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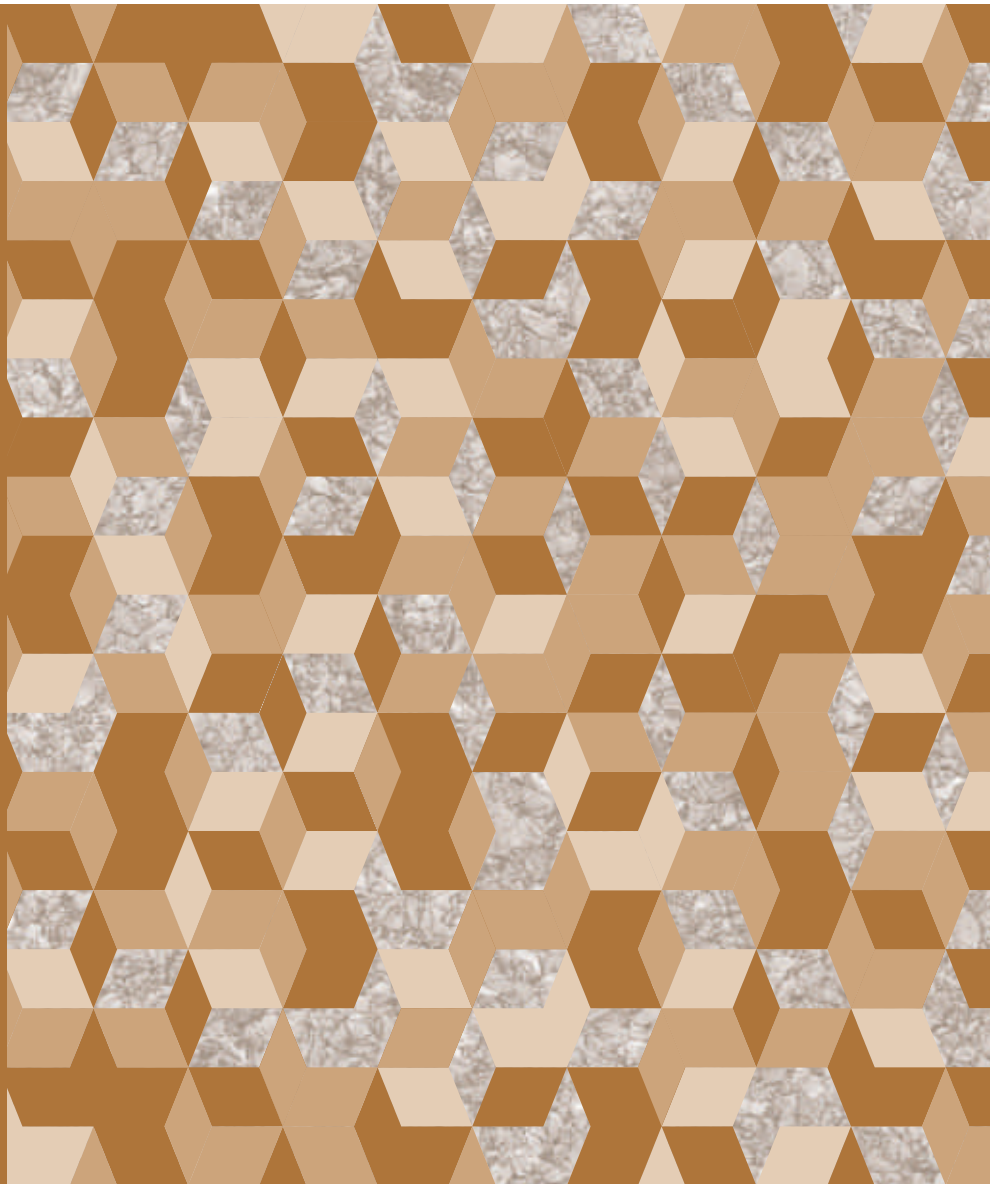

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The analyses, opinions and findings of these papers represent the views of the authors, they are not necessarily those of the Banco de Portugal or the Eurosystem

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# The unsecured interbank money market:
## A description of the Portuguese case

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August 2016

**Abstract**
Money markets were severely impaired by the financial and subsequent sovereign debt crises. Although the euro money market has been studied substantially, little has been done for the particular case of Portugal.
This thesis investigates how the Portuguese part of the euro unsecured interbank money market was affected by the two consecutive crises. I constructed and adapted a Furfine-based algorithm to identify the loans traded and settled in TARGET2, in which a least one of the counterparties is a Portuguese bank. Identified loans have overnight and one-week maturities. Data shows a clear trend towards a closed interbank money market. In addition, there is a visibly significant reduction in the number of times banks trade in the market, accompanied by a parallel drop in volumes transacted. Finally, I find that interest rates rise above the benchmark and those in the domestic market are persistently higher than rates agreed upon through cross-border operations.

JEL: E58, G21

Keywords: money markets, Furfine.

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The views expressed in this article are those of the author and do not reflect the views of the Banco de Portugal or the Eurosystem.

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## 1. Introduction

The past decades have been marked by increasing globalization in various sectors, in particular of financial systems. Technological innovations allowed transactions to be settled in real-time and between banks on opposite sides of the globe. More than ever, it became essential to have well-functioning interbank money markets to ensure the stability of financial systems, as well as the smooth transmission of monetary policy (Heider *et al.* 2009). However, the financial crisis that began in August 2007 in the US severely impacted the unsecured interbank money market. Its dissemination ultimately disrupted the stability of the euro interbank money market. The purpose of this thesis is to get a better understanding of the Portuguese part of the euro unsecured interbank money market and examine its activity in the aftermath of the crisis.

During the summer 2007, the uncertainty surrounding the US subprime credit market provoked the suspension of investment funds of BNP Paribas, and the ECB compensated by injecting liquidity into the system. Notwithstanding, the collapse of Lehman Brothers (September 2008) deteriorated the situation and central bank intervention was needed. Besides regular monetary policy operations, the ECB increased liquidity, expanded eligible collateral, performed more refinancing operations, and opted for a fixed rate full allotment (FRFA) policy at the main refinancing rate - aiming to completely satisfy banks' demand for funds at the regular operations at a fixed rate equal to the main refinancing rate.

In 2009, conditions in Europe worsened as the euro market reacted to misgivings about Greece's government accounts. The sovereign debt crisis reinforced the instability in the euro area with its successive requests for financial assistance and the uncertainty around both governments and banks, and was responsible for creating contrasting credit conditions among European countries. Periphery countries[1] experienced increased sovereign risk premia and decreased cross-border flows, culminating in a segmentation of the euro money market.

In order to support interbank lending and foment money market activity, the ECB responded with two 3-year LTROs, an increase in available collateral, and a reduction in the reserve ratio. These measures were reinforced by two Covered Bond Purchase Programs, since this market is considered to be relevant for the funding of banks, and the Securities Market Program, with the purpose of correcting the deficient price formation process in the bond market that, consequentially, aimed to correct the transmission mechanism.

All of this economic instability was a daily presence during my years as an economics student. Professors were teaching economic theories that were suddenly being questioned, economic commentators were trying to forecast the

1. Portugal, Spain, Greece, Ireland and Italy.

next big event in the financial system, and I - as a student - was trying to understand what was happening. This was the motivation for my thesis: to answer some questions related to the Portuguese part of the euro unsecured interbank money market and its reaction to the financial and sovereign debt crisis.

First, I constructed a Furfine-based algorithm that identifies TARGET2 interbank loans in which at least one of the counterparties is a Portuguese bank. Using the resulting dataset I studied the market in terms of quantities, turnover and interest rates. Anecdotal evidence suggests that the interbank money market froze and that there might have been a shift from longer to shorter maturities. I sought to verify that this was true in the Portuguese case? Did the international market close their doors to Portuguese banks? How did market segmentation look like in Portugal?

My results show a clear segmentation in the interbank market beginning after the collapse of Lehman Brothers. Cross-border transactions and turnover suffered a substantial reduction and the domestic market became relatively more significant after 2009. Moreover, data suggests that in cross-border market transactions with a Portuguese borrower became proportionally more important during the two years that followed the financial breakdown. Looking at the impact on differences in maturities, in my data it is evident that by the end of the sample period one-week maturity contracts represented a growing fraction of transactions and turnover in the market. Finally, market segmentation is also clear in terms of interest rates. After 2009 interest rates become on average higher than the benchmark and there are clear differences between interest rates paid in the domestic and cross-border markets.

The structure of the thesis is as follows. Section 2 presents an overview on previous literature on the subject under study. Section 3 presents the data and Section 4 describes the algorithm used. Section 5 provides some descriptive statistics and results that are proved to be robust in Section 6 Finally, in Section 7 I give some concluding remarks.

## 2. Literature Review

It is in the unsecured interbank money market where banks trade liquidity, i.e., banks with a surplus lend to banks with shortages, fulfilling the overall reserve requirements of the system. Moreover, it is in these markets where monetary impulses begin[2], although their significance goes much further than that. The

2. The central bank injects liquidity in the overnight unsecured interbank money market, allowing institutions to endogenously distribute them. Based on expectations theory, longer term interest rates depend on the expectations market participants have on future conditions of the overnight market. In such a manner, monetary policy impulses propagate to other financial markets.

importance of interbank markets in distributing liquidity is widely recognized in the literature. Bhattacharya and Gale (1986) argue that trading in the interbank market is a way for banks to insure against idiosyncratic shocks. Such shocks can be a result of uncertainty in the timing of depositors' consumption (Allen and Gale 2000) or a result of uncertainty on where to consume (Freixas *et al.* 2000). The common feature of these papers is that having well-functioning interbank markets is important for banks to access liquidity and ultimately to the stability of financial systems (Cocco *et al.* 2009).

Other authors have studied the importance of the interbank market with respect to its bilateral nature and the established relationships between banks. Banks' relationships are relevant to determine the amount of liquidity in the market and their access to it (Cocco *et al.* 2009). They also influence pricing conditions in the market, since repeated interactions lead to a cooperation outcome among banks where those with larger imbalances end up trading at more favorable prices than they would otherwise (Cocco *et al.* 2009; Carlin *et al.* 2007). Moreover, smaller banks and banks with a higher proportion of non-performing loans tend to rely on relationships in the domestic market because these have been developed over a longer period of time, information on foreign banks is poorer, and access to cross-border markets is limited (Cocco *et al.* 2009; Freixas 2005). Finally, larger banks tend to be net borrowers and pay lower rates while smaller banks tend to be net lenders receiving lower interest rates (Cocco *et al.* 2009; Carlin *et al.* 2007). Larger banks are able to get better pricing conditions due to their bargaining power - which increases in periods of crisis (Cocco *et al.* 2009; Acharya *et al.* 2012).

The recent financial collapse disrupted interbank money markets as banks became reluctant to trade with each other and revealed how these markets are important for the financial stability of banks themselves and of financial systems. Additionally, it showed how global financial systems are integrated (Heijmans *et al.* 2011). The crisis had its roots in the US market, but a series of events led an initially regional shock to impact financial markets all over the world. In short, the US banking system was changing its traditional model[3] into an "originate and distribute" banking model in which "loans are pooled, tranched and then resold via securitization[4]"[5] (Brunnermeier 2008) . Moreover, there was also a trend for banks to finance their asset holdings with shorter maturity instruments and increasingly rely on repo financing. These changes left US banks particularly exposed to ceased funding liquidity. In early 2007 defaults in subprime mortgage began to rise and generated concern over the valuation of structured products. As a result, the short-term asset-backed commercial paper market started to freeze. After this period money market

3. In which issuing banks hold loans until they are repaid.

4. Increasing securitization was accompanied by a decrease in credit quality.

5. Brunnermeier (2008)

participants became reluctant to lend to each other, and this fear was then exaggerated by the bank-runs[6] on investment banks and the collapse of Lehman Brothers in September 2008 (Brunnermeier 2008).

It is not clear how the crisis propagated to the euro interbank money market, but it is known that on August 2007 BNP Paribas suspended redemptions for three investment funds, alluding to an inability to value structured products (Brunnermeier 2008). In order to overcome this freeze in the interbank market, the EBC injected €95 billion in overnight credit. Afterwards, interbank lending was disturbed in a number of different ways. Either lenders in the market were asking for larger amounts of (quality) collateral and/or higher credit risk premium (ECB 2010), or borrowers - perceived as being riskier - were not finding liquidity in the market or were not willing to pay high risk-premium. As a consequence, there were no opportunities to trade and transactions in the unsecured interbank money market suffered a significant reduction. In addition, with the outbreak of the sovereign debt crisis, different credit conditions were being offered to different countries, i.e., country risk became a significant part of bank risk (Heijmans *et al.* 2011). Reis (2014) named this link between the interbank market and sovereign uncertainty the diabolic loop, which occurs when commercial banks hold sovereign bonds. In the particular case of the euro market there were country bonds - Portuguese bonds, French bonds, and so on - and so each country's commercial banks was holding their own national bonds. According to Angelini *et al.* (2011), the first phases of the crisis were characterized by this liquidity risk on the aggregate level rather than due to concerns over individual banks. Ultimately, asymmetric information was responsible for the market freeze and increasing fragmentation of the single financial market (Afonso *et al.* 2010).

From mid-October 2008 onwards, the ECB provided unlimited liquidity to the system, especially through a full allotment fix rate policy. The ECB also resorted to a number of unconventional monetary policy measures, attempting to restore stability in the market (Szccerbowicz 2014). These measures, however, did not prevent interbank lending turnover in the unsecured market to suffer a tremendous reduction. Liquid banks could either turn to the safety of the ECB's deposit facility to store their surpluses or trade in the secured market. As for illiquid banks, they could fulfill their funding needs directly from regular monetary policy operations against a wide range of collateral, instead of finding it by trading in the market (Cappelletti *et al.* 2011). Such changes in banks' trading patterns towards a fragmented interbank money market are what define market segmentation.

This thesis focuses on the Portuguese part of the euro unsecured money market by using an extensive database in which all interbank transactions are

6. Brunnermeier (2008) states that not rolling over commercial paper is a run on the issuer of the asset-backed commercial paper.

registered. The methodology followed uses an algorithm[7] first developed by Furfine in his 1999 paper *The Microstructure of the Federal Funds Market* which allowed the identification of overnight payments transferred trough Fedwire[8]. Furfine's goal with the construction of the algorithm was to understand the microstructure of the U.S interbank money market - as suggested by the title - during the first quarter of 1998 by using the resulting transaction-level dataset. In the federal funds market three main rates are recorded every day: the opening rate (11:00 rate), the closing rate and the effective rate (a value-weighted rate for the day). Furfine uses these three rates as reference when deciding upon a plausible interval for the interest rate which overnight transactions may lay down. The interval is a corridor of 50 basis points (bp) above the highest of the three rates of the day - usually the closing rate - and 50 basis points below the lowest - usually the opening rate. Finally, Furfine also noticed that interbank lending is usually made in round amounts of over $1 million, selecting only loans that fit this criterion.

Many researchers have used Furfine-based algorithms to perform similar exercises for different economies. Farinha (2007) adapted the algorithm to the Portuguese economy in order to assess whether the interbank market had a soft integration into the euro area market. In this algorithm it was also used a 50 basis points corridor, but with EONIA[9] as the reference rate. Only loans ending in at least five zeros above EUR 100 000 were considered, as they found that for a smaller economy it did not make sense to include only amounts as large as those used for the US economy. Moreover, Heijmans *et al.* (2011) describe the microstructure of the Dutch part of the euro market and improve the algorithm by expanding the maturities captured. Besides overnight transactions, the algorithm selects contracts with maturities up to three months. Their corridor depends on both EONIA and EURIBOR and for most of the time period 50 bp above and below the reference rate is enough, temporarily increasing the lower bound to 100 bp for the after crisis period. In addition to the corridor around the reference rate they also stipulate a minimum interest rate of 5 bp and a minimum loan size of EUR 100 000 with 100 000 increments. Finally, Arciero *et al.* (2014) study the Eurosystem unsecured money market for overnight, one week, and monthly maturities up to one year (12 months). When constructing an interest rate's plausibility area they contemplate different corridors depending on the maturity and added that interest rates needed to be multiples of $1/2$ basis point. As they study the Eurosystem market as a whole and not just a section of the market, the

7. The algorithm will be discussed in more detail in section 4. For now I will only emphasize some aspects of its construction.

8. The RTGS (Real-Time Gross Settlement) system operated by the Federal Reserve.

9. In the Eurosystem, EONIA and EURIBOR are the reference raes in the interbank market depending on the maturity of the transaction. They are not exactly the same as the federal funds rate. In section 3.1.2 I will explain these rates in more detail.

minimum loan size allowed was of EUR 1 million with increasing increments depending on the amount of the transaction, starting at 10 000 euros.

Although Portugal can no longer use monetary policy of its own, *Banco de Portugal* is responsible for ensuring the implementation of monetary policy operations at the national level. In doing so, knowing how the Portuguese part of the unsecured interbank money market responded to the financial crisis gives an insight on how the ECB's monetary impulses were embraced by this part of the economy. Furthermore, such an understanding of the Portuguese economy may improve the future use of monetary policy instruments during stress times. Following the work previously developed, this thesis adds to the literature an adaptation of the algorithm to the recent Portuguese market and fills a gap by analyzing one of the economies mostly affected by the financial collapse.

## 3. Data and Methodology

### *3.1. Data*

There are two ways in which banks can lend to each other. They can either transfer the money directly to one another, or they can do it through the medium of a Real-Time Gross Settlement System (RTGS). In the former case transactions are only registered on the account books of both institutions and it is virtually impossible to account for that activity. Furfine (1999) states that for the federal funds case this takes place mainly between very small institutions for which the major financial markets are of difficult access. In the latter case, the two sides agree upon a loan amount, a term, and an interest rate. These transactions are then registered in a RTGS system usually operated by a central bank.

RTGS systems are a particular case of large value payment systems (LVPS), and have been subject to huge developments, playing an increasingly important role in financial systems and on modern central banking activity. According to Heijmans *et al.* (2011), there was a tremendous increase in interbank payments over the past 30 years that resulted from the integration and globalization of the financial sector. Financial institutions mainly settle large value transactions - including interbank loans - in these systems, and central banks provide liquidity through their own accounts.

In the Eurosystem all liquidity provisions and monetary policy operations have to be settled via RTGS systems. In addition, any monetary transfer between two banks that is not performed exclusively via the institutions' account books has an entry in those systems. The issue here is that the nature of those transactions is not specified in these cases. Consequentially, amidst such an enormous amount of records, interbank loans are difficult to identify.

It is relevant to note that having systems where transactions are settled by each bank individually and in real time calls for larger liquidity in the market.

For example, a bank can only lend or pay a certain amount to another bank if enough money is available on its account at the time the transaction is to be settled. In this environment, it may be the case that a bank cannot pay a loan because it has not yet been paid by another bank, the so-called gridlocks. In order to avoid a market freeze due to transaction timing, central banks grant intraday credit to the market through their own accounts. Usually the central bank provides liquidity to the bank in need expecting a repayment later that day. If the repayment is delayed to the day after, this will be considered an overnight transaction and an interest is added to the amount in debt. In the European Union these liquidity provisions are collateralized and free of charge.

Finally, it is important to mention that in the euro area there are two LVPS operating, TARGET2 and EURO1. The difference between them is that TARGET2 is owned and operated by the Eurosystem while EURO1 Service of EBA CLEARING is privately owned. EURO1 balances are settled once a day in TARGET2 via a settlement account held with the European Central Bank. The following section explains TARGET2 in more detail.

To be able to see changes in the market due to the financial crisis, the data collected begins on the first business day of January 2005 and ends on the last business day of December 2013.

*3.1.1.* ***TARGET2.*** Data used in this thesis originated in TARGET2[10], the RTGS owned and operated by the Eurosystem. This is an improvement on the system that was previously at work, TARGET ("Trans-European Automated Real-time Gross settlement Express Transfer" system). The transition from the later system to the former was implemented in phases beginning in 19 November 2007 and completely concluded in May 2008 (ECB 2008) . Because the period under scrutiny begins in January 2005 and ends in December 2013, data comes from both TARGET and TARGET2[11].

The main difference between the two systems is the fact that TARGET had a decentralized structure and TARGET2 is a centralized system that uses a single shared platform. Nevertheless, there are no relevant changes in the type of information extracted from these systems. They both allow euro payment services throughout the European Union (EU) and not only among countries where the currency was adopted. Institutions have to meet strict criteria in order to have access to the platform, so that consumers and most financial and non-financial firms do not have access to it. Furthermore, the transactions handled by these systems are the same and include "payments directly connected with central bank operations in which the Eurosystem is involved either on the recipient or the sender side; the settlement operations of

10. No data from EURO1 was used.

11. From now on I will use TARGET for both systems interchangeably for simplification purposes.

large-value netting systems operating in euro; and interbank and commercial payments in euro" (ECB 2008), as well as transfers between central banks connected to TARGET that are part of the European System of Central Banks (ESCB).

The Portuguese component of TARGET2 is designated as TARGET2-PT and is managed by *Banco de Portugal*: the central bank acts as an intermediary between national financial institutions and TARGET2. A Portuguese institution can only be part of TARGET if it fulfills TARGET2-PT requirements.

Data originated in these systems has, among other things, information on the amount transacted, the date and exact time of the transaction, and a Bank Identifier Code (BIC) for both participants. It is important to mention that, in this system, there are no upper or lower limits on the value of payments.

*3.1.2.* ***EONIA and EURIBOR panels.*** EONIA is the effective overnight reference rate for the euro. "It is computed as a weighted average of all overnight unsecured lending transactions in the interbank market, undertaken in the European Union and European Free Trade Association (EFTA) countries"[12]. Having information on this rate is fundamental to the study of the microstructure of the unsecured interbank money market because most of the transactions settled in this market are overnight.

For transactions with one week or higher maturities, the reference rate used is EURIBOR. This is the rate "at which Euro interbank term deposits are offered" by and between prime banks within the euro area. According to the ECB "the choice of banks quoting for EURIBOR is based on market criteria"[13]. EURIBOR can be used as an efficient and representative reference rate, because the choice of banks assures the diversification of the euro money market.[14]

Historical data on both EONIA and one week EURIBOR are used as benchmark rates in this thesis.

*3.1.3.* ***Data: Purpose.*** Many different types of payments are settled in TARGET. To study the unsecured interbank money market, I am only interest in transactions that correspond to interbank loans, and these are only a fragment of the data provided. When payments are settled no information on the type of transaction it corresponds to is registered. There is also no information on the interest rate agreed upon in each transaction or on its maturity. Therefore, I constructed an algorithm that allowed me to select only the payments I was interested in. With that purpose, the relevant information

12. http://www.emmi-benchmarks.eu/euribor-eonia-org/about-eonia.html

13. http://www.euribor-ebf.eu/euribor-org/about-euribor.html

14. There has been some discussion about the ability of EURIBOR to represent the market. It is said that banks may misreport the rates at which they trade, consequentially giving inaccurate signals to the market.

is the identification code of the financial institution, date and total amount of the operation. As in the case of Heijmans *et al.* (2011), neither the dataset nor the way the algorithm is constructed allows for the identification of rollovers and interest-only payments, and for this reason these will not figure the final dataset. Data on EONIA and EURIBOR was used to construct a plausible interest rate interval for loans' payments. This will be explained into more detail in Section 4.1.

## 4. The Algorithm

Before describing the algorithm constructed in this thesis, I will begin by explaining the one set up by Furfine (1999). As already mentioned, Furfine (1999) was the first to create an algorithm that permitted the extraction of overnight payments, or a close approximation, from Fedwire. This was designed to select transactions that corresponded to rounded values going from institution $i$ to institution $j$ at day $t$ , and in the opposite direction at day $t+1$ in an equal amount plus a plausible interest[15] (Heijmans *et al.* 2011). Besides the information about the interest rate on the transaction being unknown, different banks may end up trading at different interest rates even during the same day when negotiating the terms of a contract. In order to attain the plausibility area, Furfine (1999) defined a corridor of 50 basis points below and above the highest and the smallest, respectively, of the opening, closing and value-weighted daily rates of the market, and converted the implicit interest rate in a yearly rate. Finally, based on anecdotal evidence, he noticed that interbank loans were made in round amounts, allowing only the selection of first payments higher than $1 million and that ended in at least five zeros.

The outline of my algorithm is very similar to the one just described. However, the U.S. market departs in some ways from the European one, in particular from the small share to which the Portuguese market corresponds. Also, I wanted to capture not only overnight transactions, but also payments with one-week maturity so that I could have a more complete view of the very short maturities market. In short, I wanted to identify operations that corresponded to rounded values going from institution $i$ to institution $j$ at day $t$, and in the opposite direction at day $t+1$ or $t+7$ in an equal amount plus a plausible interest.

15. Notice that $t$ corresponds to a business day and $t+1$ to the following business day. For example, if $t$ is a Monday, $t+1$ is a Tuesday. But if $t$ is a Friday, $t+1$ is a Monday.

### *4.1. Step-by-step construction of the database: describing the Algorithm*

The first step was to carefully choose and match all pairwise combinations *ij-ji* in day *t* and *t+1* or *t+7*. Basing my decision on the relevant literature, I kept only the combinations with a first payment of a rounded amount larger or equal to EUR 100 000 and multiple of 100 000.

Turning to the plausibility areas, in my algorithm I had to consider two distinct ones: one for the selection of overnight payments, and another for the selection of one week maturity contracts. The reason for constructing two distinct plausibility areas is because, although both maturities are very short, each has its own reference rate: the EONIA in the former case and the one-week EURIBOR for the latter. Given this information, a corridor of 100 bp around the EONIA and another around the EURIBOR was constructed. Only implicit interest rates that fell inside the respective corridor would be considered. It is important to note that if the EONIA and EURIBOR are close to each other, the corridors may overlap and the algorithm will have multiple matches with different maturities for the same payment[16]. In short, the algorithm picks combinations of loans and refunds that meet the following criteria:

1. Both payment and repayment were made through TARGET.
2. First payment must be higher or equal to EUR 100 000 and multiple od 100 000.
3. The repayment must be equal to the first payment plus a plausible interest.
4. An implicit annualized interest rate derived for each transaction must lay inside a 100 bp interval above and below one of the reference rates.
5. A corridor is built using EONIA and another using EURIBOR.

### *4.2. Multiple matches*

The algorithm is designed in such a way that two main types of multiple matches may occur. The first type is "intraday"[17] multiple matches, which can be divided into three separate categories. There may be the case that one first payment has more than one possible refund fulfilling the algorithm's criteria. Heijmans *et al.* (2011) call this a one-to-many (1:M) multiple match. The reversed situation may also happen, i.e., one repayment at day t+1 may fulfill the requirements for more than one payment at day *t* - a many-to-one (M:1) multiple match. The third case is a combination of the previous two, when many loans have more than one possible repayment matches and vice versa - many-to-many (M:M) situation.

16. This problem will be discussed in further detail in section 4.2.

17. Following Heijmans *et al.* (2011) denomination.

To solve "intraday" multiple matches problem, I begun by selecting the pairs of payments to which the interest rate was closest to the reference rate. If the problem persisted, I opted for transactions with 1 day or full weeks maturities. For the two first types, whenever there were still more than one possible match, I randomly selected one combination of payments. For the last case I chose in chronological order. I would keep the first combination, eliminating all the other cases in which any of the two payments involved would appear, then the second, and so on until I exhausted all possibilities.

The second type of multiple matches happens when plausibility areas overlap, and the same loan may have a repayment that happened one day or seven days after, and vice versa. Heijmans *et al.* (2011) states that this happens because of policies aimed at reducing interest rates. As there is a zero lower bound on interest rates, decreasing longer term interest rates result in a convergence between different maturities' interest rates.

Inside this type of multiple matches there might also occur different cases. The first is when the same repayment is a match for payments beginning in different days, i.e., it might be a repayment for an overnight transaction but also for a one-week maturity. Again, the opposite is also possible, when the same first payment has different repayments with different settlement dates fulfilling the criteria. Finally, a combination of the previous two may occur.

Solving this problem involved different phases. In the first phase I opted for the transactions with a lowest implicit spread relative to its maturity. If the problem persisted I chose the smaller term transaction. This criteria decision was based on ECB reports stating that during the crisis the euro market concentrated on overnight operations.

### *4.3. Type 1 and Type 2 erros*

This section presents some potential problems regarding the loans and matches picked up by the algorithm, resulting from the way it is constructed and the type of information in its original form.

Up front, some transactions may fall into the false positive category. A false positive (also known as type 1 error) happens when a pair of payments is incorrectly identified as a bank loan. The first and most obvious reason for this kind of mistake is when two completely random payments are paired, and the wider the plausible interest rate interval, the higher the probability this will occur. Second, the selection between multiple matches discussed in section 4.2 is an important source of mismatch, particularly when a first payment is correctly identified, but has several possible repayment matches such that the incorrect match survives the selection process. In this case there is no significant bias on the characteristics that matter for the present analysis since this would only be a problem if I had wanted to study individual transactions instead of aggregated data.

A third source of error is due to the fact that information from TARGET does not allow me to distinguish whether payments carried out between the two identified banks actually correspond to an interbank loan or if banks are acting in the name of a client or another bank[18] . Such a situation may bias a transaction level analysis because to what concerns the size of the bank the results may not accurately reflect the interbank market. However, in an aggregate data context this does not present an obstacle.

Another type of error may arise, the false negatives (type 2 error). A false negative is a true interbank loan that was wrongly rejected by the algorithm. The main source of this mistake is the strict criteria that has to be satisfied for a transaction to be considered part of the unsecured interbank money market. If the principal of a bank loan is less than EUR 100 000 or is not a multiple of 100 000 it is not selected. In addition, the choice of an interval for the interest rate is again important in order to avoid these mistakes. In times of high volatility in interest rates, banks might have agreed upon on an interest that is either higher or lower than the interval limits.

There is still a potential problem when the interest is not paid simultaneously with the principal. However, Armantier and Copeland (2012) state this was not frequent in the fed funds case, even during the crisis period. Making an educated guess, we can assume this was also infrequent in the euro market. Although there are some caveats, based on related literature the algorithm gives a good approximation of the activity in the euro market, and, to this extent, in the Portuguese part of the unsecured interbank money market.

## 5. Statistics and Results

The constructed algorithm enables the characterization of the euro unsecured interbank money market. My description will be made in 3 phases, characterizing market activity in terms of quantities, turnover and interest rates.

Based on the time division defined by Heijmans *et al.* (2011), I will specify different time periods along this section:

1. Pre-crisis period (I): 01-01-2005 to 30-06-2007
2. Start of turmoil (II): 01-07-2007 to 14-09-2008
3. Period between Lehman Brothers and Europe's sovereign debt crisis (III): 15-09-2008 to 30-06-2009
4. Sovereign debt crisis before Portuguese financial request (IV): 01-07-2009 to 16-05-2011
5. Portuguese financial assistance period (V): 17-05-2011 to 31-12-2013.

18. The bank may be pursuing a foreign bank transaction.

### *5.1. Market Activity in Quantities*

During the nine year period considered in this study the number of transactions in the market suffered a significant reduction. From 2005 to 2013 there were on average 42 daily transactions, from which 89% were overnight operations and only 11% had a one-week contract period. Moreover, another distinction can be made. Of these 42 daily operations on average, 24% were domestic. We can clearly visualize the changes in the market by looking at Figure 1.

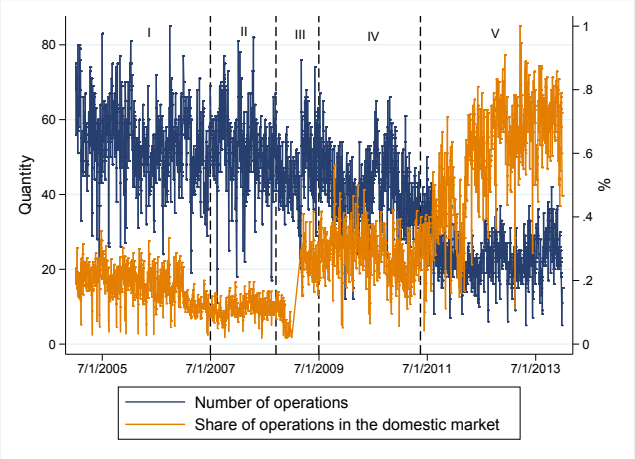


FIGURE 1: Number of daily operations - share of domestic operations throughout the period.

Along the period, the daily number of transactions decreased by a significant amount and domestic transactions gained expression from 2009 onwards, after a period when Portuguese banks were almost not trading with each other. In particular, the average number of daily transactions in period II - representing the beginning of the turmoil - was 52 from which domestic transactions comprised of only 11%. By period V an average of 24 transactions were traded per day - nearly half the number recorded in period II. This decrease in interbank loans, combined with an increase in the number of domestic loans, explains the 55% average share of domestic operations in this last period. This can be summarized in the following results:

Result 1: *There was a substantial decrease in the total number of daily operations.*

Result 2: *The number of operations between domestic banks increased after the bankruptcy of Lehman Brothers, increasing its relative importance in the market - in the last period domestic operations represent on average 55% of daily transactions.*

Looking closely at the cross-border market, it is visible from Figure 2 that besides the reduction in relative importance of cross-border transactions in the market, these were also reduced considerably in absolute value. In addition, there is evidence that Portuguese banks during the periods III and IV actually increased the share of transactions in which they acted as borrowers in the international market.

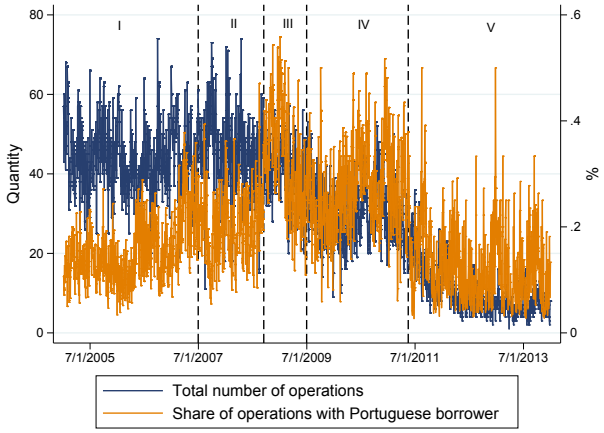


FIGURE 2: Number of daily operations in the cross-border market - share of cross-border operations with a Portuguese borrower.

In period I, from the daily average of 44 cross-border operations only 18% had a Portuguese bank as a borrower, but - with an increase in the number of daily transactions with Portuguese borrowers and a reduction in the number of operations in which a Portuguese bank acted as lender - this share progressively increased from period to period, and in period III on average 38% of cross-border transactions had a Portuguese borrower. The decreased number of cross-border operations was then accompanied by a decrease in the share of Portuguese borrowers and in period V on average 11 operations were cross-border and 27% had a Portuguese borrower. Summing up:

Result 3: *Before the financial turmoil transactions in which Portuguese banks acted as borrowers represented 18% of the cross-border market. During periods III and IV Portuguese banks acted as borrowers in 38% and 37% of transactions, respectively.*

Still looking at the cross-border market, I identified Portuguese banks' main trading partners. The number of transactions in which German banks were borrowing from Portuguese banks was fairly constant along the entire period:

after increasing slightly by the start of period II it remained at almost the same - although lower - level during periods III and IV. In relative terms, the share of German banks borrowing from Portuguese banks steadily increased from 2005 to 2013.

The number of Spanish and British banks borrowing from Portugal remained fairly constant, but Spanish banks gained some importance in relative terms during 2012, the period when most foreign banks were not trading at all with Portuguese banks. Italy, Ireland, and Belgium follow a very similar pattern, borrowing from Portuguese counterparties until the beginning of 2009 and afterwards ceasing trade with Portuguese banks.

On the creditor's side, Spain, Great Britain, and Greece - and in some periods France - are the countries that present the highest number of operations with Portuguese banks. Spanish banks lent to Portuguese banks during the entire period, accounting for the highest percentage of Portuguese loans. From 2011 onwards the proportion of Spanish partners for the Portuguese cross-border market increased despite its fall in absolute value. Great Britain also lent to Portugal throughout the nine-year period, as evidenced by the fact that from 2007 to 2011 (periods II to IV) the number of transactions in which Portuguese banks were borrowing from British banks is much higher. As for Greek banks it is also visible that these kept lending to Portuguese counterparties throughout the entire period, in particular during period IV. If I exclude intragroup transactions[19] the pattern remains the same but at lower levels. This demonstrates how the market froze after the bankruptcy of Lehman Brothers and how the banking sector was closely related to countries' sovereign debt. In the same line, according to the ECB's Euro Money Market Study published in December 2012, banks were acting in conformity with top management decisions about not trading with banks in higher risk countries, as was the case of Portugal. Therefore:

Result 4: *From 2009 onwards most countries stopped trading with Portugal, a trend that worsened after 2012.*

Without further inspection, Portuguese banks were - and still are - having some difficulty finding liquidity in the market, especially from foreign counterparties. There are signs of market segmentation in the data that can be associated with the perceived high risk due to the diabolic loop. Country instability induced a contraction in the supply of and demand for liquidity by foreign counterparties and increased the relative significance of Portuguese lending in the international market during the Portuguese financial assistance period. This proportionate increase in Portuguese borrowing during high stress times - periods III and IV

19. I constructed a proxy for intragroup transactions considering that if the four first letters of the BIC code were the same, banks belonged to the same banking group.

- is related to the high the liquidity needs of Portuguese banks. Portuguese banks were not trading in the domestic market and it may have been the case that the ones perceived as less risky were being able to find the needed liquidity in the international market.

Looking now at changes in maturity contracts, it seems that before Greece's financial assistance program had been approved, shares for each type of contracts were roughly constant.

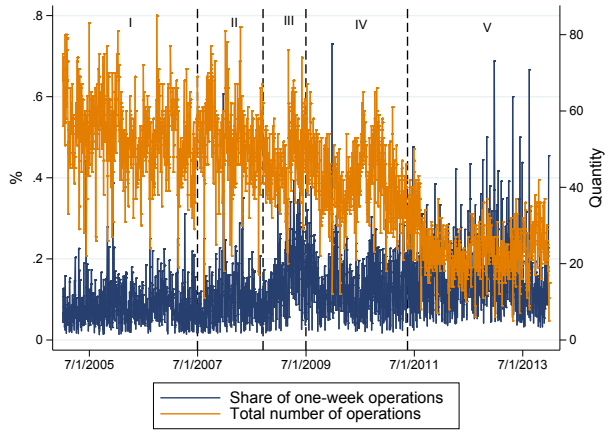


FIGURE 3: Number of daily operations - share of one-week operations throughout the period.

In Figure 3 we can see that around 2009 the share of one-week maturity loans increased a little, representing approximately 20% of transactions, but before the beginning of 2010 it had already returned to pre-crisis levels. At the end of the analyzed sample period (period V) it is possible to notice again a slight increase in the relative importance of longer maturity contracts, but it is evident that overnight contracts dominated the market during the whole time period as expected.

In more detail, for period I on average 54 operations took place in the market, 49 (92%) were overnight payments and 4 (8%) had one-week maturity. As mentioned above the average daily number of transactions decreased steadily from period to period and overnight payments accompanied this trend. The average number of one-week contract operations remained rather constant, its share in the market increased, and that is why we see that modest raise in its share by the end of the period. In fact, during period V on average 24 transactions were being traded per day from which 3 had one-week maturity. It is roughly the same number as in the first period but representing now 14% of transactions, almost twice the share as before. So:

Result 5: *Although the number of operations with one-week maturity remains constant, its relative importance in the market becomes higher during period V (accounting for 14% of transactions).*

### *5.2. Market Activity in Turnover*

The evolution of market turnover[20] follows the discussion in the previous subsection. If we look at Figure 4 we clearly see that daily market turnover steadily decreased from 2005 to the end of 2013; from period I to period V daily turnover decreased by 69% on average. This reduction in market turnover was in great part a result of the contraction in cross-border turnover, especially the turnover from operations with Portuguese lenders, which for the same periods fell by 70%, approximately in the same proportion as the overall market. In period I the average daily turnover of operations with Portuguese lenders was 4409 million euros; in period V this number dropped to 732 million euros - 16% of the previous value.

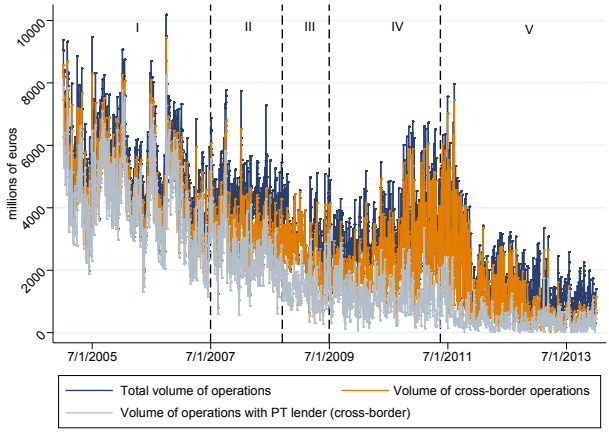


FIGURE 4: Total volume of operations. Total volume traded in the cross-border market and, in particular, total volume traded in operations with a Portuguese lender.

Still on the cross-border market and looking at some countries in particular it is possible to confirm that in fact lending and borrowing turnover decreased by a great amount. Turnover evolution was very similar to the evolution of the number of transactions, and the main countries for the analysis remain the same. Considering turnover on the borrowing side, it is possible to see that until 2009 turnover from foreign banks' borrowing was more or less constant,

20. Literature defines turnover as the total volume transacted by banks at the end of each day.

although different countries borrowed different amounts. After 2009, fewer and fewer banks were borrowing from Portuguese banks. The main exceptions are French, German, British, and Spanish banks, but even in these cases turnover decreased to almost zero around 2012. During this period the share of Spanish turnover increased significantly since these were roughly the only banks that continued trading with Portuguese banks.

Looking at turnover on the lending side we can see that throughout the entire period Spanish banks lend the most to Portuguese banks, even though its average turnover decreased around 69% from period I to period V. Greek banks also lend to Portuguese banks during the entire period - especially in 2010 and 2011, the period of Greece's financial assistance program. Although at first glance it seems that they lent in large amounts, the values are much lower than that of Spain: for the entire period Greek banks' lending turnover was on average 3% of that of Spanish banks. Finally, British and French banks also lent to Portugal, especially during the core period of the crisis, from the beginning of 2007 to the end of 2010. In sum:

Result 6: *Money market turnover reduced considerably from period I to period V. This reduction is associated with a fall in turnover in the cross-border market.*

As in the previous subsection it is possible to find some market segmentation. There is evidence that the domestic market became proportionately more important with the considerable reduction in cross-border turnover. Moreover, on the lending side, the countries that continued their relationship with with Portuguese banks during the whole period were mainly periphery countries facing similar financial struggles, even though on the core period of the crisis Great Britain and France also lent to Portuguese banks. This segmentation may reflect the impact of adverse selection in the unsecured interbank money market, or the fact that having long-standing relationships with the same banks allow better pricing conditions.

When classifying the market in terms of overnight and one-week maturities it is possible to relate the overall market reduction with the turnover developments of the overnight market. From Figure 5, we see a striking rise in daily turnover for the longer maturity between 2010 and 2012, as well as its escalating importance in relative terms. This is somewhat puzzling because if banks wanted to limit their exposure to risk, they should have been trading higher amounts in the overnight market. This period corresponds to the one when the cross-border market shows the highest degree of closeness, meaning that this higher turnover in the longer term market took place essentially in the domestic market. Keeping in mind that from period I to period V the average daily number of one-week maturity transactions remained fairly constant, what might justify this phenomena is the fact that banks were reluctant to trade, reducing their overall activity in the market. Since they were trading fewer

times, it might have been the case that when they did trade they would chose to trade in higher amounts in one-week contracts instead of trading on the overnight market. Another possible explanation is that increased intermediation by the central bank caused individual banks to pay less attention to treasury management, decreasing the relative importance of the overnight market in favor of the one-week maturity one. We can also conjecture that another reason for this increase in turnover could be the change from longer maturity loans - e.g. three-month maturity loans - to shorter period ones. However, my algorithm does not allow me to prove this last statement as it does not identify longer term loan contracts.

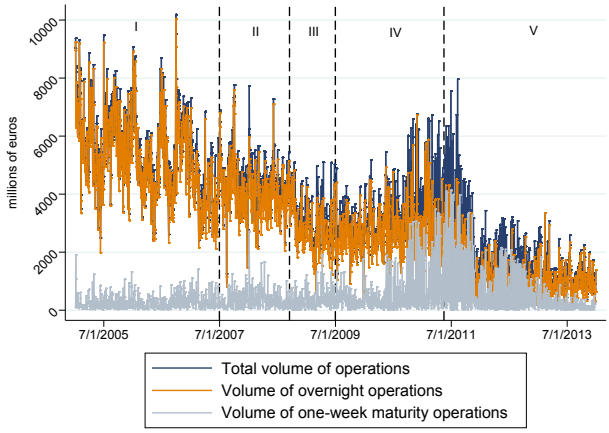


FIGURE 5: Turnover in the market and volumes traded in each of the maturities' markets.

Result 7: *Significant increase of turnover in one-week maturity operations from 2010 to 2012.*

### *5.3. Market Interest Rates*

Interest rates are crucial for a complete understanding of the interbank market. In this section I will divide the analysis. First I will describe the overnight market and then the market for one-week maturity contracts since each of these markets has a different reference rate: the EONIA is the benchmark for overnight operations and the one-week EURIBOR for one-week loans.

The top panel in Figure 6 depicts the ECB's deposit and marginal rates, EONIA and the daily overnight rates found by the algorithm for domestic and cross-border operations. As a result of the way the algorithm is constructed, implicit interest rates are very close to the EONIA. Even though in the first part

of the sample - until the Lehman Brother's collapse (periods I and II) - interest rates captured do not show much variation around the EONIA, beginning in 2009 the dispersion becomes higher, notably for domestic interest rates. We can compare the spreads of the weighted average interest rates found in relation to the EONIA. It is clear that from 2010 onwards both rates - domestic and cross-border market - start to depart from the EONIA. As it was expected, interest rates paid become higher than the benchmark for both types of transactions. A peculiar aspect is that on average interest rates in the domestic market are actually higher than cross-border ones.

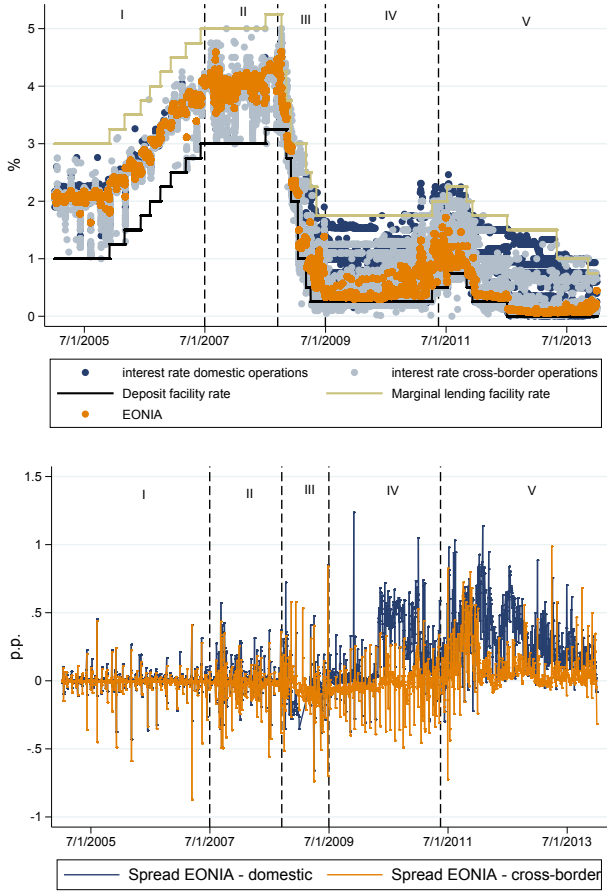


FIGURE 6: The top panel shows policy and money market interest rates in the overnight market. The bottom panel shows the spreads of domestic and cross-border operations traded in the overnight market em relation to EONIA.

As the cross-border market is of particular interest, I also compare the spreads of weighted average interest rates of operations with Portuguese borrowers to those with a Portuguese lender. Both interest rates follow very

similar paths until 2008. Afterwards operations with a Portuguese lender have, on average, higher interest rates. The exception is the period from 2010 to mid-2011 in which transactions with a Portuguese borrower are on average more expensive[21].

Looking at the one-week maturity market, its developments are very similar to the ones in the overnight market. Again, identified interest rates for the domestic and cross-border markets follow one-week EURIBOR closely, especially for the period prior to the crisis. In this case I find that the dispersion of interest rates for the financial crisis period to be higher than in the previous case. For the one-week maturity market spreads in the domestic market for the period right after the Lehman Brothers' collapse are smaller than for the overnight case. In addition, in this market, on average, interest rates for both domestic and cross-border transactions are closer by the end of the sample. The period when the turnover in the one-week maturity period increases is roughly the same when interest rates in the domestic market are below EURIBOR, meaning that the increased turnover may have been a result of cheaper one week loans. Therefore we can say that:

Result 8: *Interest rates of overnight and one-week maturity operations increased above the benchmark after the Lehman Brothers' bankruptcy for both the domestic and cross-border markets.*

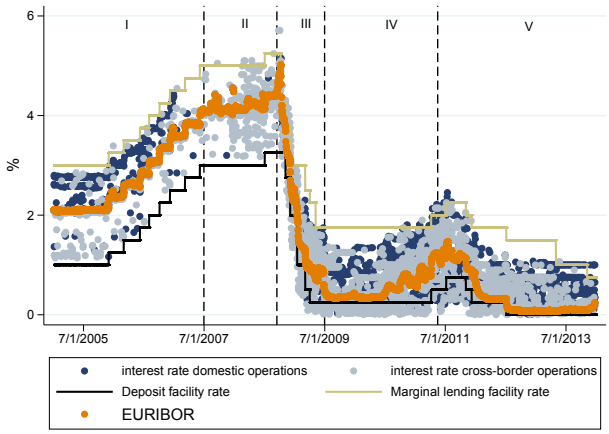


FIGURE 7: Policy and money market interest rates in the one-week maturity market.

After inspecting the developments in terms of interest rates I take a step further in trying to understand what happened in the unsecured

21. Check Figure A.1 in the appendix which shows the spread between the implicit interest rate of cross-border transactions with a Portuguese lender and the implicit interest rate of cross-border transactions with a Portuguese borrower.

interbank market. From 2005 until the financial collapse interest rates in both domestic and cross-border markets are really close to each other and close to EONIA/EURIBOR. As the euro market is a financially integrated market, it seems reasonable to assume that during this period it was acting as a single free market. However, the departure from EONIA/EURIBOR - in line with the decrease in the number and turnover of transactions - shows that markets were disrupted and uncertainty in counterparties increased as interest rates became higher than benchmarks. The divergence between domestic and cross-border rates, as well as the divergence among cross-border interest rates, indicates that the once single market may have become segmented into three different markets, since otherwise interest rates would have remained close because of arbitrage. These three markets can be classified as the domestic market, the cross-border market with Portuguese lenders, and the cross-border with Portuguese borrower. If we think of each market as a having a typical demand and supply function of liquidity, the increase in prices and decrease in quantities is explained by a contraction of the supply. In the first and second cases Portuguese banks largely had liquidity shortages and banks with excess liquidity might have chosen to deposit it in the ECB's overnight deposit, contracting the supply of liquidity in both markets. In the last case, foreign banks did not rely on Portuguese banks, reducing the amount of liquidity available to them in the market[22].

The market with the highest price is the domestic one. Assuming banks could decide in which market to trade, why would Portuguese banks keep borrowing in the more expensive domestic market? One answer can be explained in part by the uncertainty foreign banks had about Portuguese banks, meaning that in fact these banks would probably like to move to the cross-border market but were not finding supply there.

On the other hand, why would Portuguese banks lend in the cross-border market if they could so at a higher price in the domestic market? Considering that prices are signaling counterparty risk, this means some banks were not willing to take higher risk not even at higher prices. Furthermore, liquid banks may be using the extra liquidity provided by the ECB to earn some interest in safe bets, asking for lower interest rates to foreign counterparties. Looking at the problem from another, yet complementary, perspective, asymmetric information in the market can be responsible for an inaccurate perception of risks. Domestic banks have more information about one another due to proximity and longer relationships, and so they are more aware of each others' risk. On the other hand, information on foreign counterparties is coarse, and it may be that Portuguese banks perceive foreign banks as less risky, justifying price differences. Last but not least, the presence of Portuguese banks' lending

22. It is also reasonable to assume some increase in the demand for liquidity, but these should not be enough to offset the contraction of supply.

in the cross-border market can be a sign of adverse selection in which the banks able to raise funds in the international market are also the most reliable ones.

## 6. Robustness

The reliability of the results presented in the previous section depends on the precision of the algorithm in identifying overnight and one-week maturity interbank loans. The only way to validate my algorithm is by matching the identified interbank loans with information on transaction-level data of the payments that actually took place in the interbank money market. However, that information does not exist, and consequentially, I am not able to perform a validation test to my algorithm.

Nevertheless, some authors have performed validation tests on Furfine-based algorithms for parts of the euro money market. Arciero *et al.* (2014) used the Italian MID platform and de Frutos *et al.* (2013) the Spanish MID platform. Both concluded that up to three-month maturities the algorithm is very reliable for identifying TARGET2 interbank loans. Moreover, the final MaRs Report also supports the accuracy of the algorithm for the euro area. Therefore, it is safe to argue that my results present a good picture of the activity in the Portuguese part of the euro unsecured interbank money market.

## 7. Conclusions

In this thesis I developed an algorithm that identifies unsecured interbank money market loans that go through TARGET and in which at least one of the counterparties is a bank registered in Portugal. My algorithm is an extension of the one set up by Furfine (1999) and Demiralp *et al.* (2006), and a particular case of the ones built up by Heijmans *et al.* (2011) and Arciero *et al.* (2014), as it is design to capture overnight and one-week maturity contracts in the Portuguese part of the money market. The construction of the algorithm may generate some errors, namely type 1 and type 2 errors, and it fails to identify rollovers or interest only payments. However, based on validation tests performed by other authors for parts of the euro market to which they have information on the real transactions, it seems reasonable to assume the algorithm provides a reliable dataset of the microstructure of the Portuguese interbank money market. In addition, the algorithm limitations do not affect the type of analysis I executed.

The results show that there was a significant reduction in the overnight unsecured interbank money market, not only in absolute terms but also comparing with the activity in the longer maturity market: after the Portuguese request for financial assistance, overnight turnover decreased by 64% from before the turmoil. Moreover, data also shows a clear segmentation between the

domestic and cross-border market. After 2009 foreign banks stopped trading with Portugal due to the perceived higher risk of Portuguese banks. The exceptions were Germany, Great Britain, France and Spain on the borrowing side, and mainly Spain and Greece on the lending side. During the core period of the crisis British banks also lent to Portuguese banks and there is also an increase in the relative importance of Portuguese lenders in the market during this period, which possibly only represents the reduced borrowing opportunities in the domestic market.

The algorithm provides some information on interest rates. I conclude that prices charged in the domestic and in the cross-border market had converged before the financial collapse, implying that the Portuguese part of the unsecured interbank money market was integrated in the overall euro money market. Afterwards, prices increased in both markets and for both maturities, indicating some market segmentation. Finally, interest rates in the domestic market are higher than interest rates for markets with Portuguese lenders and markets with Portuguese borrowers, likely due to adverse selection phenomena, as the Portuguese banks that were able to lend abroad are the most reliable ones.

Having such an algorithm may prove useful for monitoring the Portuguese interbank money market. Interbank loans are registered in RTGS systems and their nature is not specified. Having an approximation of the activity in the interbank market facilitates and may help reduce the risk that local failures threaten the stability of financial institutions, markets, and ultimately the transmission channel for monetary policy.

The algorithm may also have other uses, opening a wide range of further research. First, combining the algorithm's payment data with bank-level information would allow us to study the effect unconventional monetary policy measures had on interbank markets. Understanding how the market responded to these impulses during stress times may improve monetary policy's design towards a more efficient mechanism. Another application could come from combining this data with bank-level accounting information which would allow us to study how bank-specific characteristics affect transactions, namely how different sized banks respond to interbank market changes during a crisis. Additionally by applying network theory to this algorithm, it will be possible to analyze the interconnectedness in the interbank market and the channels through which systemic risk propagates. Finally, there is still room for improving the algorithm, constantly adapting it to money market developments.

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## Appendix: Additional Figures

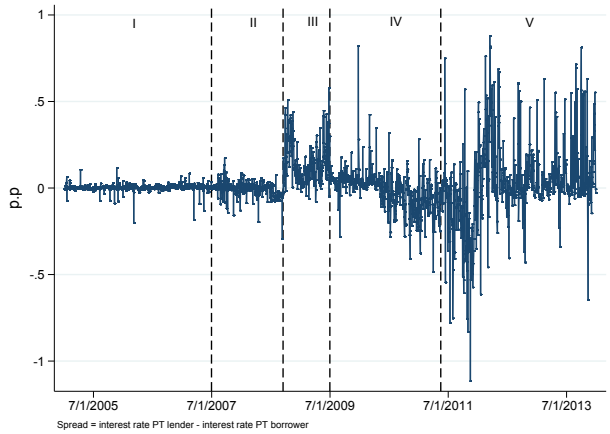


FIGURE A.1: Spread in the overnight cross-border market.

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