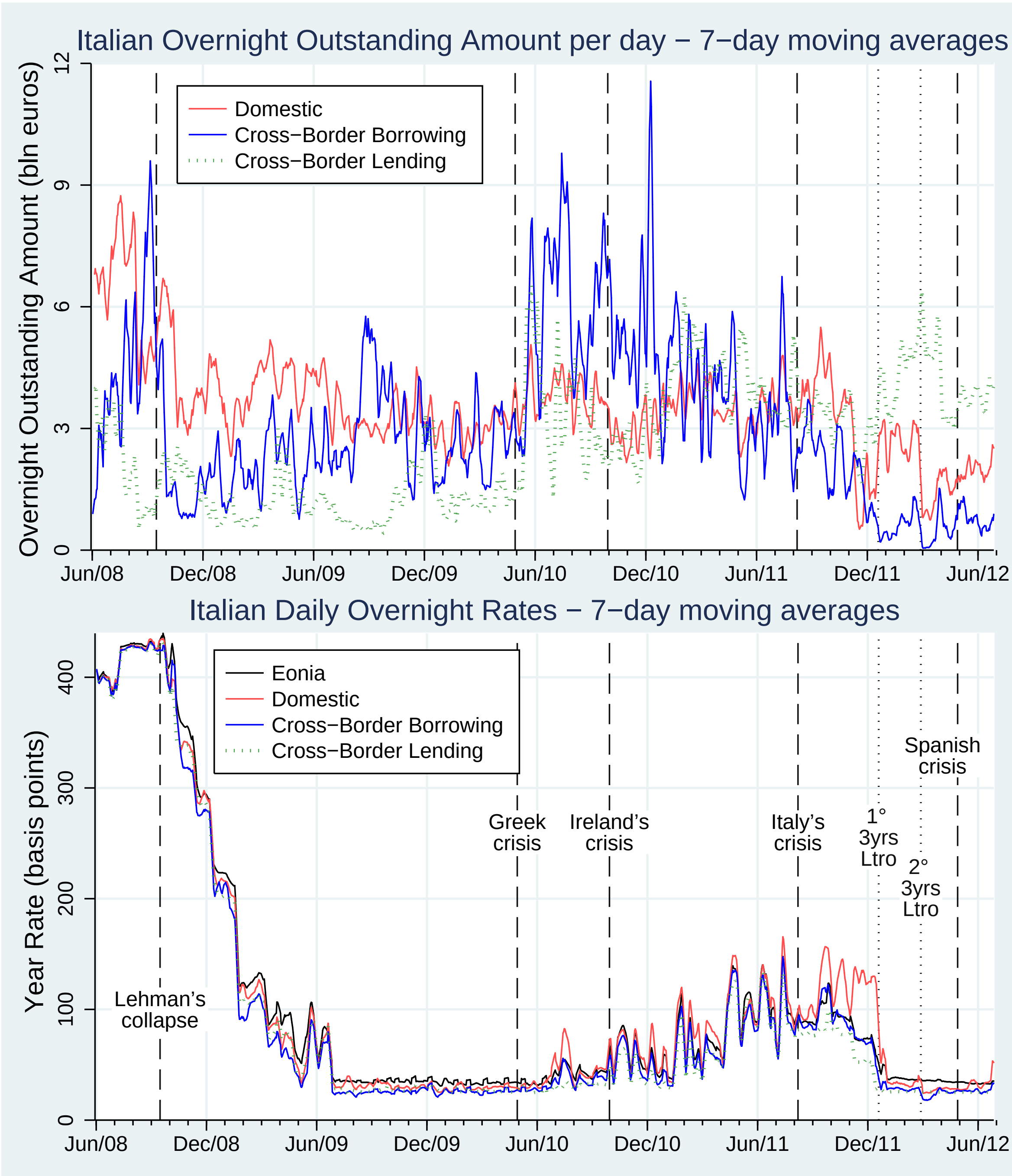

Figure 13: Italian overnight rates, breakdown into domestic and cross-border borrowing and lending.

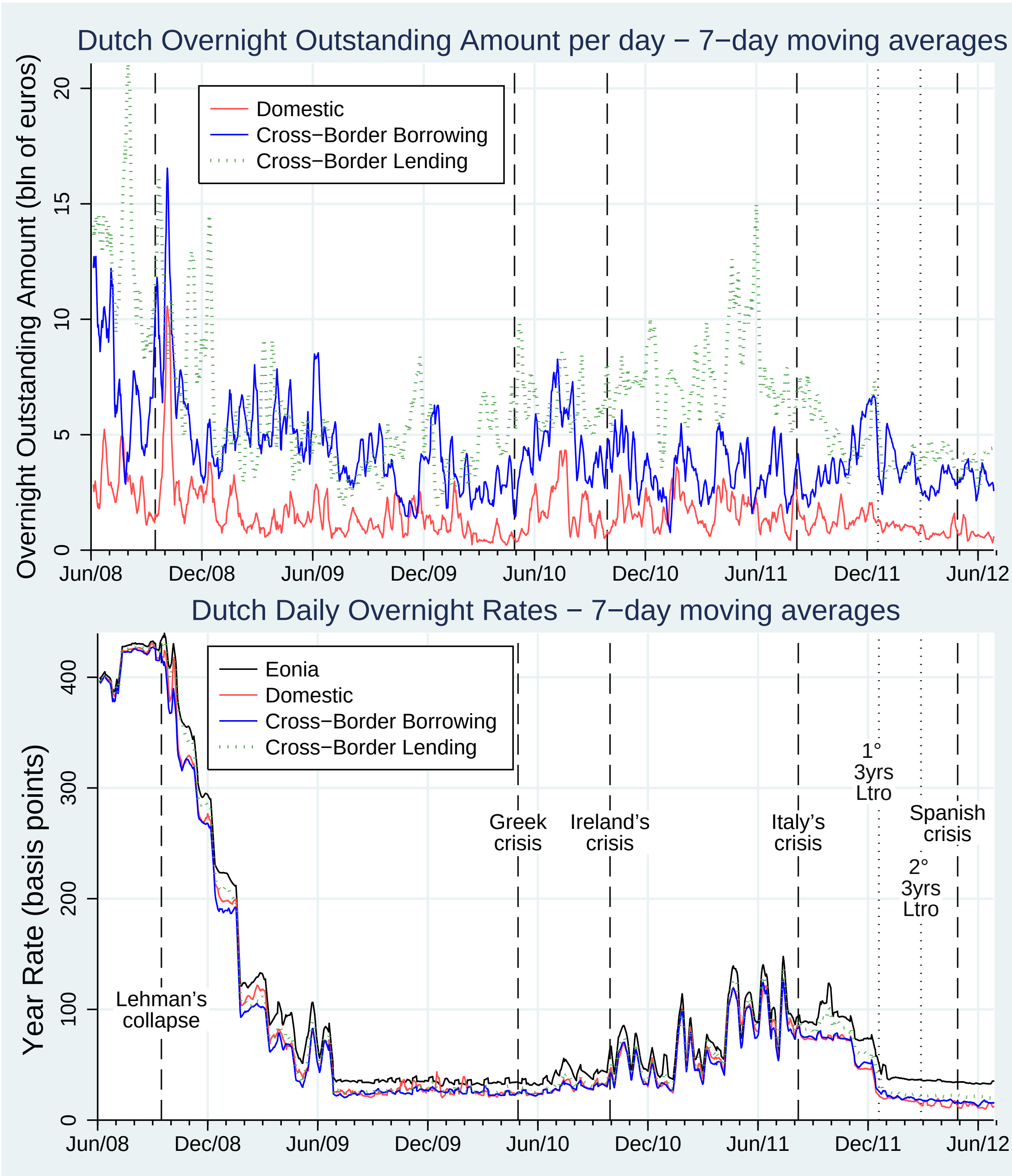

Figure 14: Dutch overnight rates, breakdown into domestic and cross-border borrowing and lending.

6 Conclusions

This paper develops an algorithm to identify unsecured interbank money market loans for the whole euro-area using TARGET2 data. This algorithm is an improvement on the version developed by Furfine (1999), who was the first to develop such an algorithm for overnight loans only, and that put forward by Heijmans et al. (2010), who first developed an algorithm for a subset of the euro-area money market. With respect to the original algorithm, several enhancements have been made. The algorithm has been extended in three ways: (i) it identifies money market loans with a maturity of up to one year; (ii) it incorporates criteria for implied interest rates: inclusion of the rate in a plausibility corridor and rounding to half a basis point. Specifically, we investigated two plausibility corridors: the first centered on the EONIA rate for loans up to 4 days and EURIBOR for other maturities and the second using the ECB standing facility corridor bounded by the overnight deposit facility rate and the marginal lending rate. Each corridor was then tested for several sizes; and (iii) the algorithm includes a procedure for the efficient selection of the correct loan in the case of multiple plausible matches. Where such matches have the same maturity, the 'correct' loan is determined randomly; where the maturities differ, the choice is made on the basis of the most plausible duration within a maturity distribution inferred from the uniquely matched TARGET2 loans.

In contrast with the literature, our dataset of identified interbank loans has been compared with real data sources, namely EONIA panel data and e-MID transaction-level data. The validation against EONIA panel data has been carried out for overnight identified TARGET2 transactions. Results show that the average interest rate found by the algorithm matches very well with the reported EONIA. The average deviation with respect to the EONIA rates was 9 basis points with the highest deviation in the period September 2008 to June 2009. Turnover, however, is roughly 50% higher than that reported in the EONIA panel. Differencesbetween the estimated and reported turnovers appear to have been due to transactions that are not reported by EONIA panel banks: (i) intra-group transactions, (ii) transactions settled on behalf of other banks, (iii) rolled-over transactions, and (iv) spot-next and tomorrow-next loans.[25] On the other hand, a source of misidentification is EONIA panel banks reporting of loans not settled in TARGET2 but in commercial bank money or in other payment systems (e.g. EURO1).

The second and more sophisticated validation method was based on the e-MID dataset. This method was applied to all maturities, transaction by transaction, and makes it possible to compute the number of unidentified loans (false negative, Type 2 error) and the wrongly matched loans (real loans but with incorrect rates and/or maturities, error Type 3). Limits of this validation technique are the impossibility to estimate the false positive error (Type 1) and the fact that e-MID data are not representative for the entire euro money market during the whole period considered. The best performing corridor setup is the one centered on the EONIA and EURIBOR rates with a width of 200 basis points. The Type 2 error rate is 1.96% while the Type 3 error rate is 0.73%. Analysis of the error rates by maturity shows that the algorithm is most reliable for transactions up to three months. It can be used for loans up to one year taking special care about the uncertainties of the loans found. Our findings are in sharp contrast with Armantier and Copeland (2012), who validated the algorithm developed for Fedwire

[25] This is because our algorithm works on the settlement dates and cannot distinguish between different trading dates.

transactions. They found an estimate of 81% for Type 1 errors and 23 % for Type 2 errors, which are significantly larger.

Our algorithm was applied to the whole TARGET2 dataset (June 2008 to end June 2012) to describe and monitor the activity in the euro-area unsecured money market. The monitoring can be done at market level (all loans found), at aggregated market level, e.g., at country group level (group A countries, namely Germany, France, the Netherlands, Belgium and Finland versus group B level namely Greece, Ireland, Portugal, Italy and Spain), at individual country level and at the level of individual banks.

The results show that turnover on overnight unsecured money market dropped significantly after the collapse of Lehman Brothers (from € 130 billion in June 2008 to € 79 billion in June 2009). The outstanding amount of all deposits with maturities up to three months exhibits a significant drop after the Lehman collapse. While loans up to three months remained constant until Portugal's request for financial assistance, the longer-term outstanding amount declined with a constant trend in the domestic component partially compensated by a slight increase in the cross-border component. The sovereign debt crisis of some European countries had a clear negative impact on turnover on the money market. One-day exchanges dropped again after the two 3-year LTROs in December 2011 and March 2012 (from an average of € 75 billion in the period before the first 3-year LTRO to an average of € 47 billion between January and June 2012). The interest paid by the countries most exposed to the sovereign debt crisis with respect to the EONIA is higher for the domestic deposits than for the cross-border ones, presumably due to an adverse selection effect: the banks of these countries able to raise funds from abroad were the most creditworthy counterparties in their home country.

The current setup of our algorithm can be further improved (i) by making a more theoretically correct assignment of multiple matches and (ii) by also looking at loans which follow the 365 day convention for calculating the rate, since British banks follow this convention. Finally, although our algorithm performs well, and with the inclusion of these improvements may well perform better, both research and policy-making would benefit from money market loans being flagged in TARGET2.

Annex

Overlapping maturities

Analysing the overlap of plausibility corridors for different loan durations provides a further insight into the mechanism of the Furfine algorithm. Given r_{OD}, r_{ML} and r_{MRO} the Overnight Deposit (OD), Marginal Lending (ML) and Main Refinancing Operation (MRO) rates, the ECB corridor used by the Furfine algorithm can be expressed as $[r_{OD}-\delta; r_{ML}+\delta]$ or as $[r_{MRO}-\delta_1; r_{MRO}+\delta_1]$ supposing that $r_{MRO}=(r_{OD}+r_{ML})/2$, where $\delta_1=\delta+(r_{OD}-r_{ML})/2$.

Let us consider a loan characterised by x the amount of the loan, r the traded rate, d the set-up date and i the duration of the loan. As the Furfine algorithm assumes that x belongs to a discrete set, not all possible loan values are allowed and the correct working of the algorithm implies that the repayment (capital plus interest) is lower than the next plausible amount in the discrete set. In other words, the sum of the loan (e.g. € 1 million) plus the interest $(1,000,000\cdot(1+r)\cdot i/360)$ should be lower than the next plausible loan amount, i.e. € 1,100,000 if we assume a minimum tick of € 100,000.

The Furfine algorithm looks for reverse transactions at days $d+i$, in the range $[x+g_{MIN}(i); x+g_{MAX}(i)]$ where $g_{MIN}(i)$ and $g_{MAX}(i)$ are given by:

$$g_{MAX}(i)=\frac{x\cdot(r_{MRO}+\delta_1)}{360}\cdot i \tag{1}$$

$$g_{MIN}(i)=\frac{x\cdot(r_{MRO}-\delta_1)}{360}\cdot i \tag{2}$$

and represent the maximum and minimum interest accruable with a loan duration of i days. In the Furfine matching process (Figure 15), there is intra-maturity ambiguity between loans with a duration of i days and those with a duration of $i+k$ and/or $i-k$ days when

$$g_{MIN}(i+k)<g_{MAX}(i) \text{ and } g_{MAX}(i-k)>g_{MIN}(i) \text{ for } k<i \tag{3}$$

and

$$g_{MIN}(i+k)<g_{MAX}(i) \text{ for } k>i \tag{4}$$

Substituting $g_{MIN}(i)$ and $g_{MAX}(i)$ in the previous formula we obtain that for $k<i$ the corridors collide twice, both if $\frac{r_{MRO}+\delta_1}{r_{MRO}-\delta_1}>\frac{i+k}{i}$ and if $\frac{r_{MRO}+\delta_1}{r_{MRO}-\delta_1}>\frac{i}{i-k}$, whereas for $k>i$ they collide once if $\frac{r_{MRO}+\delta_1}{r_{MRO}-\delta_1}>\frac{i+k}{i}$. Defining $\varphi=\frac{r_{MRO}+\delta_1}{r_{MRO}-\delta_1}$, introducing the step function $u(x-t)$ that is equal to 1 if $x\geq t$ and 0 if $x<t$ and given the maturity i, we can define the number of maturities that collide in terms of φ as

$$N(i)=\sum_{k=1}^{M-i}u\big(\varphi-\frac{i+k}{i}\big)+\sum_{k=1}^{i-1}u\big(\varphi-\frac{i}{i-k}\big) \tag{5}$$

where M is the maximum possible maturity, for example 365 days. The ratio between the overlap size and the corridor size of a given maturity is provided by

$$\beta_{UP}(i,k)=\max\big(0;\frac{g_{MAX}(i)-g_{MIN}(i+k)}{g_{MAX}(i)-g_{MIN}(i)}\big) \tag{6}$$

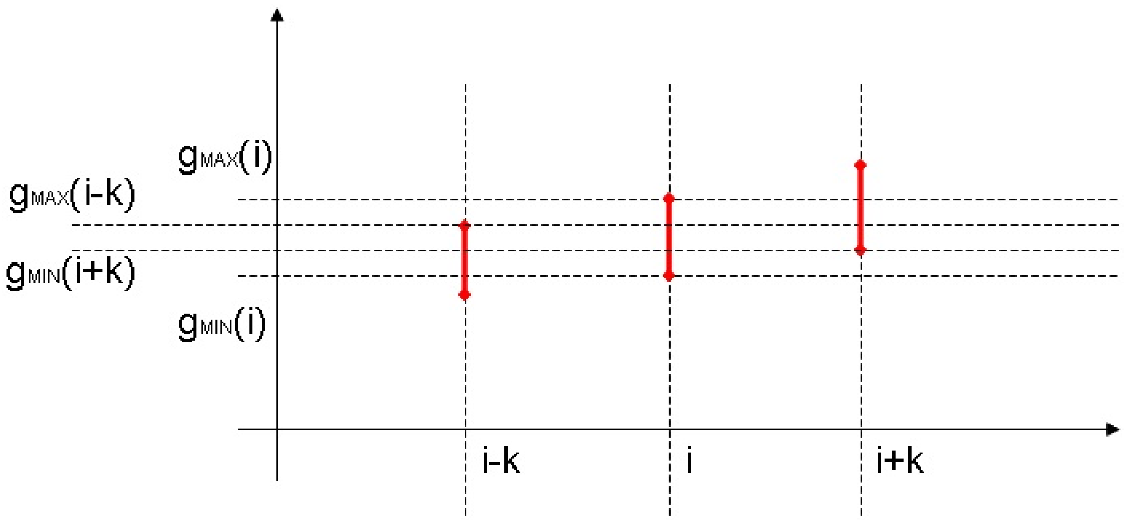

Figure 15: Overlapping corridors.

for maturities greater than i and by

$$\beta_{DOWN}(i,k) = \max\big(0; \frac{g_{MAX}(i-k) - g_{MIN}(i)}{g_{MAX}(i) - g_{MIN}(i)}\big) \tag{7}$$

for maturities smaller than i.

Weighting collisions with the ratio between the overlap size and the corridor size, we obtain the number of normalised collisions, which provides an indication of the probability of a certain maturity colliding with others. That is

$$\bar{N}(i) = \sum_{k=1}^{M-i} \beta_{UP}(i,k) \cdot u\big(\varphi - \frac{i+k}{i}\big) + \sum_{k=1}^{i-1} \beta_{DOWN}(i,k) \cdot u\big(\varphi - \frac{i}{i-k}\big) \tag{8}$$

Figure 16 depicts the weighted number of overlapping corridors for three different values of the MRO rate (1%, 2% and 4%) and for different corridor configurations (δ_1 equal to 25, 75 and 100 bps).

It can be observed that $\bar{N}(i)$ increases rapidly when the maturity increases: it reaches its maximum value, depending both on the MRO rate and on the corridor parameters and then decreases slowly because the number of overlapping corridors decreases, whereas the overlapping corridor size increases. The solid blue line depicts the case MRO=1% and $\delta_1 = 100$ bps; in this case the figure degenerates since the size of the corridors includes the 0% interest rate implying that all maturities collide with each other.

The analysis confirms that for longer maturities, the collision probability, which depends on the weighted number of overlapping corridors, increases steadily causing the reliability of the estimation of transactions to decrease as their maturity increases. This evidence shows how the rate cuts that have occurred during the time horizon considered have made it more difficult for the Furfine algorithm to disentangle higher maturities.

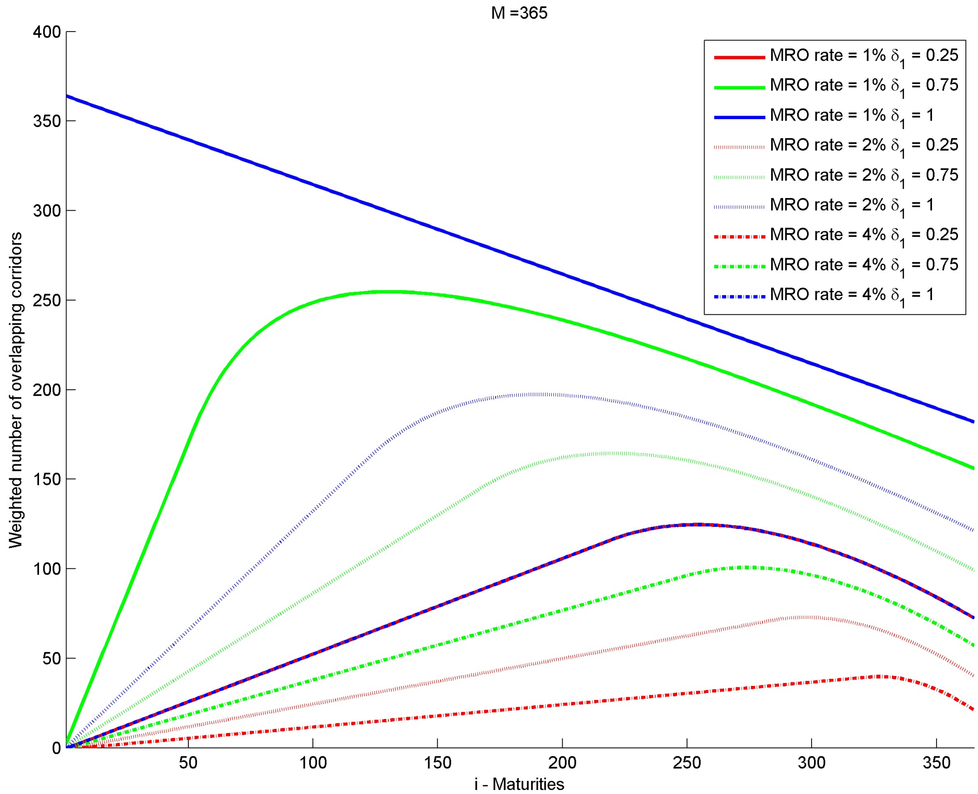

Figure 16: Weighted number of overlapping corridors for different corridor configurations.

The algorithm

All the transactions from bank A to bank B and from bank B to bank A (where a bank is identified by the BIC code of the settlement account) are stored in two vectors of N and M length respectively, x_{AB} and x_{BA} and the corresponding dates in the vectors d_{AB} and d_{BA}. From the two vectors a matrix M_{AB} of all possible matches is created, where the element (i, j) is set to 1 if a plausible match is identified from A to B, to -1 if a plausible match is identified from B to A and 0 if no match is found. For instance for a loan from A to B, given $x_{AB}(i)$, the amount of the transaction from A to B, $x_{BA}(j)$ the amount of the transaction from B to A, and $d_{AB}(i)$ and $d_{BA}j$ the dates of the two transactions, a plausible match occurred if the following conditions are met simultaneously:

- $x_{AB}(i) < x_{BA}(j)$;
- $d_{AB}(i) < d_{BA}(j)$ and $d_{BA}(j) - d_{AB}(i)$ is lower than or equal to the longest maturity searched for, e.g. 370 days;
- $x_{AB}(i)$ respects the increment rule;
- $r = \frac{x_{BA}(j) - x_{AB}(i)}{x_{AB}(i)} \cdot \frac{D}{360}$ is a multiple of half a basis point;
- r is in the plausible corridor.

If the match occurs, $M_{AB}(i,j)$ is set to 1 and the rate is stored in $R_{AB}(i,j)$. Moreover, the number of matches found is stored in two vectors, c_{AB} and c_{BA}, and increased whenever a match is found.
In the second phase, all unique matches of the M_{AB} are searched, i.e. if $M_{AB}(i,j)$ is not equal to 0 and $c_{AB}(i)$ and $c_{BA}(j)$ are 1. The value of $M_{AB}(i,j)$ is put equal to zero.
In the third phase, all the multiple matches loans of M_{AB} are searched, i.e. if $M_{AB}(i,j)$ is not equal to 0 and $c_{AB}(i)$ or $c_{BA}(j)$ are greater than 1. In this phase the plausible durations are chosen on the basis of the frequency of the duration computed from the set of unique matches set.

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