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Interbank Linkages and Contagion Risk in the Portuguese Banking System

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Abstract

Interbank money markets play a fundamental role in financial systems, since they allow for the redistribution of liquidity between financial institutions. However, they can also be a channel through which problems in one institution can spread to the remaining ones. In particular, the potential for contagion stemming from interbank money markets is closely related with the pattern of interbank lending relationships. In this study, we characterize the Portuguese overnight interbank money market between 1999 and 2009 and analyze its inherent potential for contagion, based on bilateral interbank exposures obtained from the application of Furfine's procedure to settlement data from the Portuguese TARGET component. We conclude that: *(i)* the Portuguese overnight interbank money market is ruled out by a multiple money center structure, where some banks have, simultaneously, an important role as lenders as well as borrowers; *(ii)* although unlikely, the failure of one institution can have contagion effects, pushing others into failure. However, even under the most extreme assumptions, institutions that fail by contagion represent less than 10 per cent of the total banking system assets. On the other hand, even if there are no defaults due to contagion, a foreign bank failure can have non-negligible knock-on effects under national banks. Yet, overnight interbank lending relationships do not generally represent a major threat to the stability of the Portuguese financial system.

Keywords: Money market, Interbank lending, Overnight, Financial contagion, Market structure.
JEL Classification: G15, G21, G33.

Ligações Interbancárias e Risco de Contágio no Sistema Bancário Português

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Provas concluídas em:

Resumo

O mercado monetário interbancário desempenha um papel fundamental no sistema financeiro, permitindo a redistribuição de liquidez entre as instituições financeiras. Porém, pode representar igualmente um canal para a propagação de problemas entre instituições. Em particular, o potencial de contágio existente no mercado interbancário está intimamente relacionado com a estrutura das relações estabelecidas através dos empréstimos interbancários. O presente estudo caracteriza o mercado monetário interbancário *overnight* português, entre 1999 e 2009, e analisa o potencial de contágio inerente ao mesmo, com base nas exposições interbancárias bilaterais obtidas através da aplicação do procedimento de Furfine aos dados sobre as transacções liquidadas na componente portuguesa do TARGET. É possível concluir que: *(i)* o mercado monetário interbancário *overnight* português assenta numa estrutura do tipo "*multiple money center*", sendo que alguns bancos desempenham um papel fundamental quer como financiadores, quer como mutuários; *(ii)* apesar de improvável, a falência de uma das instituições participantes no mercado pode ter efeitos de contágio, conduzindo à falência de outras instituições. No entanto, mesmo com pressupostos extremos, as instituições que poderiam falir por contágio representam menos de 10 por cento do activo total do sistema bancário. Por outro lado, mesmo não ocorrendo falências por contágio, a falência de um banco estrangeiro pode ter efeitos não negligenciáveis sobre os bancos nacionais. Não obstante, de uma forma geral, os empréstimos interbancários *overnight* não representam uma ameaça significativa à estabilidade do sistema financeiro português.

Palavras-Chave: Mercado Monetário, Empréstimos interbancários, *Overnight*, Contágio financeiro, Estrutura de mercado.

Classificação JEL: G15, G21, G33.

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1 Introduction

Interbank money markets play a fundamental role in financial systems, allowing financial institutions to cope with their day-to-day cash imbalances, by borrowing and lending central bank money among themselves. But, despite its crucial role in the redistribution of liquidity from those institutions with liquidity surpluses to those who need it, interbank lending relationships are not just a way to mitigate liquidity risk. They can also be a contagion channel through which financial problems in one institution (a bank) can spread to the remaining ones. Thus, interbank lending relationships might increase the risk of contagion, i.e., the risk that one financial institution's inability to meet its required obligations will unable others to meet their own obligations when due, causing significant liquidity or credit problems. Ultimately, contagion risk can be seen as a form of systemic risk as, in case of contagion, financial instability can become so widespread that it may impair the functioning of the financial system to the point where economic growth and welfare might suffer significantly (European Central Bank, 2009a). That is why one of the prime concerns of contemporary monetary authorities is to increase system resilience to contagion risk, since it can endanger financial stability.

This dual role of the interbank money market has been especially emphasized by the subprime crisis that started in 2007. Given the resulting context of uncertainty, and having asymmetric information about the solvency of their money market counterparties, banks stopped lending to each other, thus causing the market to become dysfunctional. As a consequence, banks highly exposed to subprime mortgages or heavily dependent on the money market funding had to be intervened by national authorities and saved from default (Cassola et al., 2008). Such was the case of the British Northern Rock and Bradford and Bingley, the Spanish Caja Castilla la Mancha, the Danish Roskilde Bank and the German IKB Deutsche Industriebank, Sachsen Landesbank and Depfa Bank, just to mention a few examples.

These public rescues of distressed institutions are normally justified as an attempt to contain contagion risk and ensure financial stability, thus avoiding a wide systemic crisis. Nevertheless, even if, for some, this justification is enough, for others, the prevention of contagion risk may not worth the financial costs and the moral hazard involved in public bailouts. In fact, this was the perspective underlying the refusal of the Lehman Brothers bail out and its consequent bankruptcy in September 2008.

Therefore, before deciding to rescue, or not, distressed institutions, national authorities should carefully balance the costs and benefits imposed by those rescues, including the potential knock-on effects that a bank's default can have on the financial health of its peers, either indirectly, via the fire-sale of assets and the emergence of credibility issues, or directly, via direct exposures arising from payment systems or from the interbank money market.

In this context, any additional knowledge about the way financial systems work, particularly about the different channels and potential effects of contagion, can be of utmost usefulness when financial instability emerges, as it happened in 2007. Following this line of reasoning, the aim of the present study is to analyze the potential for contagion stemming from a very specific source: the overnight lending relationships established in the Portuguese interbank money market. Thus, we extend the existing literature on financial contagion on the interbank money market to the Portuguese case.

In order to achieve our aim, we start by identifying overnight interbank loans based on TARGET (Trans-European Automated Real-Time Gross Settlement Express Transfer System) data for the period between 1999 and 2009. This enables us, first, to characterize and analyze the evolution of the market during this period and, afterwards, to perform a simulation analysis based on the bilateral exposures computed, in an attempt to measure the inherent potential for contagion in the market.

We conclude that the Portuguese overnight interbank money market is characterized by a high exposure to cross-border counterparties and by a multiple money center structure, where some banks play simultaneously a important role as lenders as well as borrowers. As regards contagion, although unlikely, the failure of one institution can have adverse knock-on effects, pushing others into failure. However, even under the most extreme assumptions, institutions that fail by contagion represent less than 10 per cent of the total banking system assets. On the other hand, even if there are no defaults by contagion, a foreign bank's failure can have non-negligible knock-on effects on national banks. Yet, overnight interbank lending relationships do not generally represent a major threat to the stability of the Portuguese financial system.

The remainder of the study is organized as follows. Next section reviews the theoretical and empirical literature on financial contagion, especially within interbank money markets. The third section presents a brief characterization of the Portuguese overnight interbank market and, the fourth, consists of an empirical assessment of contagion risk in this market. Last section summarizes the main findings.

2 Financial contagion in the interbank market

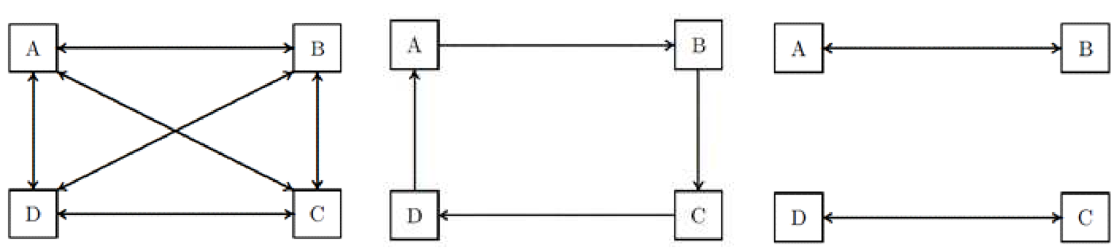
2.1 Theoretical foundation

Despite the important role of the overnight interbank money market in the daily funding activity of banks, theoretical literature on this subject, in particular on the potential for contagion stemming from this market, is not very extensive. There is, however, general agreement on the fact that contagion risk in the interbank money market depends on the pattern of interbank linkages, i.e., on the interbank market structure. Allen and Gale (2000) provide the theoretical foundation for this thesis and argue that complete structures, where all banks are symmetrically linked with each other, are more robust to contagion than incomplete structures, where banks are linked only to a small number of counterparties.

According to the authors, complete markets (as exemplified in Figure 1a) can provide a higher level of insurance against contagion. Indeed, if each institution holds deposits in all the others and if the market is sufficiently large, the impact of the failure of one of them to meet its obligations may be attenuated, as it is absorbed by a higher number of institutions and, therefore, each bears a small share of the shock. On the other hand, in incomplete markets, each institution has a small number of counterparties and, consequently, in case of failure, the impact is felt more strongly by each one.

As regards incomplete markets, the extent of contagion depends on the market interconnectedness, which can be seen as the length of credit chains. In an incomplete market with a high degree of interconnectedness, each bank is linked to the one immediately adjacent: bank A holds deposits in bank B, bank B holds deposits in bank C and so on (see Figure 1b). In an incomplete market with a low degree of interconnectedness, there are disconnected market segments, although internally connected: bank A holds deposits in bank B and bank B holds deposits in bank A, bank C holds deposits in bank D and bank D holds deposits in bank C. However, neither bank A nor bank B holds deposits in, or have claims from, bank C or D. It is a disconnected incomplete market structure, as illustrated in Figure 1c.

Figure 1: Interbank market structures



a) Complete market stucture

b) Interconnected incomplete market structure

c) Disconnected incomplete market structure

Source: Allen and Gale (2000)

While in an incomplete but highly interconnected structure a liquidity shock can spread by contagion to others because all banks are financially linked, directly or indirectly, in a disconnected structure the extent of contagion is reduced, since a bank's default effects are confined to its segment of the market. Thus, contagion can be more limited in an incomplete and disconnected structure than in an incomplete and interconnected structure.

Another seminal work on the influence of the market structure on the risk of contagion is the one by Freixas et al. (2000). Like Allen and Gale (2000), the authors also argue that complete structures enhance the system's resilience to withstand shocks, whereas incomplete ones increase system fragility. Additionally, they introduce a special kind of incomplete market structure, a money center structure, where smaller institutions are linked to a central institution, the money center, but not among them. In this case, although the problems of institutions in the periphery would hardly have significant adverse spillover effects, the money center default can have negative knock-on effects on "peripheral" institutions, thus increasing the risk of contagion.

More recently, some researchers have questioned this widely accepted thesis that complete markets are more resilient to contagion than incomplete ones. Following this strand, Brusco and Castiglionesi (2007) advocate that to overcome a certain need of liquidity and assuming no agency problems, in a completely connected market each bank has to exchange a smaller amount of deposits with its (further) counterparties than in an incompletely connected market. However, although this results in a higher diversification of risk and lower exposures, a bank's failure effects also spread to more counterparties. Therefore, even if in a complete market structure the losses of a creditor bank are lower, in an incomplete one, the number of counterparties affected by contagion is minor. Thus, a completely connected structure can be more conducive to contagion than a connected but incomplete one, although the costs of contagion can be higher on the latter than on the former.

Gai and Kapadia (2010) also highlight that complete markets, which by definition are connected, exhibit a "robust-yet-fragile" tendency as, while the likelihood of contagion can be smaller in this kind of markets, if it occurs, it will spread through the system more easily and reach more institutions. Indeed, in highly connected systems, the losses imposed by an institution's failure can be more dispersed and, hence, absorbed by a wider set of institutions, thus lowering the probability of contagious defaults. Nonetheless, if an institution fails, more institutions are exposed to contagion since there are also more financial linkages. Therefore, the chances that an institution affected by the initial failure is also exposed to other defaulting counterparties increase. Thus, even if the exposed institution survives to the initial failure, additional exposures can increase its vulnerability.

Nier et al. (2007) also attempted to summarize the relationship between the connectivity of financial systems and the potential for contagion. They argue that, depending on its pattern, interbank linkages may either act as "shock absorbers" or as "shock transmitters". While the first effect dominates when connectivity is sufficiently high, with low levels of connectivity the "shock transmitter" effect prevails. I.e., with low levels of connectivity, a connectivity increase amplifies the shock transmission effect and, as a consequence, reduces system resilience; on the contrary, when connectivity is sufficiently high, an additional increase enhances the system's resilience, since the shock spreads to more and more banks. Hence, connectivity affects the risk of contagion in a non-monotic way: in less connected systems, a slight increase in connectivity increases the contagion effect but, after a certain threshold, it improves the system's ability to withstand shocks. Yet, these conclusions just hold true for well-capitalized systems since, in undercapitalized ones, interbank linkages only act as shock transmitters, because, in the absence of capital, there is no absorption effect. Especially in highly connected systems, the better capitalized the system, the better the shock absorber effect. In contrast, the more under-capitalized the system, the more amplified the shock transmission effect.

Therefore, one should keep in mind that a system's resilience to contagion does not depend solely on the pattern of interbank linkages, but also on other aspects, such as the size of interbank exposures, the market concentration and the capitalization level of institutions. As expected, higher interbank liabilities tend to increase the risk of knock-on defaults. Similarly, as, in more concentrated systems, each bank tends to become bigger, a failure might also have a more significant impact on the remaining banks than in more decentralized systems. Conversely, adequate capital buffers tend to decrease contagion, since better capitalized banks have a higher capacity to withstand contagious defaults (Nier et al., 2007). Macroeconomic shocks leading to an erosion of banks' capital buffers can thus turn the system particularly susceptible to contagion (Gai and Kapadia, 2010).

In addition, Sachs (2010) advocates that, despite the influence of market completeness and interconnectedness, interbank contagion also depends on the distribution of interbank exposures. She argues that, in complete (and thus highly connected) structures, the more equally banks spread their claims, the better the shock stemming from a given bank's failure is absorbed. Therefore, high connectivity and an equal distribution of interbank claims amplify the shock absorption effect, due to the higher credit risk diversification verified. In incomplete markets, as the number of counterparties is lower, given a bank's failure and an equal distribution of claims among the reduced number of counterparties, the average amount of losses imposed to each one is higher. As a consequence, the probability that all will be affected by contagion increases. Conversely, if there is a more unequal distribution of claims among those few counterparties, the probability that not all will suffer knock-on effects increases.

To sum up, according to Sachs (2010), complete structures with an equal distribution of claims are the most stable ones. With lower completeness but high interconnectedness, the correlation between an equal distribution of claims and contagion weakens. Disconnected incomplete structures are more stable with an unequal distribution of claims. Therefore, in the presence of an unequal distribution of claims, a complete market structure can be more prone to contagion than an incomplete one.

All in all, we can state that, although it can depend on other factors, the completeness and interconnectedness of each market structure plays a key role in the determination of its inherent potential for contagion. In particular, it seems that completeness is especially important to determine the likelihood of contagion, whereas interconnectedness determines the extent of contagion. There appears to be a negative relation between completeness and contagion risk since, with higher levels of completeness, the diversification of interbank credit risk is also higher and, consequently, the contagion risk is smaller. On the other hand, the extent of contagion seems to vary positively with interconnectedness since, if contagion occurs, the shocks may spread more easily in highly connected systems than in disconnected ones, where it can remain confined to a single segment of the system.

Yet, it is not clear which effects are higher: the diversification effects stemming from market completeness, which decrease the contagion risk, or the increase of contagion due to higher connectedness. Therefore, it is not possible to deduce the potential for contagion in a specific market solely based on theoretical premises. This highlights the importance of empirically analyzing the potential for contagion in each market, as we do in the present study.

2.2 Empirical foundation

Empirically, contagion risk in the interbank market has been widely analyzed. Sheldon and Maurer (1998) and Müller (2006a, 2006b) studied the contagion risk in the Swiss interbank market, and Furfine (2003), in the federal funds interbank market. Blavarg and Nimander (2002), Upper and Worms (2004), Wells (2004), Amundsen and Arnt (2005) and Lublóy (2005) assessed the potential for contagion in the Swedish, German, British, Danish and Hungarian interbank markets, respectively. The contagion risk in the Dutch, Austrian, Belgian and Italian markets was studied by van Lelyveld and Liedorp (2006), Elsinger et al. (2006), Degryse and Nguyen (2007) and Mistrulli (2005, 2007), respectively. More recently, Toivanen (2009) analyzed the Finnish interbank market and Krznar (2009), the Croatian one.

In general, these empirical analyses were based on a two-steps approach: the first step consists in determining the matrix of bilateral interbank exposures; the second one is the assessment of the potential for contagion, based on scenarios where it is simulated the default of each participant in the market, one at the time. These steps are described in the next two subsections.

2.2.1 Determining bilateral interbank exposures

The interbank market structure can be represented by a $N \times N$ matrix of bilateral exposures (as exemplified in Figure 2), where x_{ij} is the exposure of bank i towards bank j, i.e. the liabilities of bank j towards bank i, and N is the total number of banks. Each bank's total assets (bank lending) and liabilities (bank borrowing) is represented by a_i and l_j, respectively.

Figure 2: Matrix of bilateral interbank exposures

$$
\begin{array}{cc}
 & \begin{array}{ccccc} & & & & \end{array} \quad \sum_i \\
X = & \left[\begin{array}{ccccc}
0 & \cdots & x_{1j} & \cdots & x_{1N} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
x_{i1} & \cdots & 0 & \cdots & x_{iN} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
x_{N1} & \cdots & x_{Nj} & \cdots & 0
\end{array}\right]
\begin{array}{c} a_1 \\ \vdots \\ a_i \\ \vdots \\ a_N \end{array} \\
\sum_j & \begin{array}{ccccc} l_1 & \cdots & l_j & \cdots & l_N \end{array}
\end{array}
$$

With the exception of Mistrulli (2005, 2007), generally, data about all interbank bilateral exposures is not available. So, the first question has to be: how to determine the matrix of bilateral exposures?

We found that the methodology adopted by the different authors largely depends on the data available. For instance, Furfine (2003) computed the matrix of bilateral exposures based on overnight loans identified from the transactions of the Federal Reserve's large-value transfer system (Fedwire). Amundsen and Arnt (2005) also used the same methodology. They computed the matrix of bilateral exposures based on the information about overnight interbank loans extracted from Denmark's gross settlement system data.

However, normally settlement data is not available due to confidentiality issues. Therefore, most part of the empirical literature on contagion risk mentioned before relies on balance sheet data. This approach allows authors to cover all exposures arising from interbank lending and not just overnight ones. Nevertheless, balance sheet data only provides aggregate information about each bank's interbank assets and liabilities. Thus, authors have to estimate each element of the matrix of bilateral exposures through the maximum entropy method.

The maximum entropy method allows to estimate the bilateral exposures based on the sum of each bank's interbank claims and liabilities and on assumptions regarding how banks spread their interbank lending among their counterparties. In the absence of additional information regarding the pattern of interbank lending relationships, authors normally assume that banks spread their interbank lending equally among counterparties, maximizing the dispersion of their interbank exposures. This is equivalent to assume a complete market structure, where banks symmetrically hold claims on each other, conditional on their size (Upper and Worms, 2004).

However, it is not realistic to assume that interbank activities are completely diversified. Indeed, due to transaction and information costs, institutions may not lend to all the other institutions but just to a small number. For instance, just to the banks in the same geographical area, i.e., just to "neighboring banks" (Allen and Gale, 2000). Cocco et al. (2009) confirm that interbank lending relationships are an important feature of interbank markets and, therefore, it is not correct to rule it out. Moreover, as to apply the maximum entropy method, authors have to make assumptions regarding the interbank lending pattern, which might not correspond exactly to the actual interbank lending pattern of the market, this approach makes it difficult to assess the effect of market structure on the potential for contagion.

To circumvent the above mentioned drawbacks of the maximum entropy method, whenever possible, authors complement balance sheet data with additional information about interbank linkages reflected in large exposures or survey data. Such was the case of Wells (2004), Upper and Worms (2004), Degryse and Nguyen (2007), van Lelyveld and Liedorp (2006) and Toivanen (2009). This information can be used as proxy to determine the interbank market structure and leads to conclusions significantly different about the contagion risk in each market.

Indeed, by comparing the results obtained using the maximum entropy method based only on balance sheet data and those obtained using also additional information about interbank linkages, van Lelyveld and Liedorp (2006) showed that the first approach underestimates contagion effects, namely the number of failed banks and the percentage of total assets lost, and concluded that it is not appropriate to estimate bilateral exposures in concentrated markets such as the Dutch one. Upper and Worms (2004) have also come to the same conclusion: the maximizing entropy method applied only to balance sheet data leads to an underestimation of the contagion effects when compared with those obtained using additional information available on the actual pattern of interbank linkages.

On the other hand, by comparing the extent of financial contagion measured using data on actual bilateral exposures and the one measured based on the maximum entropy method applied to balance sheet data, Mistrulli (2007) found that, in the Italian case, the maximum entropy method overestimates the scope of contagion. Elsinger et al. (2006) also reached similar conclusions. Indeed, by computing one interbank lending matrix using only balance sheet data and another one incorporating additional information on the interbank linkages (thus representing a complete and a more incomplete market structure, respectively), the authors found that contagion increases when there is a greater diversification of interbank lending, i.e. when the market is complete.

Therefore, the maximum entropy method is not the most adequate to estimate the matrix of bilateral exposures, as it tends to bias the extent of contagion. According to Mistrulli (2007), this bias can either be negative or positive, depending on the actual interbank linkage structure, the recovery rate and banks' capitalization.

All in all, we can conclude that the choice of methodology to determine the bilateral exposures represents a trade-off between the interbank exposures that each kind of data allows to cover and the information provided on the interbank linkage structure. If, on the one hand, applying the maximum entropy method may bias the potential for contagion, on the other, using settlement data allows the identification of contagion risk stemming solely from a specific segment of interbank exposures.

In our case, given the availability of a unique dataset – the data on the transactions settled in the Portuguese large-value payment system – , we will also compute the matrix of bilateral exposures based on settlement data, following Furfine's approach, as described in section 4.1. In addition, this approach allows us to infer the actual pattern of lending relationships, which would be ruled out by the application of the maximum entropy method.

2.2.2 Assessing the potential for contagion

To analyze contagion risk, after estimating the matrix of bilateral exposures, it is necessary to assess the effect that an institution's failure may have on the entire system. With that purpose in mind, authors tend to simulate the sudden and unexpected insolvency of each institution in the system due to an idiosyncratic shock, and verify the (direct or indirect) effect of that failure on the remaining institutions. This approach raises two questions. First, when is an institution considered insolvent? Second, which is the loss rate that creditor banks have to support in case of a counterparty's default?

Regarding the first question, and based on the idea that the primary function of capital is to absorb losses that otherwise would have to be borne by creditors (Kaufman, 1994), an institution is considered insolvent (i.e., it fails) when its losses exceed a specific capital threshold. For instance, Müller (2006a, 2006b) considers as threshold the regulatory capital holdings. Blavarg and Nimander (2002) consider that a bank fails if its Tier 1 capital ratio falls below the statutory level of 4 per cent. Degryse and Nguyen (2007), Mistrulli (2007), Wells (2004), van Lelyveld and Liedorp (2006) and Krznar (2009) consider that a bank fails if losses are higher than its Tier 1 capital. Sheldon and Maurer (1998) assume that a bank is insolvent if the return on assets falls below a default threshold defined by the ratio of overheads[1] to total assets and

[1] Taxes plus expenses on personnel, materials and office space.

by the capital-to-assets ratio. For Toivanen (2009) and Amundsen and Arnt (2005), a bank fails if its solvency ratio falls below 8 per cent. In the present study, following Upper and Worms (2004), and given the availability of data, we consider that a bank is insolvent if losses exceed its capital.

As far as the second question is concerned, that is the loss rate imposed by an institution's default, i.e., the share of assets that are not recovered by creditor banks, James (1991) reported that, in the United States, in the mid-1980's, the average loss was 30 per cent of the assets of the failed bank, without taking into consideration administrative and legal costs. On the other hand, Upper and Worms (2004) pointed out the failure of Herstatt, defaulted in 1974. Its creditor banks have already recovered 72 per cent of their assets, and the process is still going on. They also referred to the case of Bank of Credit and Commerce International (BCCI). It failed in early 1990's and, although creditors were expecting losses up to 90 per cent, they ended by recovering more than half of their deposits (though many years later).

These examples show that, even if creditors are able to recover some of their assets, it can be a very uncertain and cumbersome process that might cause serious problems to banks' financial health. In fact, as Wells (2004, p. 15) remarked, "*an affected bank with much of its capital at risk may be unable to operate on the expectation of recoveries that are uncertain*". In addition, "*it may not be the actual losses borne by the creditor banks that matter, but the expected losses at the moment of failure which determine to which extent the exposure to the failing bank has to be written down and hence whether the creditor bank becomes technically insolvent or not*" (Upper and Worms, 2004, p. 839).

Given the uncertainties about the loss rate, most authors assess the losses imposed by a hypothetical process of contagion using different values for this parameter. Such was the case of Upper and Worms (2004), Degryse and Nguyen (2007), Mistrulli (2007), Blavarg and Nimander (2002), Wells (2004) and Toivanen (2009). Indeed, it seems more reliable to measure the contagion risk using different loss rates rather than an average or a well-defined value for this parameter, since estimated rates can introduce even more arbitrary parameters in simulations than assuming fixed rates (Mistrulli, 2007; Upper and Worms, 2004). Besides, the share of assets recovered can be influenced by several factors such as the availability of collateral or the hypothesis of bailouts. Therefore, we also use different loss rates to simulate the contagion process (as explained in subsection 4.2).

2.2.3 Some empirical results

Despite the weaknesses of the methodologies adopted to estimate the matrix of bilateral exposures and the assumptions behind the measurement of contagion risk, it is possible to draw some conclusions about the inherent contagion risk in each market and, in some cases, about the importance of the pattern of interbank linkages as a determinant of the potential contagion effects.

As regards the first issue, that is the inherent contagion risk in each market, although contagion may occur in general, its impact on the banking system differs from market to market. Thus, while in some markets financial contagion is not considered a major threat to the banking system's stability, in others, like the German and the Swiss ones, financial contagion should indeed be a primordial concern for monetary authorities.

In fact, Upper and Worms (2004), after investigating the contagion risk in the German interbank market, concluded that a bank insolvency has almost always knock-on effects, mainly on small banks. Although those knock-on effects typically account for less than 1 per cent of total banking system assets, it might occur large scale contagion if the loss rate is above 40 per cent. For instance, with a loss rate of 75 per cent and in the worst-case scenario[2], a single bank failure can cause the bankruptcy of institutions representing 76 per cent of the total banking system assets.

Müller (2006a) also found that there is some potential for contagion in the Swiss interbank market since a default situation can trigger the insolvency of 9 per cent of the Swiss banks, accounting for 3 per cent of the total banking system assets. Additionally, 30 per cent of the banks (representing 89 per cent of total assets) became illiquid, i.e. are not able to repay the full amount of their liabilities. It should be noted that Sheldon and Maurer (1998) have also analyzed the Swiss interbank market but reached different results. According to the authors, although the likelihood of a bank's failure in each year is quite high, contagion effects are small, i.e., the probability of failure propagation via interbank lending relationships is quite low. However, Sheldon and Maurer (1998) relied on the application of the maximum entropy method to balance sheet data. Therefore, they have presumed a complete structure, which probably does not represent the actual pattern of interbank linkages in the interbank market. Besides, they analyzed the Swiss interbank market for short-term loans (up to 3 months) in the period between 1987 and 1995, whereas Müller's analysis was applied to data on bilateral interbank claims and liabilities for December 2003.

In the Finnish interbank market, analyzed by Toivanen (2009), although contagion is considered a low probability event, it may occur in a large scale, since half of the institutions in the banking system are contagious banks, i.e., their failure can push others into failure. The extent of contagion depends on the bank that is the starting point of the contagion process. Yet, for a loss rate of 100 per cent, at least three Finnish banks can trigger losses above 80 per cent of total banking assets.

In the British interbank market, in the worst-case scenario with a 100 per cent loss rate, knock-on effects can trigger the failure of banks representing more than one

[2] The worst-case scenario is the one where, for a given loss rate, the highest share of banking assets is affected.

quarter of the banking system assets. Even if banks do not fail, a single bank insolvency can lead banks accounting for over half of the banking system assets to suffer losses exceeding 10 per cent of their Tier 1 capital. Nonetheless, contagious bank failures are rare and, with loss rates below 50 per cent, less than 1 per cent of total banking system assets is affected by contagion (Wells, 2004).

In the remaining banking systems analyzed, although financial contagion due to exposures in the interbank money market may also occur, it does not seem to represent such a threat. For instance, Furfine (2003) found that, with a loss rate of 40 per cent, even the failure of the bank with the major share of borrowing funds affects just a small number of institutions of reduced dimension, accounting for less than 1 per cent of the total assets held by the US banking system.

Mistrulli (2007) also concluded that the extent of contagion in the Italian banking system is quite limited, depending if the bank that fails first is contagious or not. However, just a small number of banks (and not necessarily the large ones) are contagious. Actually, with a loss rate of 100 per cent, the majority of banks (accounting for around 60 per cent of the total banking system assets) are contagion-proof banks, i.e., they never fail no matter the bank that fails first. Thus, it is not surprising that even in the worst-case scenario with a 100 per cent loss rate, just 16 per cent of the banking system total assets are affected by contagion.

Elsinger et al. (2006) also found that the Austrian banking system is very stable and default events are unlikely. The median default probability of an Austrian bank is below 1 per cent and the vast majority of defaults are due to macroeconomic shocks instead of interbank contagion.

In the Belgian interbank market, analyzed by Degryse and Nguyen (2007), even with a 100 per cent loss rate, from the 65 domestic banks in the system, only four large banks are contagious and none of them are able to trigger the failure of another large domestic bank. Actually, even in the worst-case scenario, the banks that lose their Tier 1 capital never account for more than 3.8 per cent of the system total assets. On the other hand, the default of some large foreign banks can trigger significant domino effects by causing the failure of 7 domestic banks, accounting for 20 per cent of the system total assets. Thus, the increase in cross-border exposures lowers the risk of contagion stemming from domestic banks but increases the risk deriving from foreign ones. The same holds true for the Dutch interbank market. As noted by van Lelyveld and Liedorp (2006), although the bankruptcy of a large bank can have a sizable impact, it will not lead to the collapse of the domestic interbank market. Indeed, since large banks are especially linked to foreign ones, a large bank failure is mainly absorbed by the latter, hence reducing the effect on domestic banks. This is hardly surprising as, given the asymmetric information involved in interbank market transactions, large banks, with better information than smaller ones, transact easily with other large banks, while the smaller ones tend to transact just domestically (Gropp et al., 2006).

The results of the contagion simulations mentioned above for the Belgian and the Dutch interbank markets exemplify well the increasing importance of cross-border interbank exposures in almost all markets. It also shows the increase in the risk of cross-border contagion in the European Union as a consequence of the growing financial integration and internationalization of interbank linkages, especially after the entry into stage three of Economic and Monetary Union (EMU) and the emergence of an integrated money market, from which only countries with low cross-border interbank exposures, like Finland, remain insulated (Gropp et al., 2006).

As regards the second question, that is the importance of the pattern of interbank linkages as a determinant of the extent of contagion, conclusions are also not completely consensual.

Upper and Worms (2004) and van Lelyveld and Liedorp (2006), after analyzing the

German and the Dutch interbank markets, respectively, found that the likelihood of contagion is smaller in a complete market than in a more concentrated one. Furthermore, Upper and Worms (2004) found that the German interbank market is characterized by a two-tier structure: an upper tier with a pattern of interbank linkages closer to a complete structure, where institutions establish lending relationships with a variety of other banks belonging to the same tier, and a lower tier, with a money center structure, composed of banks with few direct linkages, except for those with their head institution in the upper tier[3]. They concluded that the largest contagion effects occur when a money center bank fails.

Müller (2006a, 2006b), who has represented the interbank market as a network where banks are nodes and interbank lending are links, also highlighted the significant impact of the pattern of interbank linkages on system resilience against spillover effects. She concluded that centralized markets are more prone to contagion than homogeneous ones.

Wells (2004) has also tried to give a comprehensive overview of the market structure impact under the risk of contagion by assessing the potential for contagion in the United Kingdom's interbank market under different market structures. He showed that different interbank structures do imply different levels of contagion. Thus, in the UK market, and assuming it to have a complete structure, the failure of smaller and foreign banks is not a threat to other institutions, since direct failures are only triggered by the failure of large domestic institutions. The majority of failures occur as a first-round effect (i.e., as direct effect of the initial failure) and only affects small banks. Notwithstanding this, in the worst-case scenario with a 100 per cent loss rate, contagion can affect up to 25 per cent of the banking assets. Even if the initial failure

[3]Although the authors have used the maximum entropy method based on balance sheet data, they also use additional information about the interbank lending breakdown by maturity and bank category of the counterpart, which allows them to deduce these patterns of interbank linkages.

does not push other banks into bankruptcy, it can have a large impact on the system by reducing other banks' capital levels. For instance, with a 40 per cent loss rate, although just one bank fails (accounting for less than 1 per cent of total banking system assets), three other banks lose more than 20 per cent of their Tier 1 capital, and six banks, accounting for 38 per cent of total assets, lose more than 10 per cent of it.

By assuming a more realistic representation of the interbank market structure, adding information about interbank linkages reflected on large exposures data collected by the Financial Services Authority (FSA), the author found that a complete market structure assumes larger interbank loans between domestic banks than those reflected by the large exposures data, leading to an underestimation of UK-owned banks exposures to foreign banks operating in the country. Thus, in this case, the risk of contagion between major domestic banks is smaller but the potential for contagion following shocks on overseas banks increases. The impact on banking system assets is also smaller than in a complete structure.

In a third case, the author assumes that larger banks act as money centers for the remaining ones, thus representing a money center structure. He found that, for lower loss rates, the results are quite similar to those obtained with the two other structures. However, in extreme cases, this third structure is more susceptible to contagion. Indeed, with a 100 per cent loss rate, a bank failure can trigger failures accounting for 42 per cent of total balance sheet assets. Additionally, in the worst case (with a 100 per cent loss rate), all sizable domestic banks lose at least 10 per cent of their Tier 1 capital.

Summarizing, Wells (2004) found that, even though contagion is more severe on a money center structure than on a complete one, the contagion effects on a more incomplete structure (like the second one) are lower than in a complete one.

Mistrulli (2005) also found that the change in the interbank market structure from an almost complete one to a multiple money center, due to financial consolidation, was accompanied by an increase in the risk of contagion. Conversely, in the Belgian interbank market, its evolution from a complete structure to a more concentrated one (a multiple money center) was accompanied by a decrease in the risk and impact of contagion (Degryse and Nguyen, 2007). A possible explanation for these contradictory results may lie in the trade-off between completeness and interconnectedness. In fact, in the Italian interbank market the increase in the risk of contagion, due to the decrease of market completeness, might have overcome the reduction in the extent of the contagion, due to the decline in market interconnectedness. The opposite applies to the Belgian interbank market: the decrease in market completeness amplified the potential for contagion, but the decline in market interconnectedness overcomes the first effect.

To sum up, some authors' conclusions partially corroborate the theoretical findings of Allen and Gale (2000) and Freixas et al. (2000), since more concentrated markets are more vulnerable to contagion (Upper and Worms, 2004; van Lelyveld and Liedorp, 2006; Müller, 2006a, 2006b; Mistrulli, 2005). However, complete structures are not always less conducive to contagion, as shown by Wells (2004) and Degryse and Nguyen (2007). Furthermore, the extent of contagion in incomplete market structures, such as money center ones, depends on the trade-off between market interconnectedness and completeness. Indeed, as highlighted by Nier et al. (2007), tiered structures are not necessarily more prone to contagion. It depends on the connectivity of the money center bank. If connections to the money center are significant enough, that can lead to the shock dissipation as in highly connected (and complete) markets.

3 Interbank market characterization

The Portuguese overnight interbank market has changed significantly between 1999 and 2009, especially concerning the amount of funds traded, market concentration, the number of participants and the pattern of interbank lending relationships, as analyzed below.

3.1 Amount of funds traded

Between January 1999 and December 2009, the TARGET Portuguese component[4] settled around 320,000 overnight money market operations (including advances and repayments) in the value of €23,363 billion. From those, €11,685 billion represented loans granted[5].

As Figure 3 reveals, the period between 2003 and 2006 was marked by the greatest expansion of the overnight interbank money market. In fact, if we analyze the average amount of funds traded per day, until 2002, around €2,425 million of funds were bought and sold per day, on average. Between 2003 and 2006, that value more than doubled, amounting to €5,685 million. In fact, around 50 per cent of the total funds traded during the sample period were bought and sold between 2003 and 2006. The maximum amount of loans granted per day was also reached during this phase: on January 2^{nd} 2004, there were 102 loans, amounting to more than €13,743 million. From 2007 onwards, and until the first half of 2009, the overnight interbank market suffered a clear break, since the average amount traded per day did not exceed €4,048 million.

[4]TARGET is the real-time settlement system for the euro. Its first generation started on 4 January 1999, following the launch of the Euro. It was composed of 17 national real-time gross settlement systems plus the ECB payment mechanism (EPM). In 2008, after a six-month migration phase, this first generation was replaced by TARGET2, the second generation of the system. Although based on a centralized technical platform, legally TARGET2 is still composed by the different national components of the participating countries (European Central Bank, 2009c). In our study, "TARGET Portuguese component" refers to the Portuguese component on both the generations of the system.

[5]The remaining value corresponds to the respective loans repayments.

However, in the last half of 2009, there was again a significant change in the money market, and the average amount of loans traded per day almost reached the 2003 levels, ascending to €5,417 million.

Figure 3: Amount of funds traded in the overnight interbank market

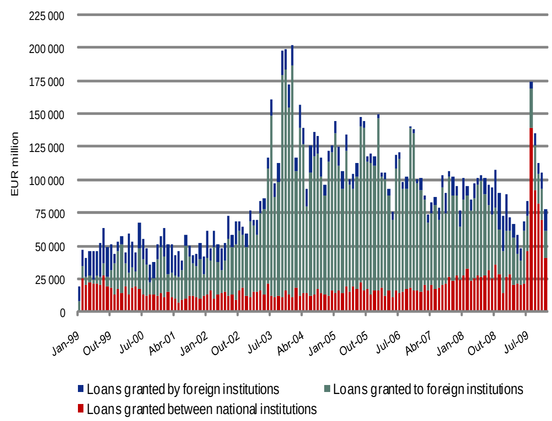
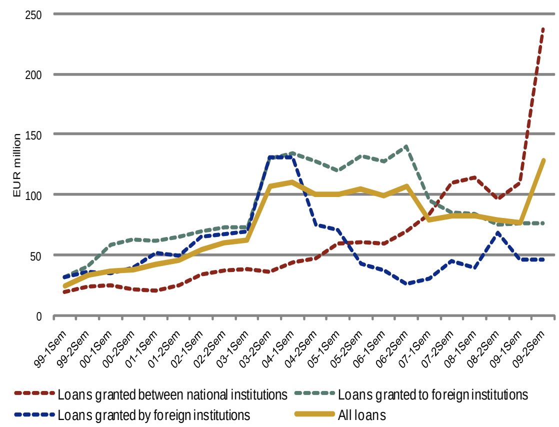


Figure 4: Average value per loan



The average value of the loans has also followed the same trend. In fact, as displayed in Figure 4, while in 1999 the average value of the loans was around €29 million, in 2002 it reached €57 million and, between 2003 and 2006, it almost doubled, ascending to €99 million. Between 2007 and the first half of 2009, there was a slight decrease in the average value per loan (to €80 million), but in the last half of 2009 it reached the historical maximum of €128 million. The maximum value of an overnight loan was also observed in this last period, namely in July, and it amounted to €7,200 million.

It should be noted that this unexpected change in the value of funds traded in the last half of 2009 does not mean that overnight interbank money market resumed the activity levels reached before 2007. Actually, it was a result of a surplus on banks' liquidity arising from the measures taken by the Eurosystem since October 2008, in the context of the "enhanced credit support" to the European banking system. That included three one-year long-term refinancing operations, which were held in June, September and December 2009, and through which banks borrowed €442 billion, €75 billion and €97 billion, respectively. However, instead of trading it in the interbank money market with each other, they recredited, at least, part of it to the central bank through the overnight deposit facility offered by the Eurosystem[6]. In this way, they were able to have almost immediate access to this liquidity surplus, holding it as a buffer in case they could not borrow from other banks when necessary. In fact, the recourse to the Eurosystem overnight deposit facility has risen considerably, especially after the settlement of the fist long-term operation held in June (European Central Bank, 2010a). Hence, the increase in the amount exchanged in the overnight money market was the result of "safe" operations held with the Eurosystem instead of the typical unsecured operations between banks.

Concerning the amounts traded in the overnight market, it is also worth highlighting that, except for the last half of 2009, most of the operations held during the sample period were cross-border, i.e., were between a national and a foreign institution[7]. In fact, until June 2009, cross-border loans accounted, on average, for 77 per cent of the total value of the overnight loans settled per month. In the last half of 2009, that share only reached 33 per cent.

The analysis of the counterparties involved in the overnight loans also reflects the quick integration of Portuguese institutions into the money market after the beginning of Stage Three of the Economic and Monetary Union, as also documented by Farinha and Gaspar (2008). Indeed, as illustrated in Figure 5, after a short period during the first half of 1999, when loans between national institutions remained significant, representing around 49 per cent of all loans, cross-border activity increased gradually, until the first half of 2009, at an average rate of 7 per cent per semester.

[6]The Eurosystem provides two standing facilities: the marginal lending facility, which allows banks to obtain overnight liquidity from their Central Bank against collateral, and the deposit facility, which enables banks to make overnight deposits with their Central Bank.

[7]National institutions are those with an account with Banco de Portugal. Foreign institutions are those with an account held with another Central Bank.

Figure 5: Proportion of loans according to the type of counterparty

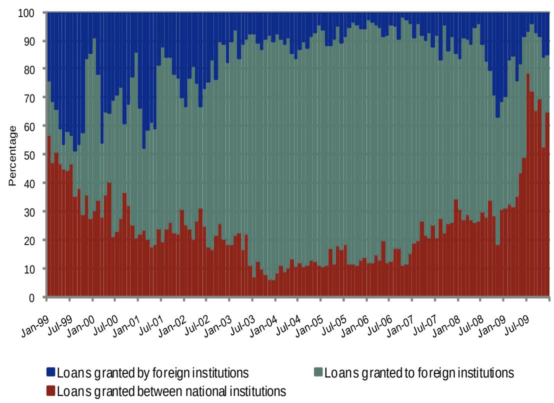
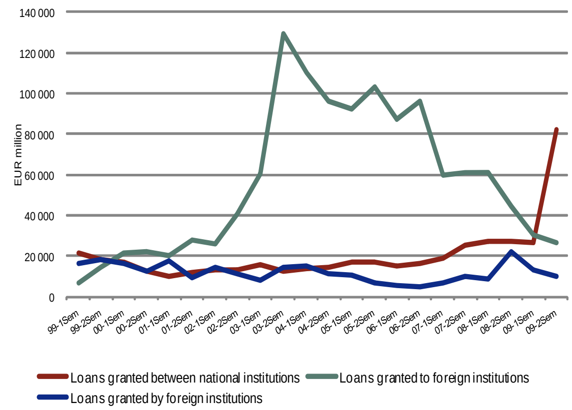


Figure 6: Monthly average of loans granted in terms of value



As shown in Figure 6, along with the integration of Portuguese institutions on the euro money market, there was also a change of their role in the market, as has been also reported by Farinha and Gaspar (2008). In fact, while in the first months of the Stage Three of the Economic and Monetary Union, cross-border interbank market was used by the Portuguese institutions mainly as a source of funding (70 per cent of all cross-border loans in terms of value were loans granted by foreign institutions to national ones), from the second half of 1999 onwards, and until September 2008, national institutions transformed themselves from borrowers to lenders. Indeed, during this period, loans granted to foreign institutions reached an average of €62,469 million per month, whereas the corresponding amount of loans received was only around €11,388 million. In October 2006, loans granted to foreign banks reached a maximum, ascending to €121 billion, 87 per cent of all interbank lending in that month. On the other hand, loans among national institutions reached a monthly average of only €16,476 million, which represents around 18 per cent of the average value of loans granted per month and, thus, a residual share of all the overnight lending activity.

These figures express the high degree of internationalization of the national institutions participating in the overnight interbank market between July 1999 and September

2008. This internationalization made them more vulnerable to the behavior of foreign markets, especially because the average value of interbank loans granted to foreign institutions during this period (around €93 million) was substantially higher than the average value of loans between national institutions (around €52 million).

Nonetheless, this dynamics was interrupted in October 2008, following the Lehman Brothers default, which accentuated the increase trend in the share of national loans, started in 2007, as a result of the financial instability triggered by the subprime crisis. Indeed, in March 2007, after 45 months during which the share of national loans in the total value of loans granted did not exceed 20 per cent, loans between national institutions started to increase. Although cross-border activity remained significant, the monthly average of loans granted to foreign institutions between October 2008 and June 2009 decreased to almost half when compared with the homologous period.

In the second half of 2009, due to the measures taken within the framework of the "enhanced credit support" provided by the Eurosystem to the banking community and the consequent bank's liquidity surplus, as mentioned above, national activity undoubtedly dominated the market. In fact, there was a sharp increase in national loans, with its monthly average amounting to €81,848 million, while the corresponding value of loans granted to foreign institutions did not exceed €26,378 million.

Yet, this was mainly the result of standing facilities operations contracted with the central bank[8] instead of the normal functioning of the market, since, during this period, institutions relied more on the central bank standing facilities than on their usual counterparties in the overnight money market. In fact, as Banco de Portugal (2010) has reported, between July and December 2009, there was an unprecedented recourse to the Eurosystem's standing facilities, mainly to overnight deposits.

[8]It should be noted that we also identify as overnight loans the standing facilities operations contracted with the central bank, since it allows a better analysis of both the interbank market behavior and the role played by the central bank in providing liquidity to the banking system. That does not affect financial contagion simulations, since it is assumed that the central bank never fails.

3.2 Market concentration

Another remarkable aspect about the Portuguese overnight money market is the high concentration on the lending side, despite the relative dispersion among borrowers. Indeed, during the sample period, while the five and ten major lenders were responsible, on average, for 65 per cent and 78 per cent of the total amount lent each year, respectively, the five and ten major borrowers just borrowed, on average, 35 per cent and 47 per cent of the total amount of funds borrowed each year.

Table 1: Evolution of market concentration

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
5 major lenders	31.4	44.8	50.4	59.8	76.2	82.1	78.0	79.5	65.5	65.8	76.9
10 major lenders	42.4	55.8	64.3	73.7	90.0	91.5	90.3	91.5	84.3	83.3	86.5
5 major borrowers	52.2	35.5	33.2	33.0	21.5	24.5	23.6	27.5	34.5	35.5	59.6
10 major borrowers	64.3	48.7	46.2	45.0	34.6	39.8	37.8	43.4	44.7	46.0	67.7

It is also important to note that the concentration ratio on the lending side increased gradually until 2004, when the top five lenders lent over 82 per cent of all funds lent. After 2005 and 2006, when it remained relatively unchanged (around 79 per cent), the concentration ratio in the top five lenders shrank around 13 basis points in 2007 and 2008, but reached its 2003 levels again in 2009 (77 per cent). On the contrary, the concentration ratio on the borrowing side dropped until 2003 and increased from 2004 onwards. It also reached a maximum in 2009, when the top five institutions covered over 60 per cent of the borrowing activity.

A deeper inspection of the group of lenders and borrowers revealed some additional aspects about it. Regarding the group of lenders, it is noteworthy to highlight that its composition during the sample period was always very stable. In fact, during the eleven years analyzed, one institution remained as the most important lender and three other institutions remained always in the top ten lenders. It is also interesting to note that the top 5 lenders were always national institutions, except in 1999, 2003, 2004 and

2008.

Additionally, it is also worth to mention that, despite its prominent role in the interbank money market in 2009, the central bank was a residual lender, granting just 0.22 per cent of the total value of loans granted during the year. It emerged, however, as the main borrower in that year, having received 39 per cent of the total amount of funds lent. In 2008, the central bank received 2 per cent of the total value of loans and, in the remaining years, it only received, on average, 0.1 per cent of it. This confirms the thesis that, in 2009, national institutions replaced their usual counterparties in the overnight operations by the Eurosystem, resorting especially to the overnight deposit facility, as mentioned before.

Regarding the group of major borrowers it is important to note that, except for the 2004-2006 period, when the borrowing side of the market was dominated by foreign institutions, in the remaining years some national institutions had always a prominent role in the market, since they were between the major lenders and also between the major borrowers, which suggests the existence of multiple money center banks where some institutions invest in and others go for funding.

In conclusion, there is a reduced number of key institutions that assume a very important role either on the lending, either on the borrowing side of the market. This suggests the existence of a multiple money center structure during the period analyzed, even though it was relatively diluted between 2004 and 2006, when the cross-border activity in the market was at its peak.

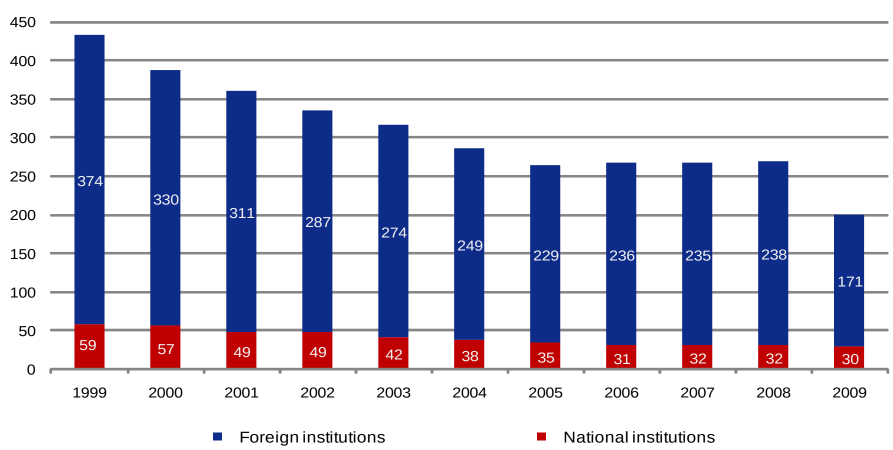
3.3 Interbank market participation

During the sample period, 772 different institutions participated in the overnight money market on at least one day, either as lender or borrower. From those, 69 were national and the remaining were foreign (91 per cent). Nevertheless, 678 were present in the market only once. On the other hand, 61 institutions were present in the market more than one quarter of the period, and 27 were there more than 50 per cent of the days.

Interestingly, if we rank lenders and borrowers according to the number of days they were present in the market, we realize that four institutions were almost always among the top ten borrowers and, simultaneously, among the top ten lenders. This reinforces the idea about the existence of several money center banks within the Portuguese interbank market.

As regards market participation, it is also important to note that, as shown in Figure 7, during the sample period, the number of institutions participating in the market in each year gradually decreased to less than half. Indeed, while in 1999, 433 institutions participated in the market at least once (374 foreign), in 2009 that number only included 201 institutions (171 foreign).

Figure 7: Number of institutions on the market per year



As expected, this decrease in the overall number of participants also affected the average number of banks present in the market per day. Indeed, while in 1999 the average number of banks in the market on any given day was 62 ± 14 (mean $\pm$ standard deviation), it dropped about 29 per cent until 2002. Although the market seems to have gained a new impulse in 2003, when 58 ± 11 institutions participated in it on any given day, this number dropped again in 2004 and remained relatively stable until 2008. During this period there were, on average, 53 ± 8 institutions in the market per day. In 2009, the trend in market participation changed again, when the average number of active banks per day dropped 21 per cent, that is to 42 ± 7.

The significant reduction in the number of banks present in the market between 1999 and 2002 can be explained by the several restructuring processes experienced in this period. Indeed, as pointed out by Barros et al. (2010), in 2000 only, there were several consolidation moves involving four of the seven major financial Portuguese groups. From these moves, one should highlight the extinction in March 2000 of the group Banco Pinto e Sotto Mayor (BPSM), which included the banks BPSM, Banco Totta e Sotto Mayor de Investimento, S.A. (BTSM Inv), Banco Totta e Açores (BTA) and Crédito Predial Português (CPP). BPSM was bought by Banco Comercial Português (BCP). BTSM Inv was acquired by Caixa Geral de Depósitos (CGD) and became Caixa – Banco de Investimento. BTA was created and acquired CPP. In September 2000, BTA was bought by Santander (Barros et al., 2010).

In addition, *(i)* in June 2000, Banco Mello and Banco Português do Atlântico were extinguished by incorporation into Banco Comercial Português; *(ii)* in July 2000, Argentaria, Caja Postal y Credito Hipotecario, S.A. was incorporated into Banco Bilbao Vizcaya (Portugal), S.A.; *(iii)* in November 2000, Banque Nationale de Paris merged with Banco Paribas, thus becoming BNP Paribas; *(iv)* in May 2001, Crédit Lyonnais Portugal, S.A. was merged by incorporation into Banco Bilbao Vizcaya Argentaria (Portugal), S.A.; *(v)* in July 2001, Banco Nacional Ultramarino was merged by incorporation into Caixa Geral de Depósitos (Associação Portuguesa de Bancos, 2011).

It should be noted that this consolidation process justifies not only the decrease in the number of national banks participating in the market (less 10 from 1999 to 2002), but also the decrease in the number of foreign banks (less 87). Indeed, this period was marked by an unprecedented process of financial consolidation not only at national level, but also across the entire European Union as a result of the introduction of the Euro, the effect of technological change and financial globalization (Altunbas and Ibáñez, 2004). Additionally, the reduction in the number of institutions acting in the Portuguese overnight market can also be explained by the replacement of the counterparties in the money market of the incorporated or acquired institutions by the ones from the acquiring institutions.

Overall, the evolution in market participation also points to the existence of a structure like a multiple money center, which became more and more concentrated along the time due to the reduction in the number of banks present in the market. This reduction was mainly due to the restructuring processes that took place until 2002 and, also, to the shutdown of the interbank market, following the failure of the Lehman Brothers in September 2008 (European Central Bank, 2010a).

3.4 Pattern of interbank lending relationships

To analyze the pattern of interbank lending relationships, we will use some useful measures drawn from Graph theory, following a growing literature that has resorted to this approach to depict and analyze financial systems, namely Boss et al. (2004), Müller (2006a, 2006b), Soramäki et al. (2007), Bech and Atalay (2008), Iori et al. (2008), Pröper et al. (2008), Lazzeta and Manna (2009), Wetherilt et al. (2010).

Graph theory is the branch of mathematics that studies graphs, i.e., a collection of dots connected to each other through lines (in the case of undirected links) or arrows (in the case of directed links). The graphs that are normally used to depict financial systems are the “networks”. These graphs provide additional information on the lines or arrows linking the dots, which are normally called “nodes”. If nodes are banks, that additional information can be, for instance, the amount of interbank exposures or the amount of payments settled between each pair of banks (Müller, 2006b).

Therefore, in order to analyze the interbank lending relationships in the Portuguese overnight interbank money market following a graph theory approach, we have to represent it as a network, where banks are nodes and the interbank lending relationships are the links between them. In our study, we model each day as a separate network (which results in 2,815 daily networks). Each lending relationship represents a directional link from the lender to the borrower and is weighted by the value of loans between them. If there is a link between two banks in a given day, then there was at least one interbank loan between them on that day. Additional loans on that same day increase the link weight in terms of value and volume. Therefore, the weight of each link stands for the strength of the interbank relationship between the lender and the borrower.

Over the sample period there was a total of 4,854 different directed links[9] established in the Portuguese overnight money market. Nevertheless, 93 per cent of the links lasted less than 100 days and 25 per cent lasted just one. On the other hand, only two links lasted more than 50 per cent of the days, and they were both between institutions from the same financial group. Moreover, as a consequence of the reduction in the number of active banks in the market per year, there was also a sharp reduction in the number of links. Actually, between 1999 and 2009, the number of directed links per year dropped by 69 per cent, from 2,192 to 671.

The number of links relative to the number of possible links, given the number of

[9]Each directed link is counted on both sides.

nodes, is a measure of the degree of completeness of a network. To put it differently, the degree of completeness is given by $m/(n \times (n-1))$, where m is the number of links and n, the number of nodes. It varies between zero, for completely disconnected networks, and 1, for complete networks (Bech and Atalay, 2008).

As shown in Table 2, over the sample period, the Portuguese overnight interbank market was extremely sparse as, on average, the degree of completeness barely exceeded 2 per cent. This means that almost 98 per cent of the potential links were not used. Indeed, while a complete directed network of similar size[10] is expected to have 2,756 links per day[11] , the daily average of directed links was 54 $\pm$ 16, and the maximum, registered on June 30^{th} 1999, was 173 links.

The maximum degree of completeness (2.4 per cent) was achieved in 2009, due to the sharp reduction in the number of active banks in the market, as a consequence of the freezing of the interbank markets after the Lehman Brothers default.

Table 2: Network descriptive statistics

Year	Daily number of active nodes			Daily number of links			Daily degree of completeness		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
1999	62	101	4	74	173	2	2.1	16.7	1.3
2000	58	103	12	61	135	9	1.9	6.8	1.1
2001	51	78	15	51	91	9	2.1	4.6	1.4
2002	48	73	13	47	84	9	2.2	5.8	1.5
2003	58	81	17	62	116	12	2.0	4.4	1.3
2004	54	77	21	54	94	16	1.9	3.8	1.4
2005	53	73	26	53	80	22	2.0	3.6	1.4
2006	50	69	24	48	80	20	2.0	3.8	1.5
2007	53	71	19	50	76	14	1.9	4.1	1.4
2008	53	69	23	52	80	18	1.9	3.6	1.4
2009	42	58	12	40	65	11	2.4	8.3	1.6

[10] The network size is defined by the number of nodes, which correspond to the number of active banks in the interbank market per day. During the sample period there were, on average, 53 active banks per day.

[11] $(n \times (n-1))$,where n is the number of nodes.

To summarize, it is possible to identify three distinct phases in the Portuguese overnight money market between 1999 and 2009. First, an "adaptation phase", from 1999 until 2002, marked by the restructuring processes held in this period, both at national and European level, and also by the integration in the European Monetary Union, which allowed the access to wide funding sources as well as wide investment opportunities. While the former aspect was reflected in the decrease in the number of institutions participating in the market, the latter had its major reflection between 2003 and 2006, through the great expansion of the cross-border segment of the market in terms of the funds traded (particularly in terms of the funds lent to foreign institutions). Actually, the period 2003-2006 delineates the second phase of the overnight money market, which we can call "the peak years of the interbank money market".

However, in 2007, a new trend in the money market started to emerge, as a result of the 2007's financial turmoil. The amount of funds traded started to decrease and the national segment of the market began to diverge from its residual role. This trend culminated in the actual shut down of the interbank market following the failure of the Lehman Brothers in September 2008. In an attempt to control the situation, the Eurosystem enhanced its intermediation role in the Euro area money market by providing unlimited liquidity to those banks lacking in it and by receiving deposits from those with liquidity surpluses (European Central Bank, 2010a). In the Portuguese case, liquidity surpluses seem to predominate, since there was an unprecedented recourse to the central bank overnight deposit facility (Banco de Portugal, 2010), as reflected in the high amount of fund traded on the national segment of the market in the last half of 2009.

Despite the different phases the overnight money market went through during the period 1999-2009, it seems to have been always characterized by an underlying multiple money center structure, as evident in the number of days each institution was in the market and in the market concentration in terms of lending and borrowing. Moreover, the degree of completeness of the market during the sample period also reveals that it was always far from being a complete market.

Therefore, these results seem to be in line with Craig's and von Peter's (2010) findings. According to them, interbank markets are sparse and tiered[12], evolving around a reduced number of core banks, which act both as lenders and borrowers.

In addition, it is also worth noting that the Portuguese interbank market structure seems to be very similar to the Belgian one, which is also marked by the existence of few money center banks and by the significant importance of cross-border interbank exposures (Degryse and Nguyen, 2007).

4 Contagion risk in the interbank market

4.1 Data collection

To analyze the contagion risk in the Portuguese interbank market we have used a unique dataset provided by the Payment Systems Department of Banco de Portugal, which contains information about all operations settled through the TARGET Portuguese component between 1999 and 2009.

TARGET is the Eurosystem's real-time gross settlement system[13] and is normally seen as the "backbone" of the Euro financial infrastructure (European Central Bank, 2010b). It allows the settlement in central bank money and in real-time of every kind of transaction in a fast and reliable way. Most important, it reduces systemic risk as,

[12]Tiering occurs when the market is organized in layers as, instead of participating in the market directly, banks use other banks as intermediary. In other words, tiering arises when some banks (on the upper tier) intermediate between others (on the lower tier), that simply participate in the market via the upper tier banks (Craig and von Peter, 2010).

[13]A real-time gross settlement system (RTGS) is a settlement system where process and settlement take place continuously (in real-time), on a transaction-by-transaction basis (instead of in batch mode), allowing the settlement with immediate finality (European Central Bank, 2009b).

once settled, all transactions are final and irrevocable. Although originally intended for the processing of large-value and time critical payments in Euro, TARGET settles all kinds of payments, such as operations made by financial institutions on behalf of their customers and, in particular, transactions resulting from each institution's banking activity, including payments connected to monetary policy operations and to the cash leg of foreign exchange and derivative transactions, as well as payments related to the trade of central bank money (i.e., deposits in the central bank) in the interbank money market (European Central Bank, 2009c).

Since the aim of our study is to analyze the exposures in the overnight interbank market, to distinguish overnight loans from the remaining transactions settled via TARGET, we have applied the search procedure described by Furfine (1999, 2001), following a two-steps approach: first, we identified transactions "candidates" to loans in day d; then, we looked for the respective repayments in the following business day ($d+1$). It had to be a payment between the same counterparties like the initial one but in the opposite direction and involving a slightly large amount, representing the accrued overnight interest. Besides, the implied interest rate had to be within a reasonable range.

Regarding the first step, following Farinha and Gaspar (2008), who have already applied this procedure to the Portuguese TARGET data, we looked for transactions above a minimum threshold amount of €100,000 and in round lots.

Concerning the second step, the main issue is to decide what a reasonable range for the interest rate is. Farinha and Gaspar (2008) considered as reasonable rates the ones between the minimum and the maximum rate in the EONIA panel[14], minus and plus 50 basis points, respectively. In our study, given the lack of detailed information on

[14] EONIA (Euro OverNight Index Average) is the reference rate for overnight operations in the Euro money market. It is a weighted average of the lending rate of all overnight unsecured lending transactions in the interbank market made by the contributing panel banks (European Banking Federation, 2010).

the EONIA panel interest rates, we started by allowing the interest rates to fluctuate within an interval defined by the official interest rates fixed by the ECB council for the Eurosystem's standing facilities: the marginal lending facility and the deposit facility. Through the former, the Eurosystem makes overnight liquidity available to the banks that request it against the presentation of eligible assets to collateralize it. Through the latter, institutions have the possibility of contracting overnight deposits with the respective Eurosystem central bank.

It is important to note that the standing facilities interest rates should be a reference for the interbank money market interest rates since, at least theoretically, banks have no motivation for lending below the overnight deposit interest rate, nor borrowing above the marginal lending facility interest rate. Indeed, in these cases, it would be preferable to resort to for the Eurosystem's overnight standing facilities. Thus, the marginal lending interest rate would provide a ceiling, and the overnight deposit interest rate would provide a floor for the overnight market interest rates. Nevertheless, intra-group loans might have smaller interest rates. Moreover, since loans from the Eurosystem have to be fully collateralized, banks can find it preferable to pay an interest rate slightly higher than the marginal lending facility interest rate.

Therefore, we have run the procedure using alternative limits for the interest rate range, like the ones defined by the EONIA plus and minus 100 basis points and the EONIA plus and minus 50 basis points[15]. The value and volume of operations identified with these different intervals were not significantly different from the ones obtained with the interval defined by the standing facilities interest rates. Nonetheless, we ended by using as upper limit the marginal lending facility interest rate, or the EONIA plus 50 basis points, if wider, and, as lower limit, the overnight deposit interest rate, or the EONIA minus 50 basis points, if lower, since this was the range that enabled us to

[15]Data about EONIA rates was taken from Thomson Reuters.

achieve the most accurate results.

In addition to the need of establishing a correct range of fluctuation for the interest rates, Furfine's procedure has some other caveats. First, it fails to identify operations made through correspondents[16] or other large-value payment systems, like EURO1, the net clearing system of the European Bankers' Association and the main competitor with TARGET. Second, it does not allow the identification of overnight operations where principal and interest are paid separately or when several initial loans are repaid through a single repayment.

But, despite these caveats, there is no doubt that Furfine's procedure allows the identification of interbank exposures, mainly unsecured, stemming from the overnight money market. Indeed, in addition to the in-depth analysis about the Portuguese banks participation on the euro money market between 1999 and 2005, a major contribution from Farinha and Gaspar's (2008) work was precisely the assessment of Furfine's procedure accuracy on the identification of overnight money market operations. The authors tested the algorithm adequacy by comparing the results obtained with the application of the procedure to the Portuguese TARGET data and the actual interbank money market operations recorded in SITEME, the Portuguese market electronic payment system. They concluded that the procedure allowed an accurate identification of 95 per cent of the overnight money market transactions.

Millard and Polenghi (2004), Amundsen and Arnt (2005) and Heijmans et al. (2010) have also reported the successful identification of overnight operations using Furfine's procedure. They applied it to settlement data from the British Clearing House Automated Payment System (CHAPS), the Danish large-value payment system (Kronos), and the Dutch TARGET component, respectively. Demiralp et al. (2006) have also made use of it to study the non-brokered overnight interbank market for federal funds.

[16]Since operations made through correspondents are record just in the correspondent bank books (in the debtor's and creditor's accounts with the correspondent) and not in the central bank books.

4.2 The contagion process

Following the approach adopted by previous empirical studies on financial contagion, we will measure the contagion risk stemming from overnight lending in the Portuguese interbank market by performing a scenario analysis where each bank is left to fail at once due to a sudden, idiosyncratic and exogenous shock. Then, we will estimate the knock-on effects on the remaining participants using different recovery levels.

Hence, given the initial failure of a particular bank, any creditor bank that has an exposure to the failed bank larger than its capital (which represents each bank's capacity to withstand shocks) is also considered insolvent. To put it differently, given the matrix of bilateral exposures, bank i is considered insolvent if $LGD\,(x_{ij}) > c_i$, where LGD is the loss given default rate (i.e., the loss rate imposed by the default of bank j), x_{ij}, the exposure of i towards j, and c_i, the capital of bank i. Bank i default is a first round failure. Second round failures occur if, given bank z , its combined exposure to all the first-round failures exceeds its capital, i.e., if $LGD\,(x_{zj} + x_{zi}) > c_z$. The process is iterated until there are no additional failures. The chain of failures triggered by the initial failure is the "domino effect", which can persist for several rounds.

It should be noted that, following previous studies (van Lelyveld and Liedorp, 2006; Mistrulli, 2007; Wells, 2004; Toivanen, 2009), in order to measure the potential for contagion we need to assume that:

(i) the time span between the increase of debtors' credit risk and their failure is too short for creditor banks to react, for instance, by decreasing their exposure to the affected institution or by raising capital to compensate for the losses suffered;

(ii) the loss rate is constant across banks and over time. Therefore, it does not reflect an increased risk awareness following the initial default, nor banks' heterogeneity;

(iii) the analysis focuses on the propagation of shocks among domestic banks, following an initial shock on a domestic or a foreign bank. Since we do not have information

about capital buffers nor interbank lending relationships between foreign institutions, we are not able to measure contagion between them. As a result, foreign institutions can only cause contagion by acting as the source of the initial shock, never failing by contagion. This might underestimate contagion risk since spillover effects of a domestic failure on foreign banks and the possible repercussions of those effects on the domestic market are not taken into consideration. However, these underestimation effects can be offset by the overestimation implied by assumptions *i)* and *ii)* since, in practice, banks experience a gradual weakening rather than a sudden failure. Therefore, their counterparties can prevent losses by taking corrective actions (Wells, 2004). For instance, they can fix the rates charged on the interbank loans granted or even alter their degree of participation in the market (Iori et al., 2006).

Moreover, we also assume that the central bank, due to its role as lender of last resort, never fails.

To sum up, there are four key elements in this contagion process that determine the severity of the spillover effects stemming from an institution's failure: its assets structure, its capitalization level, its liabilities structure and the loss rate imposed to its creditors (Wells, 2004). The assets structure determines whether or not the institution is affected by the previous default of other institution. Capitalization levels define the relative strength of each institution to support losses. If the institution has enough capital to support the losses without jeopardizing its counterparties, it can even stop the contagion process. On the other hand, if losses are higher than the institutions' capital, thus pushing it into default, that will amplify the dynamics of the contagion process, since the shock transferred to other banks congregates the spillover effects not only from the initial failure, but also from this second failure. The way the shock is transferred, and to whom, depends on the interbank liabilities structure. The loss rate determines the impact of the shock transmitted to creditors and, as most part of the studies highlight, the danger of contagion is crucially dependent on the assumed loss rate, i.e. the losses experienced by the creditor bank in case of insolvency of the debtor bank.

In our study, the assets and liabilities of each bank within the framework of the overnight interbank money market are provided by the matrix of bilateral interbank exposures, computed from the information obtained through the application of Furfine's procedure to the TARGET settlement data, as explained in the previous section. The information about banks' capital level was provided by the Portuguese Bankers' Association, the main entity to represent the Portuguese banking sector, bringing together most of the national banks and, also, foreign banks that carry out banking activities in Portugal.

Therefore, we gather all the necessary elements to simulate the contagion process, except for the loss rate. However, given the uncertainty involving the losses imposed to other banks due to one of their peers' failure (as mentioned in section 2.2.2), we decided to run the contagion process assuming four different levels of loss: 25 per cent, 50 per cent, 75 per cent and 100 per cent. The results obtained are presented in the next section.

4.3 Results

A general result from the contagion simulations carried out based on the interbank exposures established in the Portuguese overnight money market during the period 1999-2009 is that, even though it can materialize in some scenarios, contagion risk stemming from this market has never represented a significant threat to the Portuguese financial system and it has even decreased over the sample period.

As shown in Table 3, in the 1999-2009 period, from the 190 possible scenarios of contagion that existed on average per year, even assuming a loss rate of 100 per cent, contagion could have only occurred in 3.2 per cent of the cases. If we assume a more reasonable loss rate, such as, for instance, 75 per cent, contagion could have occurred in just 2 per cent of the cases. With a 25 per cent loss rate, contagion hardly occurs. These results are similar to the ones obtained by van Lelyveld and Liedorp (2006), Degryse and Nguyen (2007) and Mistrulli (2007), who also found that, for loss rates below 75 per cent, contagion is unlikely.

Table 3: Impact of contagion on the interbank market

Year	Number of possible scenarios	% of scenarios where contagion occurs				Median scenario								Scenario with maximum loss							
						Number of failing banks				% of total assets				Number of failing banks				% of total assets			
		Loss rate				Loss rate				Loss rate				Loss rate				Loss rate			
		25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100	25	50	75	100
1999	217	0.0	0.7	2.8	4.4	0	≤ 2	≤ 2	≤ 2	0.0	1.1	0.9	1.1	0	≤ 2	4	7	0.0	1.5	2.0	5.9
2000	215	0.0	0.5	2.8	4.7	0	≤ 2	≤ 2	≤ 2	0.0	≤0.5	≤0.5	≤0.5	0	≤ 2	≤ 2	5	0.0	≤0.5	1.9	2.4
2001	201	0.0	0.5	1.0	2.2	0	≤ 2	≤ 2	≤ 2	0.0	≤0.5	≤0.5	≤0.5	0	≤ 2	≤ 2	≤ 2	0.0	≤0.5	≤0.5	0.9
2002	207	0.5	1.5	1.7	2.9	≤ 2	≤ 2	≤ 2	≤ 2	≤0.5	≤0.5	≤0.5	≤0.5	≤ 2	≤ 2	≤ 2	≤ 2	0.9	0.9	0.9	0.9
2003	223	0.0	1.3	2.5	4.0	0	≤ 2	≤ 2	3	0.0	≤0.5	1.1	1.6	0	≤ 2	≤ 2	3	0.0	0.9	8.5	8.6
2004	200	0.0	1.8	2.3	3.3	0	≤ 2	≤ 2	≤ 2	0.0	1.7	2.6	1.9	0	≤ 2	≤ 2	≤ 2	0.0	9.3	9.8	9.8
2005	186	0.5	1.3	1.6	1.6	≤ 2	≤ 2	≤ 2	≤ 2	≤0.5	≤0.5	≤0.5	≤0.5	≤ 2	≤ 2	≤ 2	≤ 2	0.6	0.6	0.8	0.8
2006	151	0.0	1.3	2.3	4.0	0	≤ 2	≤ 2	≤ 2	0.0	≤0.5	≤0.5	1.2	0	≤ 2	≤ 2	≤ 2	0.0	0.7	≤0.5	7.2
2007	180	0.3	1.1	1.7	2.5	≤ 2	≤ 2	≤ 2	≤ 2	≤0.5	≤0.5	0.6	0.7	≤ 2	≤ 2	≤ 2	≤ 2	≤0.5	0.7	1.6	1.6
2008	178	0.0	1.1	1.7	2.8	0	≤ 2	≤ 2	≤ 2	0.0	≤0.5	≤0.5	≤0.5	0	≤ 2	≤ 2	≤ 2	0.0	≤0.5	≤0.5	≤0.5
2009	136	0.0	0.7	2.2	2.9	0	≤ 2	≤ 2	≤ 2	0.0	0.0	≤0.5	≤0.5	0	≤ 2	≤ 2	≤ 2	0.0	0.0	≤0.5	≤0.5
Yearly Avg.	190	0.1	1.1	2.0	3.2	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_

Note: The median scenario is the average number of failed banks and the average share of total banking system assets represented by failed banks (except the one that is left to fail at first), across all the scenarios where contagion occurs; The worst case scenario gives the maximum number of banks failed and the maximum percentage of banking assets represented by banks failing (excluding the initial failure) in a given scenario where contagion occurs; In order to avoid banks' identification, cells with two or fewer banks are signed with "≤ 2". The same applies to the cells regarding the percentage of assets affected by contagion and filled with "≤ 0.5".

When contagion could have occurred, assuming a median scenario and any loss rate, banks' failing were never more than 3 and never represented more than 2.6 per cent of the total banking system assets. As shown in Table 3, except for the years 1999, 2003, 2004 and 2006, assets represented by the failing banks never exceeded one per cent of the total banking system assets. It should be noted that, following Degryse and Nguyen (2007), our median scenario represents the average impact across all the scenarios where contagion could have occurred, expressed as the average percentage of total banking systems assets represented by (and the average number of) failed banks per scenario.

Yet, in the worst-case scenario under contagion (i.e., the scenario among the ones where contagion occurs for which the share of the total banking system assets represented by the failing banks is higher), and assuming a 100 per cent loss rate, the impact of contagion could have had a more significant effect. In fact, as shown in Table 3, in some cases the percentage of banking system assets affected could have surpassed 5 per cent. For instance, in 1999, 2003, 2004 and 2006, the percentage of the total banking assets represented by the failing banks reached 5.9, 8.6, 9.8 and 7.2 per cent, respectively.

Nevertheless, we should keep in mind that these results just hold true for the worst-case scenario and assuming a 100 per cent loss rate, which is an extreme assumption. In addition, 2003-2006 was the period when interbank exposures were also higher, as shown in section 3. Moreover, as Figure 8 illustrates, bank's capital levels have increased substantially from 2004 onwards, thus increasing the median buffer available per bank to withstand shocks.

Figure 8: Average capital level per bank

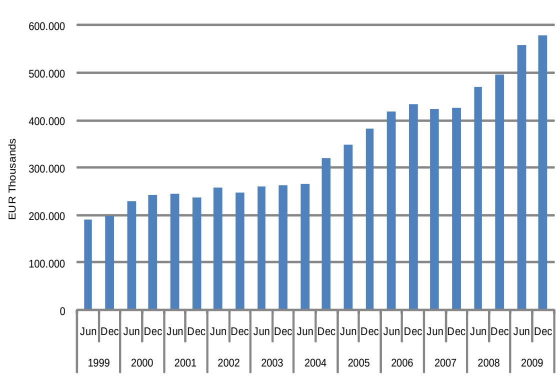
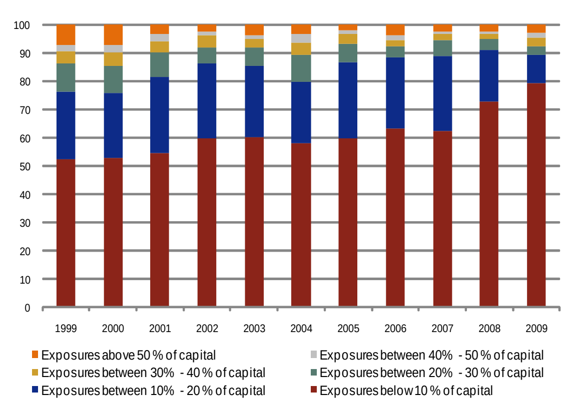
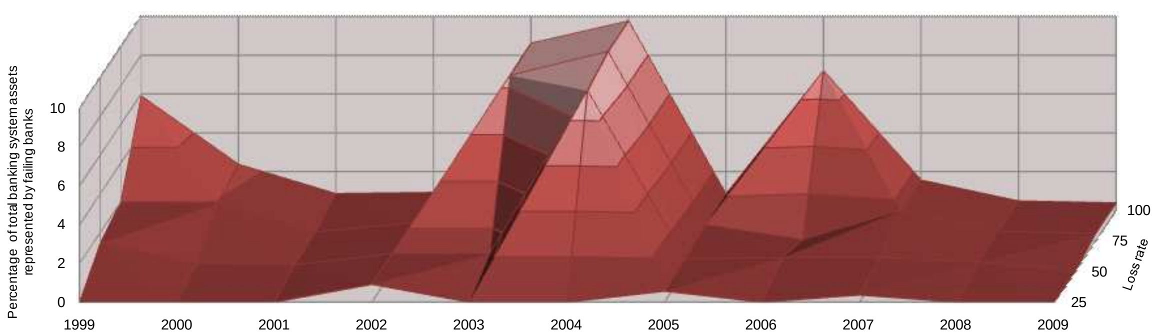


Figure 9: Weight of exposures on banks' capital



As a result of the reinforcement on capitalization levels, the proportion of exposures with a weight above 20 per cent on capital had also declined, with the corresponding increase in the proportion of exposures that represent less than 10 per cent of banks' capital (as illustrated in Figure 9). This has also contributed to a substantial decline in the severity of contagion effects throughout the time, measured as the percentage of banking system assets represented by the failing banks, as graphically shown in Figure 10. Actually, in 2008 and 2009, with the decrease in the money market activity and the reinforcement of the average capital levels per bank[17], even in the worst-case scenario assuming contagion, banks failing by contagion represented just a negligible share of the total banking system assets (not exceeding half per cent).

Figure 10: Severity of contagion (worst-case assuming contagion)



The potential for contagion can also be expressed by the number of banks whose default causes at least another bank's failure (contagious banks). As presented in Table 4, despite the high number of contagious banks in 1999 and 2000 (10, if we assume a 100 per cent loss rate), it decreased sharply in 2001 (when there were just 5 contagious banks). With the exception of 2003 and 2004, when it almost reached the 1999 and 2000 levels, the number of contagious banks remained relatively constant until 2009 (averaging 5, considering a 100 per cent loss rate).

[17]The average capital level per bank increased 16 per cent between December 2007 and December 2008 and around 17 percent between December 2008 and December 2009.

It is also important to highlight that, as shown in Table 4, most of the exposed banks in the overnight interbank money market over the sample period were contagion-proof banks, i.e., they never failed irrespective of the loss rate assumed and of the bank that failed first. Indeed, on average, contagion-proof banks always accounted for more than 82 per cent of the banking system total assets.

Table 4: Contagious and contagion-proof banks

Year	**Number of contagious banks**				**Contagion-proof banks**							
					Number				% total banking system assets			
	Loss rate				Loss rate				Loss rate			
	25	50	75	100	25	50	75	100	25	50	75	100
1999	0	2	6	10	38	36	34	30	90.2	88.7	87.6	84.6
2000	0	1	6	10	36	36	33	31	88.8	88.6	86.8	86.4
2001	0	1	2	5	33	32	32	31	85.2	85.1	84.9	85.3
2002	1	3	4	6	31	31	31	30	86.2	86.0	86.0	86.0
2003	0	3	6	9	31	29	27	25	89.8	88.5	89.2	80.3
2004	0	4	5	7	29	27	26	25	86.9	81.3	76.8	76.3
2005	1	3	3	3	27	26	25	25	83.7	83.0	82.6	82.6
2006	0	2	4	6	25	23	23	21	85.1	84.5	83.7	79.2
2007	1	2	3	5	26	25	24	22	84.2	83.3	82.4	81.4
2008	0	2	3	5	22	20	19	19	83.0	82.3	82.1	82.2
2009	0	1	3	4	22	21	20	19	82.1	82.1	81.9	81.7

Nonetheless, as highlighted by Wells (2004), even if a bank does not fail, the losses suffered can deteriorate its financial health and trigger ratings downgrades, collateral calls or even turn it unviable. Therefore, in addition to the number and share of assets represented by failed banks, another important measure of the potential impact of a bank failure on the banking system is its spillover effect on other institutions' capital (i.e., their capital loss), even if the latter do not fail.

Actually, as Figure 11d illustrates, the worst-case scenario (not conditional to contagion) does not always occur when there is contagion. This happened in 2001, 2005 and

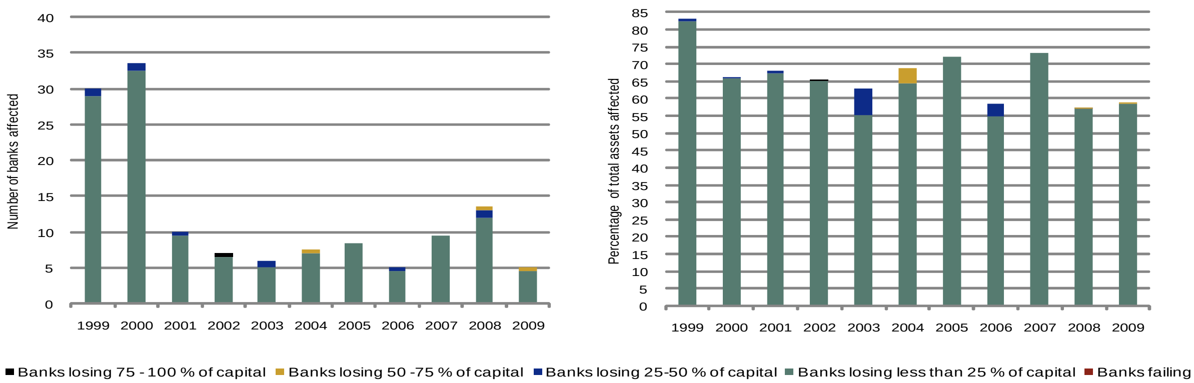
2007 when, although there were no defaults by contagion, the failure of a given counterparty could have imposed losses above 25 percent on banks representing around 5, 8 and 9 per cent of the total banking system assets, respectively (under the assumption of a 100 loss rate).

It is also noteworthy to highlight that in the situations where contagion could have occurred (and irrespective of the loss given default assumed), the contagious banks were mainly national ones. Nonetheless, the worst-case scenario not conditional to contagion is normally triggered by exposures to foreign institutions, as a reflection of the high degree of internationalization of the Portuguese banks in the overnight money market. Thus, even if is mainly the failure of a national bank that leads to defaults by contagion, foreign institutions' defaults can have non-negligible effects on domestic banks, as cross-border exposures are also higher than national ones, as analyzed in section 3.

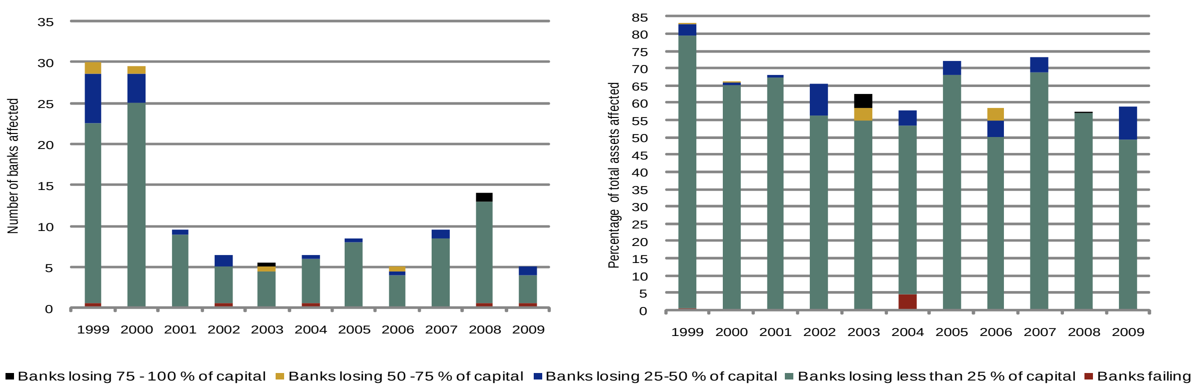
The analysis of the worst-case scenario not conditional to contagion also highlights the decrease on the severity of spillover effects' stemming from a given counterparty default over the sample period. Indeed, assuming a loss rate of 100 per cent, in the worst-case scenario, in 1999, a counterparty failure could have affected 33 banks, representing about 84 per cent of the total banking system assets, and almost half of them would lose more than 25 per cent of their capital. In 2009, that effect would be felt just for 6 institutions, most of which would lose less than 25 per cent of their capital. The conclusions are similar if we assume a loss given default of 25 per cent, 50 per cent or 75 per cent, as shown in Figures 11a, 11b and 11c, respectively.

Figure 11: Impact of a bank failure (worst-case not conditional to contagion)

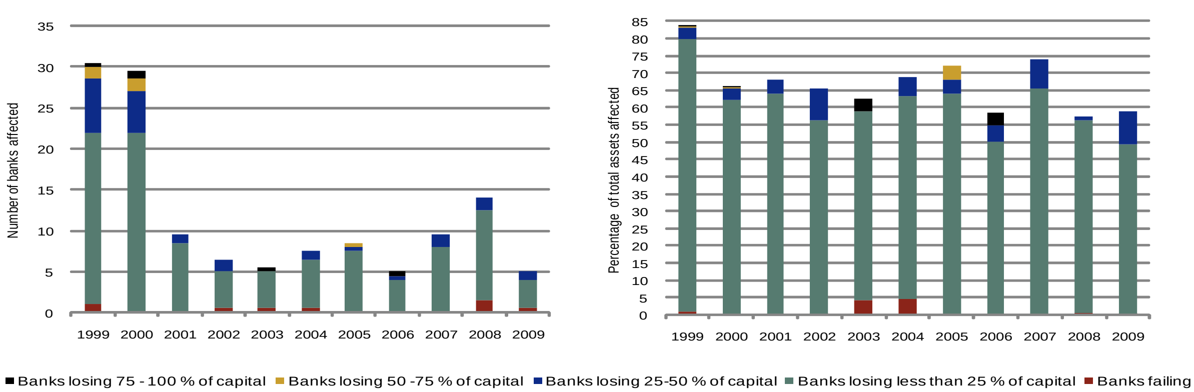
(a) Assuming a 25 per cent loss rate



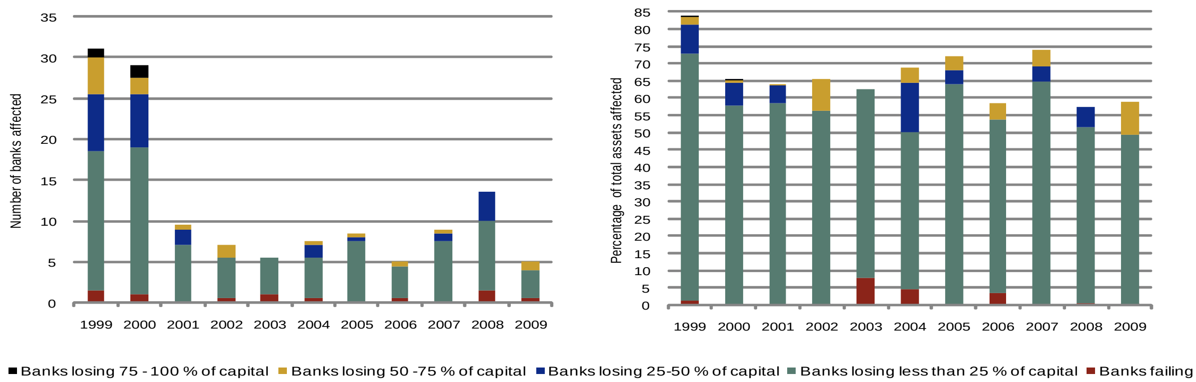
(b) Assuming a 50 per cent loss rate



(c) Assuming a 75 per cent loss rate



(d) Assuming a 100 per cent loss rate



To sum up, contagion in the overnight money market is a very low probability event and, even if it had occurred between 1999 and 2009, it would not have led to the collapse of the Portuguese banking system.

Yet, it is possible to observe a change over time in the possible impacts of contagion. Thus, in case of contagion, in the worst-case scenario, it could have had sizable effects in 1999 and also in 2003, 2004 and 2006. As we have seen in section 3, the Portuguese banking system suffered a profound restructuring process between 1999 and 2002, which can justify the decrease in the potential for, and severity of, contagion in the period after 1999. On the other hand, the increased effects of contagion in 2003, 2004 and 2006 can be explained by the fact that these were the years when the interbank money market most expanded, particularly concerning cross border activity. However, we can advocate that the underlying multiple money center structure of the Portuguese interbank money market helped to maintain the potential effects of contagion on relatively low levels. These conclusions are in line with the ones by Degryse and Nguyen (2007), who found that in the Belgian interbank market the moving towards a multiple money center structure decreased the risk and impact of contagion.

5 Concluding remarks

Despite the commitment of most central banks to ensure financial stability, it has been repeatedly questioned by episodes like the subprime crisis and the current debt crisis, during which public authorities have undertaken large efforts to prevent contagion effects that may exacerbate the instability of financial markets.

However, can systemic risk in general, and the risk of contagion in particular, be a real threat to financial systems? Or, in the end, it is just like Sheldon and Maurer (1998, p. 685) ironically state: "*Systemic risks are for financial market participants what Nessie, the monster of Loch Ness, is for the Scots (and not only for them): Everyone knows and is aware of the danger. Everyone can accurately describe the threat. Nessie, like systemic risk, is omnipresent, but nobody knows when and where it might strike. There is no proof that anyone has really encountered it, but there is no doubt that it exists.*"

With the present work we tried to find whether the contagion risk is a real threat to the Portuguese financial system, particularly the contagion risk that emerges from the interbank lending relationships established in the overnight money market, expanding the existing empirical analyses on contagion risk to the Portuguese interbank market. In fact, since theoretically thesis do not allow drawing definitive conclusions about the inherent potential for contagion of each market (yet), empirical analyses reveal to be extremely important to achieve that aim.

The conclusions empirically drawn for the Portuguese interbank market are in line with the ones regarding other markets such as the Italian, the Belgian, the Austrian and the Dutch one: although contagion may occur, its impact on the banking system cannot be considered a major threat to financial stability. Indeed, even in the worst-case, institutions failed by contagion represented less than 10 per cent of the banking system total assets.

Nonetheless, it was possible to identify three distinct phases of evolution in the contagion risk in the Portuguese overnight money market. The first, between 1999 and 2002, when the profound restructuring process held in this period led to a gradual decrease in the contagion risk. The second, between 2003 and 2006, when the fully integration of the national institutions in the European Monetary Union led to the emergence of significant cross-border exposures, thus increasing the contagion risk again. The third and last phase, in the period after 2006, when market activity decreased, as a consequence of the financial turmoil that emerged in 2007, causing contagion risk to lower as well. As expected, with the interbank market frozen after the failure of the Lehman Brothers in September 2008, the risk of contagion almost ceased to exist. However, the interbank market also ceased to play its redistributing role and forced institutions to turn to the Eurosystem's standing facilities operations to adjust their day-to-day cash imbalances. Thus, the risk of contagion disappeared but the interbank market also stopped to function correctly, which can be as harmful to the intermediation role of the banking system in the economy as an event of contagion.

We also concluded that, similarly to the Belgian one, the Portuguese interbank market is characterized by a high importance of the cross-border segment of the market. Furthermore, it is ruled out by a multiple money center structure, i.e., it revolves around a reduced number of money center banks, which have, simultaneously, an important role as lenders as well as borrowers.

Therefore, and since the potential for contagion is relatively low, our results are in line with Nier et al.'s (2007) thesis that incomplete market structures, such as money center ones, are not necessarily more prone to contagion, as it depends on the connectivity of the money center banks. In the Portuguese case, it seems that connections of the money center banks are significant enough, leading to the dissipation of a given shock, instead of its amplification.

We have also confirmed Nier et al.'s (2007) views that, as expected, an increase in the banks' capitalization levels leads to a decrease in the potential for, and severity of, contagion, and that the risk of contagion is higher when interbank liabilities are also higher. Indeed, the improvement of banks' capitalization levels can be an explanation for the overall reduction in the potential for contagion, especially after 2004. On the other hand, the potential for contagion risk within the Portuguese overnight interbank market reached some of its highest levels when interbank exposures were also higher.

Thus, our results empirically sustain Nier et al.'s (2007) findings. Yet, a major contribution of our work was to fill a gap in the existing research on financial contagion as, even though this exercise has already been carried out for the majority of the European interbank markets, at least to the best of our knowledge, no similar work existed for the Portuguese case until now. Moreover, contrary to other studies that focus on a single point in time, we have analyzed the evolution of contagion risk in the interbank overnight money market over a period of eleven years.

More importantly, we have contributed to a better understanding of the Portuguese interbank market and, at the same time, we have drawn attention to a unique kind of data – the data of the large-value payment settlement systems – based on which we can obtain valuable insights regarding the behavior of financial systems and, in the limit, about the economic activity in general, almost on a real-time basis, since the data is available to the central banks running that systems on a daily basis.

Despite our achievements, the present study is just a start, since, as we mention in the next section, there is room for improvement.

6 Future research

Large-value payment settlement systems' databases, as the one of the Portuguese TARGET component, make it possible to explore multiple lines of investigation around the behavior of financial institutions, either in the field of payment systems or in the field of interbank money markets. This work results from the study of one of those lines, namely the inherent potential for contagion of the Portuguese overnight interbank money market. However, it would be also of major interest to explore others.

For instance, as our analysis was carried out considering just overnight exposures, future developments of this work could include, however subject to the availability of data, the run of the simulation process based on information covering a wide range of interbank exposures, thus complementing the data about overnight interbank exposures with data about longer-term exposures.

In addition, as pointed out by Mistrulli (2005), due to the increasing internationalization of interbank linkages in most of the markets, the failure of a foreign counterparty can pose a higher threat to the national financial system than the failure of a domestic institution. However, since the majority of contagion analyses are limited to domestic markets, disregarding the possible effects of second-round failures of foreign institutions on domestic institutions, that can lead to an underestimation of contagion risk, especially in high internationalized markets such as the Belgian and the Portuguese one. Therefore, one possible extension, not only of this work but, also, of the empirical research on financial contagion in general, would be to carry out the analysis including the information about the interbank exposures among cross-border counterparties. However, due to the confidentiality issues that the disclosure of this type of information normally raises, probably this kind of analysis can only be done, for instance, at the Eurosystem level and not at an academic level.

Still within the field of financial contagion, since contagion risk can also arise from the interbank exposures established through payment systems, it would also be interesting to analyze this source of contagion using the TARGET settlement data. Actually, there are already some works in this field, such as the ones by Soramäki et al. (2007), who have analyzed the Fedwire Funds Service, the Federal Reserve Banks' real-time gross settlement system, Becher et al. (2008), who have examined the Clearing House Automated Payment System (CHAPS), the United Kingdom's large-value payment system, and Pröper et al. (2008), who have studied the Dutch real-time gross payment system.

On the other hand, in this work, network theory was only used as a useful tool to draw some conclusions about the pattern of interbank lending relationships. However, another interesting line of research would be to carry out a deeper network analysis of the interbank money market which, combined with the contagion simulations, would help to identify the role played by each institution in the market. That would help to design measures adjusted to the systemic risk that each institution's problems may represent, which is of utmost importance as problems from one (systematically important) institution can be a higher threat to financial stability than problems in another (non-systematically important) institution. This approach could also help to justify (or not) the assistance provided to some distressed institutions, by assessing the possible contagion effects of their default.

Finally, it would also be of major interest to analyze the interbank relationships established through the payment systems following a network approach, since it could reveal important information for the operators of these systems (for instance, the strongest and the weakest nodes). This could be especially useful in the context of real-time settlement systems, were the window to solve problems is very short and the measures required to solve it may be different, depending on the role played by the institution in trouble. For example, in case of technical disruptions that prevent institutions from carrying out their normal payment business and redistributing their liquidity, or in case of a participant's lack of liquidity, the measures to overcome the problem may differ, depending if the institution is a money center bank or a small bank with very few counterparties.

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