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# The role of banks in the Brazilian Interbank Market: Does bank type matter?

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**Abstract**

This paper presents an empirical analysis of the Brazilian interbank network structure. We have found that the Brazilian interbank market clearly presents a topology that is compatible to the free-scale networks. This market is characterized by money centers, which have exposures to many banks and are the most important source of large amounts of lending. Therefore, they have important positions in the network taken into account by the minimal spanning tree and the power domination measures of the network. We have also developed a methodology to compare different banks and their relative importance in the network.

*Key words:* Banking, Complex Networks, Network theory, Interbank market, Econophysics.
JEL CODE:E5; G21.

## 1 Introduction

A recent financial literature has exploited the differences in the various dimensions of the banking firms such as origin (domestic or foreign), size (large or small), control (public or private), sector (retail, treasury, business, credit) as factors that define role, strategy and performance.

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La porta *et al.* (2002) showed that government ownership of banks in 1970 is associated with lower productivity growth. Bonin *et al.* (2005) investigating the impact of bank privatization in transition economies reinforces this idea suggesting that early-privatized banks are more efficient than later privatized banks. Di Patti and Hardy (2005) have shown that new private banks are the most efficient in Pakistan. In fact, it seems that in most situations bank privatization has increased efficiency, but less than is typically observed in non-banking industries [Megginson (2005)]. For instance, Nakane and Weintraub (2005) have shown that state-owned banks are less efficient than the private banks. However, the evidence of improvement provided by private ownership is mixed. Altunbas *et al.* (2001) has shown that in the German banking market there is indication that public and mutual banks have cost and profit advantages over their private peers.

An interesting branch of this literature is to study diverse aspects of foreign ownership of banks. Clarke *et al.* (2003) review the causes of foreign bank entry in developing economies. Peria and Mody (2004) study how foreign participation and concentration impact bank spreads and Clarke *et al.* (2005) assess how lending to small business is affected by foreign entry. Furthermore, De Haas and Lelyveld (2006) investigate whether foreign and domestic banks react differently to business cycles and crises. In this context, several works have also investigated the differences of efficiency between foreign and domestic banks. For example, Sturm and Willians (2004) have found that foreign banks are more efficient than domestic banks in Australia and this same result was found by Havrylchyk (2006) analyzing the Polish banking industry.

Other dimension which is also studied frequently is related to the bank size in the bank industry. For instance, Berger and Mester (1997) have found that small banks are more profit efficient than larger banks. This result was supported by Akhigbe and McNulty (2003) in the United States.

One fascinating market which has been very little investigated is the interbank market. The appealing of this market is supported by the influential papers due to Allen and Gale (2000) and Freixas *et al.* (2000) who defend that a relevant channel of financial contagion is the overlapping claims that different institutions have on one another. [1] In fact, they showed that there is a strict relation between network topology and financial stability. One interesting issue also considered in Freixas *et al.* (2000) is the "Too big to fail approach" in dealing with large banks and money centers. Furthermore, Allen and Gale (2000) divide the bank system in regions where each region may be seem as a local community of banks. Therefore, based on these works one may pose the

[1] Actually, three types of operations define the existence of this network of financial contracts: the payment system, the interbank market and the market for derivatives. Here, we deal just with one of them – the interbank market.

following questions: (1) Which is in fact the relation between money centers and large banks in the interbank market? [2] Are the large banks also the large creditors in the system? Which are the most systemic relevant banks in the system? (2) Are the banks in the interbank market divided in communities? (3) Is there a role for each bank in the interbank market? Does Bank type influence strategy in the interbank market? (4) Is the interbank market homogeneous as presented in Allen and Gale (2000)?

In this paper, we try to answer the questions posed above by investigating the role and strategy of each type of bank in the network formed by the Brazilian interbank market using a unique data set formed by 109 financial institutions and two years of data. Considering as a starting point the empirical evidence of the presence of differences in efficiency and strategy in different types of banks presented above, we compare the role and the strategies of these institutions dividing the sample by control (public, private and foreign), type (retail, treasury, business and credit), size (large, medium, small and micro) and bank and non-bank institutions. We have found that bank type matters as they have different role in bank networks, the Brazilian bank network is characterized by money centers, in which large banks are important sources of borrowing and finally that the Brazilian interbank market presents a topology that is compatible with free-scale networks.

The methodology considered here is based in a recent developed field known as complex networks that have been developed in the last years as a branch of the statistical physics literature to provide a unified view of dynamic systems that may be described by complex weblike structures [3] and non-parametric statistics. However, instead of explicitly using the measures [4] introduced in this literature, we adapt these measures according to our needs to get a better characterization of the banks in this network.

In fact, it is essential to stress that the modeling of a financial networks using tools provided by the theory of complex networks is totally reasoning. Cajueiro (2005) using a computational framework and Jackson and Rogers (2005) using a microeconomic framework have shown that complex structures such as the ones provided by small world networks [Watts and Strogatz (1998) and Watts

[2] Money centers are defined as banks that lend and borrow to other banks, and are important sources of funding in the interbank system.

[3] Comprehensive reviews of this literature may be found in Albert and Barabasi (2002) and Boccaletti *et al.* (2006).

[4] Several measures have been presented aiming at characterizing the properties of these networked systems, for instance, characteristic path length (Wiener (1947)), clustering coefficient (Watts and Strogatz (1998)), efficiency (Latora and Marchiori (2001,2002)), cost (Latora and Marchiori (2002)), node degree (Barabasi and Albert (1999)), degree correlation (Pastor-Satorras *et al.* (2001)), weighted connectivity strength (Yook *et al.* (2001)) and disparity(Barthélemy *et al.* (2005)).

(1999)] and free scale networks [Barabasi and Albert (1999)] are likely to emerge in social, economic and social interactions. Some interesting empirical results are provided by Müler (2003), Souma *et al.* (2003) and Boss *et al.* (2004a,b) who have recently shown that financial networks present typical characteristics of complex networks. Furthermore, Iori *et al.* (2007) based on a dynamical framework, which employs methods of statistical mechanics of complex networks, have studied the implications of institutional arrangements on the stability of the system and the structure of the trading relationships [5].

This paper is organized as follows. In section 2, the model of network considered in this paper is introduced. In section 3, the measures considered in this paper to quantify the role of each bank in the network are introduced. In section 4, the procedure considered to build the minimal spanning trees of the Brazilian network is introduced. Section 5 describes the data considered in this paper. The results are presented in section 6. Finally, section 7 concludes the paper.

## 2 Network modeling of the interbank market

In which follows, the definition of network that will be used in this paper is presented:

**Definition 1** *A network (graph) $G$ consists of a nonempty set of elements $V(G)$ called vertices, and list of unordered pairs of these elements, called edges $E(G)$. The set of vertices (nodes) of the network is called vertex set and the list of edges is called the edge list. If $i$ and $j$ are vertices of $G$, then an edge of the form $ij$ is said to join or connect $i$ and $j$.*

Networks can be classified as: (1) Undirected: Edges exhibit no inherent direction, implying that any relationship so represented is symmetric. (2) Directed (Digraph): Edges exhibit inherent direction, implying that there is a hierarchical structure between the vertices. (3) Unweighted: Edges are not assigned any a priori strengths. (4) Weighted: Edges are assigned a priori strengths. (5) Simple: Multiple edges connecting the same pair of vertices are forbidden; (6) Multigraphs: Multiple edges connecting the same pair of vertices are allowed; (7) Sparse: For an undirected graph, the maximal size of $E(G) = C_n^2$, corresponding to a complete graph. Sparseness implies that the number of edges $M$ satisfies $M << C_n^2$. (8) Connected: Any vertex can be reached from any other vertex by traversing a path consisting of only a finite number of of edges.

[5] See also Iori *et al.* (2006).

Generally, we should expect that banks are either net borrowers or lenders in the interbank market. Therefore, an interbank network should be modeled as a simple weighted directed network. Following this reasoning, the most important matrix used to characterize the interbank market is the so-called matrix of bilateral exposures defined bellow:

**Definition 2** *The matrix of bilateral exposures $W(G) = [W_{ij}]$ of a interbank market $G$ is the $n \times n$ matrix (where $n$ is the number of banks) whose $w_{ij}s$ denote bank $i$'s exposure to bank $j$ ,and $a_i = \sum_{j=1}^{n} w(i,j)$ and $l_j = \sum_{i=1}^{n} w(i,j)$ are, respectively, bank $i$'s interbank assets and liabilities.*

Other important matrix that arises in this paper is the so-called adjacency matrix:

**Definition 3** *The adjacency matrix $A(G) = [a_{ij}]$ assigns the value 1, if there is an edge starting in vertex $i$ and going to vertex $j$. If there is no edge starting in vertex $i$ and going to vertex $j$, then $A_{ij} = 0$.*

Although this matrix provides less information than the matrix of billateral exposures, it may work well when one only wants to take the topology of the network into account.

In the next sections, these two above-defined matrices will play an important role in the characterization of the Brazilian interbank market.

## 3 Measures used to characterize the role of banks in the interbank market

In this section, we present the measures used to characterize the role of banks in the interbank network. These measures presented bellow will be divided in in-measures and out-measures. While the banks that present higher in-measures are ones most systemic relevant, the banks that present higher out-measures are the most important as money centers.

### *3.1 Indegree and outdegree*

Indegree and outdegree may provide the simplest characterization of a bank in the interbank market. While in-degree is the number of creditors that a bank has in a given time, out-degree is the number of debtors. Furthermore, in the bank literature, if a bank has many interbank liabilities (exposures) it is said to have a high indegree (outdegree).

Therefore, using the adjacency matrix, one may define two important measures used to characterize directed networks, the indegree and the outdegree are, respectively, given by

$$indegree(i) = \sum_{j=1}^{n} A(j,i), \tag{1}$$

and

$$outdegree(i) = \sum_{j=1}^{n} A(i,j). \tag{2}$$

Since the degree depends on the size of the bank sector, Müller (2003) normalized these measures dividing them by $n-1$ (the maximal number of edges that a bank may have) and defined, respectively, the so-called indegree and outdegree centralities as

$$0 \leq dc_{in}(i) = \frac{indegree(i)}{n-1} \leq 1, \tag{3}$$

and

$$0 \leq dc_{out}(i) = \frac{outdegree(i)}{n-1} \leq 1. \tag{4}$$

This is the first interesting measure that we will use to characterize the role of banks in the interbank market.

### *3.2 Value indegree and outdegree centralities*

As noted above, since indegree and outdegree do not take the size of the liabilities and exposures into account, it is worth defining measures to cope with the size of liabilities and exposures. These measures were also introduced in Müller (2003) and defined, respectively, by value indegree and outdegree centralities as extensions of the above defined indegree and outdegree centralities

$$0 \leq vdc_{in}(i) = \frac{\sum_{j=1}^{n} w(j,i)}{\sum_{k=1}^{n}\sum_{j=1}^{n} w(k,j)} \leq 1, \tag{5}$$

and

$$0 \leq vdc_{out}(i) = \frac{\sum_{j=1}^{n} w(i,j)}{\sum_{k=1}^{n}\sum_{j=1}^{n} w(k,j)} \leq 1. \tag{6}$$

### 3.3 In-efficiency and out-efficiency of a node

The concept of efficiency in complex networks was introduced by Latora and Marchiori (2002), for undirected networks, based on the idea of efficiency of communication between two nodes $i$ and $j$ not necessarily connected, i.e., according to this measure, two closer nodes have better communication than two distant nodes. Here, the issue is to use this measure to describe deeper the position of the banks in the network. Differently from the four measures presented above, where only the first neighbors are considered to describe the position of a bank in the network, here we introduce a variation of the concept of efficiency considered in Latora and Marchiori (2002) adapted for directed networks to cope with this situation. Therefore, we define here the so-called in-efficiency of a node

$$0 \leq \epsilon_{in}(i) = \frac{\sum_{j=1}^{n} 1/d(j,i)}{n-1} \leq 1, \tag{7}$$

and out-efficiency of a node

$$0 \leq \epsilon_{out}(i) = \frac{\sum_{j=1}^{n} 1/d(i,j)}{n-1} \leq 1, \tag{8}$$

where the characteristic path length $d(i,j)$ is the minimal number of paths needed to reach bank $i$ from bank $j$.

### 3.4 Weighted in-efficiency and weighted out-efficiency

Since the measures in-efficiency and out-efficiency considered above do not take the size of liabilities and exposures into account, here we introduce the weighted in-efficiency as

$$0 \leq \epsilon_{w,in}(i) = \frac{\sum_{j=1}^{n} 1/d^{w}(j,i)}{n-1} \leq 1, \tag{9}$$

and

weighted out-efficiency as

$$0 \leq \epsilon_{w,out}(i) = \frac{\sum_{j=1}^{n} 1/d^{w}(i,j)}{n-1} \leq 1, \tag{10}$$

where $d^w(i,j)$, the weighted path length, is defined here for the connected neighbors of first order as $d^w(i,j) = 2 - \frac{W^s_{ij}}{max_w}$ where $max_w$ is the maximal element of the matrix of bilateral exposures. The $d^w(i,j)$ of the higher order neighbors are calculated from this definition. One should note also that if the network is unweighted by nature, then for the first neighbors $d^w(i,j) = 1$ and for higher order neighbors $d^w(i,j) = d(i,j)$. This definition ensures that $d_{ij}$ satisfies the usual properties of a distance. [6]

### *3.5 Domination power*

The domination power introduced in Van den Brink and Gilles (2000) is a measure of centrality of a node in a network that takes the direction and the weight of the relations into account. It can be interpreted in the following way. If the set V(G) represents a set of economic agents that are engaging in some economic trade process, then the fact that agent $i$ dominates agent $j$ can have the interpretation that agent $i$ sets the conditions under which binary trade between agents $i$ and $j$ will take place. Another interpretation is that if alternative $i$ dominates alternative $j$, then an individual or group of individuals prefers alternative $i$ to alternative $j$.

Mathematically, in Van den Brink and Gilles (2000), domination power is measured using the generalized $\beta$-measure

$$\beta(i) = \sum_{j=1}^{n} \frac{W(i,j)}{\lambda(j)}, \tag{11}$$

where $\lambda_{ij}$ is the dominance weight of node $j$ given by

$$\lambda(j) = \sum_{i=1}^{n} W(i,j). \tag{12}$$

In the context of the interbank market presented here, the generalized $\beta$-measure is a nice way of ordering money center in degree of importance.

## 4 Minimal Spanning tree

The minimal spanning tree problem, an old problem in graph theory, is concerned with finding the set of edges of given network that has the shortest

[6] For details, see Kolmogorov and Fommin (1975).

total length.[7] Mantegna (1999), using the correlation between two stocks as a measure of distance, adapted this concept in order to characterize complex networks of financial stocks. Since in the original problem is formulated to an undirected network with a clear notion of distance, first we have to define the notion of distance considered in this network and, then we have to adapt this concept to deal with directed networks. This procedure will be apt to identify the most important relations in the Brazilian interbank market.

The procedure used to achieve this effort may be described by the following steps:

(1) Keep the directions of the matrix of bilateral exposures;[8]

(2) Transform of the matrix of bilateral exposures in a symmetric matrix called here as $W^s$;

(3) Determine the maximal weight $max_w$ between all nodes of the network;

(4) Define the distance $d_w(ij)$ between two neighbors $i$ and $j$ of first order of the network as $d_w(ij) = 2 - \frac{W^s_{ij}}{max_w}$ and calculate all the other distances of higher order neighbors;

(5) Find the minimal spanning tree based on a typical algorithm;[9]

(6) Using the directions kept in step (1), recover the directions of the minimal spanning tree.

The role of the minimal spanning tree here is to provide the notion of community between the banks. Using the spanning tree, as one may see later, it is possible to see graphically the role of each bank in the system. Furthermore, since we have defined the distance here in the same way that we defined the distance in order to evaluate the weighted efficiencies in section 3.4, the spanning tree in this case will be a graphical representation of the most locally weighted efficient banks.

[7] Details may be found for instance in Hillier and Lieberman (1967).

[8] One should note that if there is an edge between bank $i$ and bank $j$, then either bank $i$ is the creditor of bank $j$ or bank $i$ is the debtor of bank $j$. Both situations at the same time are not possible.

[9] The description of a typical algorithm for finding the minimal spanning tree of a network may be found in any book of operations research such as Hillier and Lieberman (1967).

## 5 Data

The analysis performed in this paper is based on information of all interbank exposures in the Brazilian interbank market. All financial institutions report their counterpart in the interbank market and their size exposure. Therefore, we have complete information on interbank exposures.

The interbank market in Brazil accounts for 10% total balance sheet value of banks. The exposures are largely not collateralized. The interbank data has been collected for the period from January 2004 to December 2005 for all banks and financial institutions that have exposures in the interbank market. The sample comprises 86 banks and 23 non-bank financial institutions [10] .

We consider conglomerates (group of financial institutions that are considered as a single institution) in our analysis. Therefore, we analyze interbank lending between banks that do not belong to the same financial institution.

We include public, domestic and foreign banks in our sample. The role of these types of bank is examined by studying their relative importance in the interbank network.

The Central Bank of Brazil classifies banks by main activity. We employ this classification to study the role of each bank type in the interbank market. These types are retail banks, banks specialized in credit loans, banks with focus in treasury operations,banks specialized in business and others (non-bank financial institutions).

We also study the relation of size and bank's role in the interbank market. If large banks behave as money centers then we should expect to find a prominent role of these banks in the interbank market. Such hypotheses can be tested by characterizing the interbank network topology, which is the focus of the next section.

## 6 Empirical Results

This section intends to understand the role of the banks in the Brazilian interbank market. Two resources are used: (1) the measures introduced in section 3.4 and the minimal spanning tree described in 4.

[10] These are mainly credit institutions.

From now on, we call w-in-efficiencies, in-efficiencies, in-degree centralities and value in-degree centralities as in measures and w-out-efficiencies, out-efficiencies, out-degree centralities and value out-degree centralities as out-measures.

The w-in-efficiencies, w-out-efficiencies, in-efficiencies, out-efficiencies, in-degree centralities, out-degree centralities, value in-degree centralities, value out-degree centralities and power dominations of all banks of the Brazilian interbank market were calculated. These results may be found in table 1. It is possible to infer that the degree of heterogeneity in the interbank system is high. For example, domination power ($\beta$-measures) range from 12.8 to 0.00. Furthermore, all measures are not normally distributed, positively skewed and in some cases with a high excess kurtosis (domination power has an excess kurtosis of 64.44).

Place Table 1 Here

We also present in table 2 the Spearman correlation coefficients and their respective p-values. [11] We have found, there is strong significant positive correlation among the in-measures and among the out-measures. Moreover, we have found significant correlation between most in-measures and out-measures. This means that, in general, money centers that have exposures to many banks are also the most important source of large amounts of money. Therefore, they have important positions in the network taken into account by the the power domination measure.

Place Table 2 Here

On the other hand, banks that have large liabilities in general borrow money from many different banks. It seems this is good news in terms of systemic risk, i.e., the risk of the default of one of these banks is divided among the ones that provide funds. The strategy performed by these banks implies in high values of information centralities. Furthermore, the fact that in and out measures are correlated means that the same banks that sometimes are sources of money also borrow money from the system.

Table 3 presents median interbank measures for public, private and foreign banks. The last two columns present a Kruskal-Wallis test for equality of medians and its respective p-value. The differences appear in out-efficiency and beta measures. For out-efficiency measures both public and private domestic banks have values significantly higher than foreign banks. This suggest that

[11] To evaluate these correlations, the unconnected banks (8 banks at all) were removed.

on average such bank types may have a more prominent role as money centers. From the $\beta - measure$ we have that public banks are the most important in the network, followed by private domestic banks.

If a bank has a high indegree of value indegree measures then it has large liabilities in the interbank system (it is a net borrower) with outdegree and value outdegree representing the extent of lending in the interbank system. It is worth mentioning that from table 3 we can see that value indegree is much higher for foreign banks, which suggests that these banks are net borrowers in this market, with public banks being net lenders (value outdegree of 0.00245). Public banks often benefit from having a large number of public servants accounts as their payroll is often made through public banks. Therefore, public banks tend to have high liquidity, which can be channeled to the interbank market.

Place Table 3 Here

Table 4 presents median interbank measures for retail, treasury, business and credit banks. The last two columns present a Kruskal-Wallis test for equality of medians and it's respective p-value. The most important banks in the network are retail and credit banks with high in-efficiency measures. Is important to highlight that from $\beta - measures$ we find that retail banks are the most important in the interbank network.

We compare retail banks with other bank types and found that retail median power-domination are statistically different from treasury specialized banks at the 5% significance level, while it is statistically different from credit and business specialized banks only at the 10% significance level.

Retail banks play a major role in the interbank market as their value outdegree and their domination power ($\beta$-measures) are higher than those from other bank types.

Place Table 4 Here

Table 5 presents median interbank measures for banks and non-bank financial institutions. The last two columns present a Kruskal-Wallis test for equality of medians and it's respective p-value. Results suggest that banks play a prominent role in the interbank market, which can be seen from all measures. [12]

Place Table 5 Here

Table 6 presents median interbank measures for large, medium, small and

[12] In all measures the median of bank institutions is statistically different from non-bank financial institutions.

micro banks. The last two columns present a Kruskal-Wallis test for equality of medians and it's respective p-value. Results suggest that large banks play a proeminent role in the interbank market. Besides the relative importance of each type of banks depends positively on size.

Large banks have high values of outdegree and weighted outefficiency suggesting that they play the role of money centers in the interbank market and also that they are the most systemically relevant, which in line with the "too big to fail hypothesis".

Place Table 6 Here

It is important to notice that our sample period includes the failing of Banco Santos (medium-sized bank) in 2004. The failure of a medium-sized bank has reduced liquidity to similar banks and borrowing opportunities in the interbank markets for a while. Therefore, as we can see in Table 6 the behavior of medium and small banks is very similar in the bank network.

### *6.2 Minimal spanning tree*

In figure 1 we plot the minimum spanning tree generated for the banking system by activity using the definition of distance given previously. On this tree, we can identify different communities, and that the interbank market seems to be characterized by money centers.

Place Figure 1 About Here

Figures 2 and 3 present the minimum spanning tree for control and size, respectively. From these figures it is clear that private domestic and foreign controlled banks have important positions in the network and also that large banks are important as well.

Place Figures 2 and 3 About Here

## 7 Conclusions

This paper presents an empirical analysis of the Brazilian interbank network structure. The Brazilian interbank market clearly presents a topology that is compatible to the free-scale networks.

The Brazilian interbank market is characterized by money centers, which have exposures to many banks and are the most important source of large amounts of lending. Therefore, they have important positions in the network taken into account by the information centrality and the power domination measures. Large banks play the role of money centers in the interbank market.Besides the degree of heterogeneity is high as different types of banks play different roles in the interbank market.

We also develop a methodology to compare different banks and their relative importance in the network. Our results suggest that different types of bank have a different role in the network. Retail banks play a major role in the interbank market as their value outdegree and their domination power ($\beta$-measures) are higher than those from other bank types. Public banks are net lenders, while foreign banks are net borrowers.

Finally, the minimal spanning trees suggest the existence of communities in the interbank markets, as public, private and foreign banks are connected among themselves.

## References


[1] Albert, R. and Barabasi, A. L. Statistical mechanics of complex networks. *Reviews of Modern Physics*, **70**, 056104, 2002.

[2] Akhigbe, A. and McNulty, J. E. The profit efficiency of small US commercial banks *Journal of Banking and Finance*, **27**, 307-325, 2003.

[3] Altunbas, Y., Evans, L. and Molyneux, P. Bank ownership and efficiency. *Journal of Money, Credit and Banking*, **33**, 926–954, 2001.

[4] Allen, F. and Gale, D. Financial contagion. *Journal of Political Economy*, **108**, 1–33, 2000.

[5] Barabasi, A. L. and Albert, R. Emergence of scaling in random networks. *Science*, **286**, 509-512, 1999.

[6] Barthélemy, M.,Barrat, A., Pastor-Satorras, R. and Vespignani, A. Characterization and modeling of weighted networks. *Physica A*, **346**, 34–43, 2005.

[7] Berger, A. N. and Mester, L. J. Inside the black box: what determinates differences in te efficiency of financial institutions. *Journal of Banking and Finance*, **21**, 895–947, 1997.

[8] Boccaletti S., Latora V., Moreno Y., Chavez M. and Hwang D. U. Complex networks: Structure and dynamics. *Physics Reports*, **424**, 175–308, 2006.

[9] Bonin, J. P., Hasan, I. and Wachtel, P. Privatization matters: bank efficiency in transition countries. *Journal of Banking and Finance*, **29**, 2155–2178, 2005.

[10] Boss, M., Summer, M. and Thurner, S. Contagion flow through banking networks. *Lecture notes in computer science*, **3038**, 1070–1077, 2004a.

[11] Boss, M., Elsinger, H., Summer, M. and Thurner, S. Network topology of the interbank market. *Quantitative Finance*, **4**, 677–684, 2004b.

[12] Cajueiro, D. O. The agents' preferences and the topology of networks. *Physical Review E*, **72**, 047104, 2005.

[13] Clarke, G., Cull, R., Peria, M. S. M. and Sanchez, S. M. Foreign bank entry: experience, implications for developing economies and agenda for further research. *The World Bank Research Observer*, **18**, 25–59, 2003.

[14] Clarke, G., Cull, R., Peria, M. S. M. and Sanchez, S. M. Bank lending to small businesses in Latin America: Does Bank origin matter? *Journal of Money, Credit and Banking*, **37**, 83–118, 2005.

[15] De Haas, R. and Lelyveld, I. V. Foreign banks and credit stability in Central and Eastern Europe. *Journal of Banking and Finance*, **30**, 1927–1952, 2006.

[16] Di Patti, E. B. and Hardy, D. C. Financial sector liberization, bank privatization and efficiency. *Journal of Banking and Finance*, **29**, 2381–2406, 2005.

[17] Fortunato, S., Latora, V. and Marchiori, M. A method to find community structures based on information centrality. *Physical Review E*, **74**, 47–97, 2002.

[18] Freixas, X., Parigi, B. M. and Rochet, J. C. Systemic Risk, interbank relations and liquidity provision by the central bank. *Journal of Money Credit and Banking*, **32**, 11–638, 2000.

[19] Havrylchyk, O. Efficiency of the Polish banking industry: foreign versus domestic banks *Journal of Banking and Finance*, **30**, 1975–1996, 2006.

[20] Hillier, F.S. and G. J. Lieberman *Operations research.*, Holden-Day, San Francisco, 1967.

[21] Iori G., De Masi. G., Precup, O. V., Gabbi, G. Calderelli, G. A network analysis of the Italian overnight money market. *Forthcoming in the Journal of Economic Dynamics and Control* , 2007.

[22] Iori G., Jafarey, S., and Padilla, F.G. Systemic risk on the interbank market. *Journal of Economic Behavior and Organization* , **61**, 525–542, 2006.

[23] Jackson, M. O. e Rogers, B. W. *Journal of The European Economic Association*, **3**, 617-627, 2005.

[24] Kolmogorov, A. N. and Fomin, S. V. *Introductory real analysis.*, Dover, New York, 1975.

[25] La Porta, R., Lopex-de-Silanes, F. and Shleifer, A. Government ownership of banks *The Journal of Finance*, **57**, 265-301, 2002.

[26] Latora, V. and Marchiori, M. Efficient behavior of small world networks. *Physical Review Letters*, **87**, 198701, 2001.

[27] Latora, V. and Marchiori, M. Economic small-world behavior in weighted networks. *European Physical Journal B*, **32**, 249–263, 2002.

[28] Mantegna, R. N. Hierarquical structure in financial markets. *European Physical Journal B*, **11**, 193–197, 1999.

[29] Megginson, W.L. The economics of bank privatization *Journal of Banking and Finance*, **29**, 1931–1980, 2005.

[30] Müller, J. Two approaches to assess contagion in the interbank market. *Working paper of Swiss National Bank*, 2003.

[31] Nakane, M. I. and Weintraub, D. B. Bank privatization and productivity: evidence for Brazil. *Journal of Banking and Finance*, **29**, 2259-2289, 2005.

[32] Pastor-Satorras, R., Vazquez, R. and Vespignani, A. Dynamical and correlation properties of the internet. *Physical Review Letters*, **87**, 258701, 2001.

[33] Peria, M. S. M. and Mody, A. How foreign participation and market concentration impact bank spreads: evidence from Latin America. *Journal of Money, Credit and Banking*, **36**, 511-537, 2004.

[34] Souma, W., Fujiwara, Y. and Aoyama, H. Complex networks in economics. *Physica A*, **324**, 396-401, 2003.

[35] Sturm, J. E. and Willians, B. Foreign bank entry, desregulation and bank efficiency: lessons from the Australian experience. *Journal of Banking and Finance*, **28**, 1775-1799, 2004.

[36] Van Den Brink, R. and Gilles, R. P. Measuring domination in directed networks. *Social Networks*, **22**, 141–157, 2000.

[37] Watts, D. J. *Small worlds: the dynamics of networks between order and randomness.* Princeton University Press, 1999.

[38] Watts, D. J. and Strogatz, S. H. Collective dynamics of small world networks. *Nature*, **393**, 440–442, 1998.

[39] Wiener, H. Structural determination of paraffin boiling points. *Journal of the American Chemistry Society*, **69**, 17–20, 1947.

[40] Yook, S. H., Jeong, H., Barabasi, A. L. and Tu, Y. Weighted evolving networks. *Physical Review Letters*, **86**, 5835–5838, 2001.

[41] Zhou, H. Distance, dissimilarity index and network commnunity structure. *Physical Review E*, **87**, 061901, 2003.

| | Mean | Median | Max. | Min | Std. Dev. | Skewness | Excess Kurt. | JB | p-value |
|---|---|---|---|---|---|---|---|---|---|
| in efficiency | 0.0815 | 0.0643 | 0.2790 | 0.0000 | 0.0824 | 0.4682 | 1.8025 | 10.50 | 0.01 |
| out efficiency | 0.0815 | 0.0675 | 0.3400 | 0.0000 | 0.0782 | 0.6780 | 2.7156 | 8.72 | 0.01 |
| W in efficiency | 0.0419 | 0.0325 | 0.1590 | 0.0000 | 0.0426 | 0.5167 | 1.9731 | 9.64 | 0.01 |
| W out efficiency | 0.0419 | 0.0342 | 0.1820 | 0.0000 | 0.0405 | 0.7437 | 2.9712 | 10.05 | 0.01 |
| indegree | 0.0196 | 0.0073 | 0.1350 | 0.0000 | 0.0261 | 1.6988 | 6.1759 | 98.24 | 0.00 |
| outdegree | 0.0196 | 0.0087 | 0.2480 | 0.0000 | 0.0341 | 3.8028 | 21.8792 | 1,881.47 | 0.00 |
| value indegree | 0.0092 | 0.0006 | 0.3200 | 0.0000 | 0.0325 | 8.2376 | 78.3579 | 27,024.05 | 0.00 |
| value outdegree | 0.0092 | 0.0003 | 0.2870 | 0.0000 | 0.0347 | 5.9849 | 43.3047 | 8,028.53 | 0.00 |
| $\beta$-measure | 0.4905 | 0.1240 | 12.8000 | 0.0000 | 1.3597 | 7.1940 | 63.4359 | 17,528.62 | 0.00 |

Table 1. This table presents descriptive statistics for the banking system. The Jarque-Bera statistic and its p-value are provided in the last two lines, and they test the normality assumption of these indices.

| | in efficiency | out efficiency | W in efficiency | W out efficiency | indegree | outdegree | value indegree | value outdegree | beta |
|---|---|---|---|---|---|---|---|---|---|
| in efficiency | 1.00 | 0.53 | 0.99 | 0.53 | 0.99 | 0.55 | 0.94 | 0.56 | 0.50 |
| out efficiency | 0.53 | 1.00 | 0.53 | 0.99 | 0.53 | 0.96 | 0.54 | 0.91 | 0.83 |
| W in efficiency | 0.99 | 0.53 | 1.00 | 0.54 | 0.99 | 0.55 | 0.95 | 0.57 | 0.50 |
| W out efficiency | 0.53 | 0.99 | 0.54 | 1.00 | 0.53 | 0.96 | 0.55 | 0.91 | 0.83 |
| indegree | 0.99 | 0.53 | 0.99 | 0.53 | 1.00 | 0.55 | 0.93 | 0.56 | 0.51 |
| outdegree | 0.55 | 0.96 | 0.55 | 0.96 | 0.55 | 1.00 | 0.53 | 0.95 | 0.92 |
| value indegree | 0.94 | 0.54 | 0.95 | 0.55 | 0.93 | 0.53 | 1.00 | 0.61 | 0.50 |
| value outdegree | 0.56 | 0.91 | 0.57 | 0.91 | 0.56 | 0.95 | 0.61 | 1.00 | 0.89 |
| $\beta$-measure | 0.50 | 0.83 | 0.50 | 0.83 | 0.51 | 0.92 | 0.50 | 0.89 | 1.00 |

Table 2. This table presents Spearman rank correlations for network indices. All correlations are statistically significant at the 1% level.

| | Public | Private | Foreign | KW | p-value |
|---|---|---|---|---|---|
| in efficiency | 0.23 | 0.26 | 0.25 | 2.226863 | 0.3284 |
| out efficiency | 0.18 | 0.18 | 0.16 | 7.004819 | 0.0301 |
| W in efficiency | 0.03083 | 0.0546 | 0.06865 | 3.269478 | 0.195 |
| W out efficiency | 0.05935 | 0.0432 | 0.0679 | 1.700748 | 0.4273 |
| indegree | 0.0000 | 0.0000 | 0.0000 | 5.090099 | 0.0785 |
| outdegree | 0.0000 | 0.0000 | 0.0000 | 1.344497 | 0.5106 |
| value indegree | 0.000444 | 0.00137 | 0.005325 | 11.05534 | 0.004 |
| value outdegree | 0.002425 | 0.000364 | 0.00174 | 5.727313 | 0.0571 |
| $\beta$-measure | 1.06 | 0.14 | 0.07 | 11.71553 | 0.0029 |

Table 3. This table presents average network indices for the banking system according to control. The Kruskal-Wallis (KW) statistic and it's p-value are provided in the last two columns. The KW tests whether the median indices for the network are equal.

| | Retail | Treasury | Business | Credit | KW | p-value |
|---|---|---|---|---|---|---|
| in efficiency | 0.1405 | 0.0428 | 0.013 | 0.13 | 9.522342 | 0.0231 |
| out efficiency | 0.138 | 0.13 | 0.03 | 0.0974 | 3.871841 | 0.2756 |
| W in efficiency | 0.07145 | 0.0215 | 0.00671 | 0.0656 | 8.887594 | 0.0308 |
| W out efficiency | 0.0709 | 0.0667 | 0.0151 | 0.0494 | 4.003177 | 0.2611 |
| indegree | 0.02585 | 0.00384 | 0.00146 | 0.0242 | 10.62448 | 0.0139 |
| outdegree | 0.07015 | 0.00954 | 0.00902 | 0.016 | 5.499028 | 0.1387 |
| value indegree | 0.002955 | 0.00111 | 0.000382 | 0.00166 | 2.109468 | 0.55 |
| value outdegree | 0.00335 | 0.00145 | 0.000257 | 0.000336 | 11.23073 | 0.0105 |
| $\beta$-measure | 0.67 | 0.181 | 0.068 | 0.237 | 5.529365 | 0.1368 |

Table 4. This table presents average network indices for the banking system according to type. The Kruskal-Wallis (KW) statistic and its p-value are provided in the last two columns. The KW tests whether the median indices for the network are equal.

| | Banks | Non Bank financial institutions | KW | p-value |
|---|---|---|---|---|
| in efficiency | 0.1035 | 0 | 20.25385 | 0 |
| out efficiency | 0.1055 | 0.0167 | 10.82355 | 0.001 |
| W in efficiency | 0.0532 | 0 | 20.32075 | 0 |
| W out efficiency | 0.0539 | 0 | 10.87247 | 0.001 |
| indegree | 0.01525 | 0 | 20.12038 | 0 |
| outdegree | 0.01037 | 0.00258 | 11.16831 | 0.0008 |
| value indegree | 0.00162 | 0 | 22.16873 | 0 |
| value outdegree | 0.000691 | 0.0000246 | 13.18803 | 0.0003 |
| $\beta$-measure | 0.189 | 0.0155 | 9.361743 | 0.0022 |

Table 5. This table presents average network indices for the financial system according to type: banking versus non-banking institutions. The Kruskal-Wallis (KW) statistic and it's p-value are provided in the last two columns. The KW tests whether the median indices for the network are equal.

| | Large | Medium | Small | Micro | KW | p-value |
|---|---|---|---|---|---|---|
| in efficiency | 0.3 | 0.29 | 0.28 | 0.08 | 13.5303 | 0.0036 |
| out efficiency | 0.19 | 0.18 | 0.19 | 0.15 | 16.20889 | 0.001 |
| W in efficiency | 0.0891 | 0.0573 | 0.0526 | 0.0325 | 16.19898 | 0.001 |
| W out efficiency | 0.09905 | 0.04335 | 0.0567 | 0.0175 | 14.0699 | 0.0028 |
| indegree | 0.04265 | 0.0153 | 0.0184 | 0.00625 | 17.16262 | 0.0007 |
| outdegree | 0.01 | 0.00 | 0.00 | 0.00 | 20.06676 | 0.0002 |
| value indegree | 0.02025 | 0.00354 | 0.00137 | 0.0004 | 28.37359 | 0.00 |
| value outdegree | 0.04415 | 0.001275 | 0.000808 | 0.000187 | 26.79625 | 0.00 |
| $\beta$-measure | 1.325 | 0.28 | 0.237 | 0.068 | 17.08241 | 0.0007 |

Table 6. This table presents average network indices for the banking system according to size. The Kruskal-Wallis (KW) statistic and it's p-value are provided in the last two columns. The KW tests whether the median indices for the network are equal.

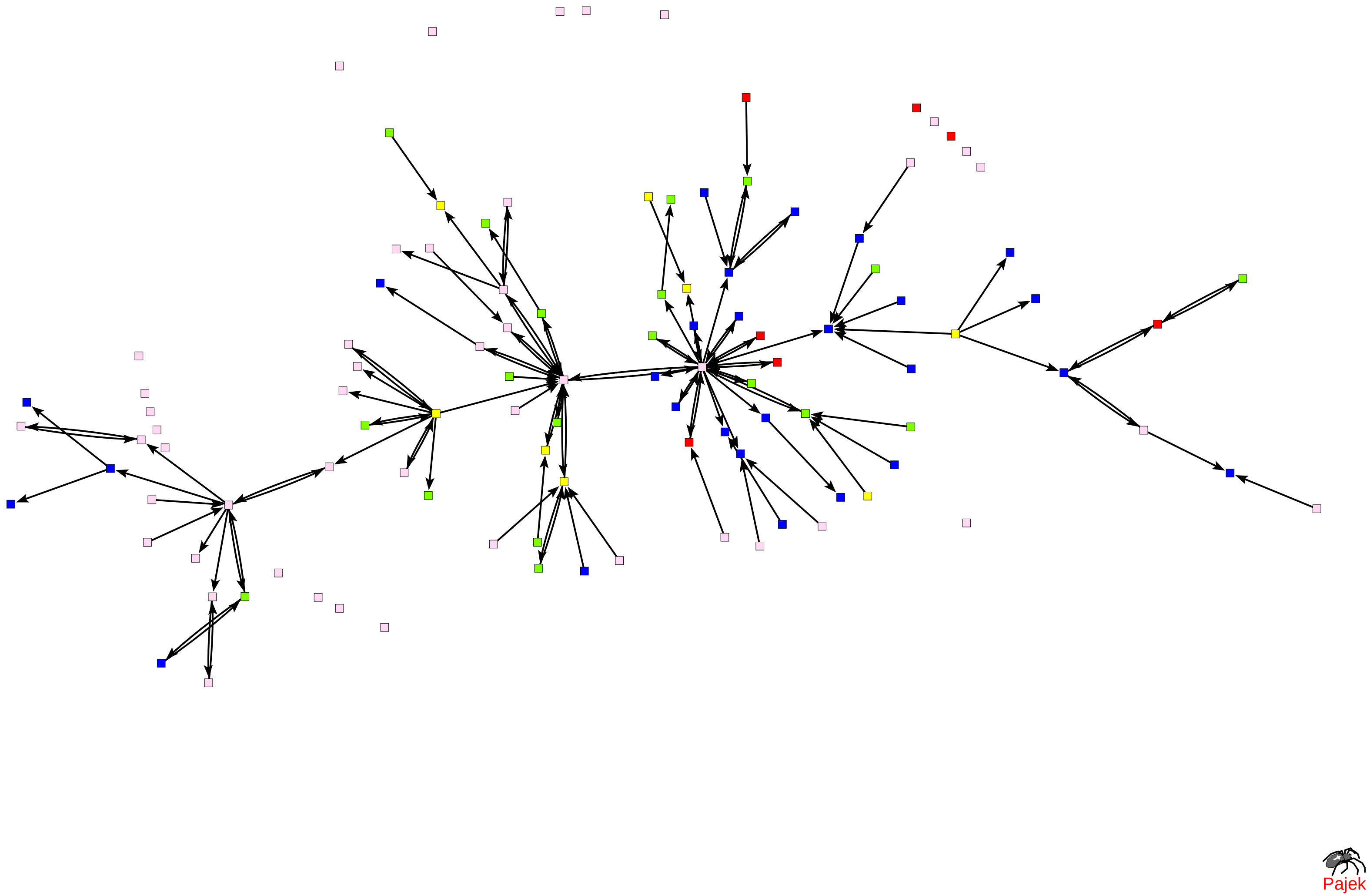


Fig. 1. Minimal spanning tree of the Brazilian interbank market. Here, different colors represent different activities: (Yellow) Retail; (Green) Treasury; (Red) Business; (Blue) Credit; (Salmon) Non-banks.

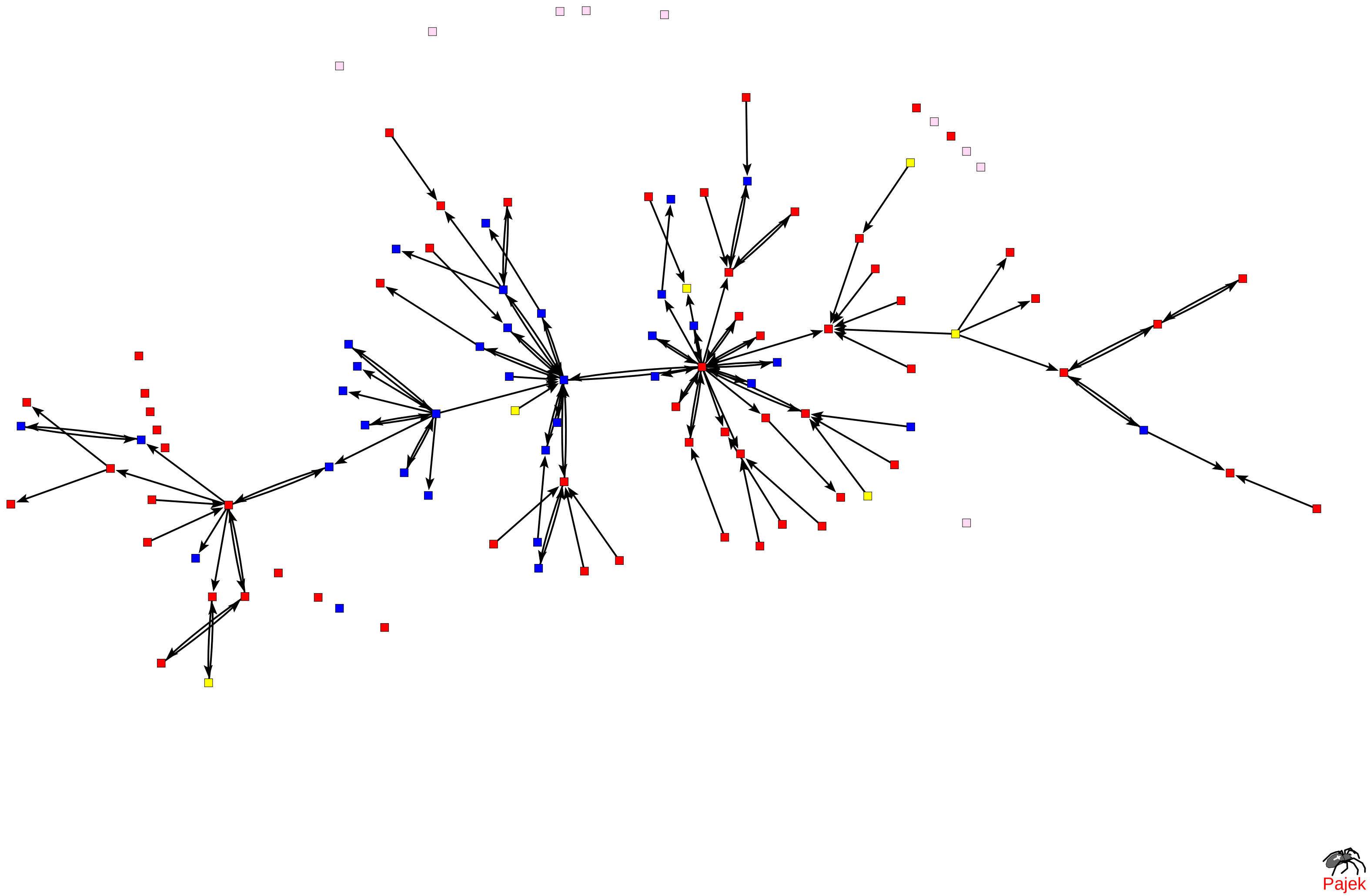


Fig. 2. Minimal spanning tree of the Brazilian interbank market. Different colors represent types of control:(Yellow) Public; (Red) Private; (Blue) Foreign; (Salmon) Non-banks.

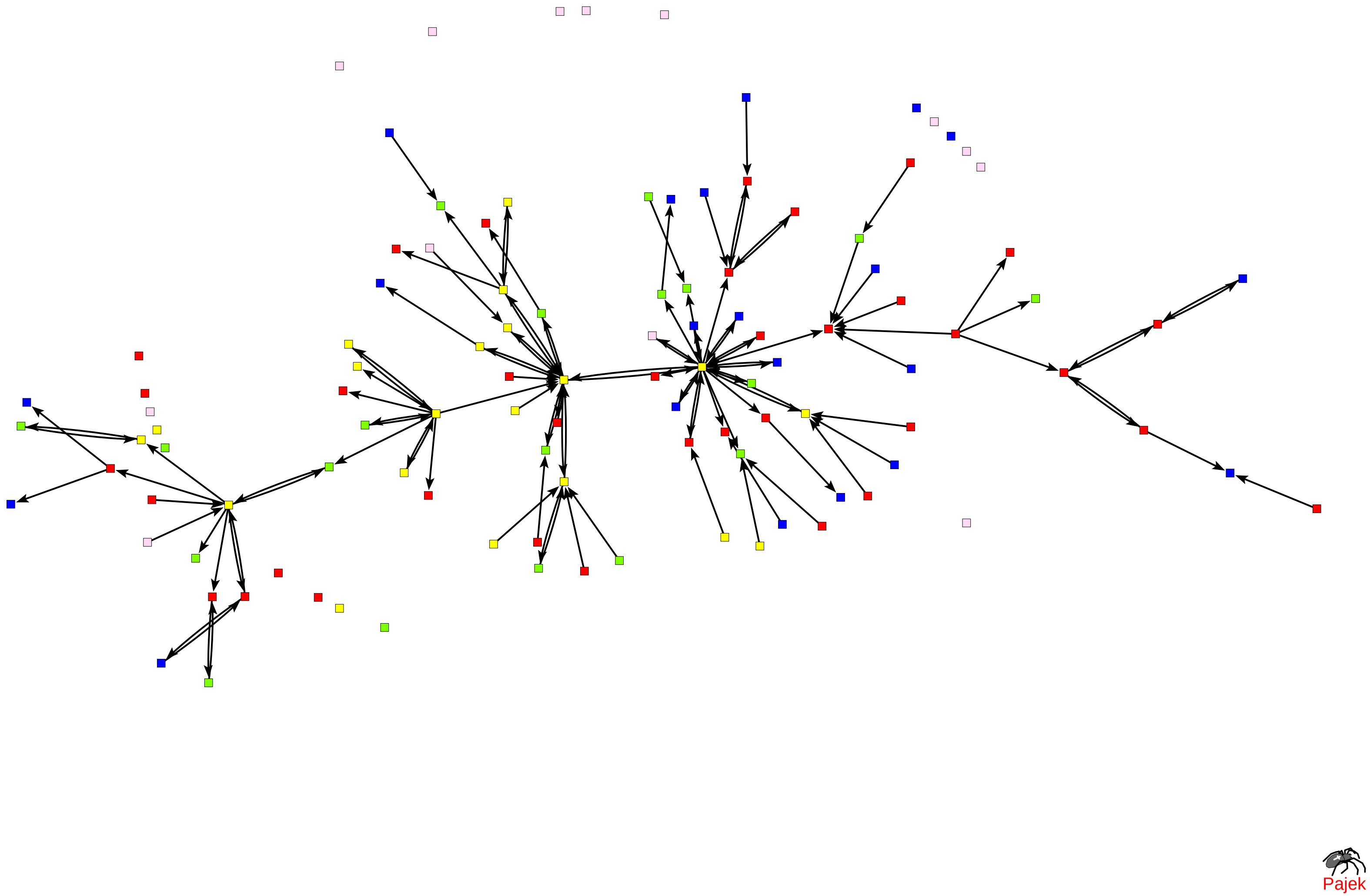


Fig. 3. Minimal spanning tree of the Brazilian interbank market. Different colors represent different sizes. (Yellow) Large; (Green) Medium; (Red) Small; (Blue) Micro; (Salmon) Non-banks.

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