DOMINO EFFECT IN THE HUNGARIAN INTERBANK MARKET

Ágnes Lublóy

Abstract

The paper deals with the systemic risk implications of the Hungarian interbank market. As a consequence of mutual interbank credits an initial failure of a bank can lead to subsequent failures. Among others this domino effect depends on the structure of the interbank market. The Hungarian interbank market is moderately concentrated and can be viewed as a structure with multiple money centres. Ten-fifteen big banks are playing the role of money centres, 60% of interbank transactions are settled among these fifteen banks, but in more than 95% of interbank transactions at least one partner is one of those fifteen banks.

The paper examines the effect of idiosyncratic bank failures based on a simulation methodology. The severity of contagion is measured by the number of first and second round bank failures, capital loss distribution of the banking sector and total assets of affected banks in percentage of total banking system assets. Different default definitions are used, market expectations and multiple failures of banks with same risk profile are also captured. Even under unrealistic scenarios the contagion is fairly limited both in absolute and relative terms, which can be mostly explained with limited interbank exposures of Hungarian banks.*

Keywords: interbank market, structure, contagion, domino effect, simulation

EFM classification codes: 130, 520, 570

---

* The paper is based on a research carried out at the Hungarian National Bank. The full paper can be read – in Hungarian – in the 2004/10 MNB Working Papers. (Lublóy [2004].) I am thankful to the staff of the Financial Stability Division of the Hungarian National Bank for their invaluable comments and help. I am also indebted to Júlia Király for helpful suggestions and discussions and to János Varga for his programming support. Any views expressed herein are my own and do not necessarily reflect those of the Hungarian National Bank. Author's address: Ágnes Lublóy, Corvinus University of Budapest, Institute of Finance, H-1093 Budapest, Fővám tér 6-8. Telephone: 0036-1-4825373, Fax: 0036-1-4825431. E-mail: agnes.luboy@uni-corvinus.hu.

1. Introduction

Macro prudential regulation of the banking system is playing a crucial role, the analysis of systemic events came to the front. The Hungarian National Bank (MNB) deals with the systemic risk implications of the banking sector since February 2001, in the Report on Financial Stability the Hungarian stress testing methodology was published. (Stress test… [2001].) The goal of the stress testing carried out by the MNB is to capture the ability of the banking sector to absorb different kind of shocks. However the model in not able to handle spill over and liquidity effects induced by the initial shock. In the closing remarks of the Stability Report the following was stated: "It may occur that the system-level lending and/or market risk is relatively moderate but, when the loss is concentrated among banks which are characterised by extensive interbank relations, then significant ripple-over effects may multiply the magnitude of the risk. Hence the mapping of interbank exposure would significantly enrich our knowledge of system-level risks. " (Stress test… [2001], p. 65.) The above cited sentences point out the systemic importance of the interbank market and the significance of the analysis of the network of mutual interbank credits.

A well functioning interbank market is playing an important role either in allocating liquidity on micro level or strengthening financial integration on macro level. Contagion in the interbank market can occur as a consequence of *insufficient aggregate liquidity*, spill over effects induced by market expectations and as a result of a collapse of a bank, which leads to domino effect. (Degryse – Nguyen [2004].) In the case of insufficient aggregate liquidity, which can be a consequence of several factors banks try to avoid the liquidation of their investments and withdraw first their interbank deposits. According to Allen and Gale [2000] as a result of this withdrawal, financial problems in one region or one bank can spread to other regions or other banks. In my paper I do not deal with this type of contagion. The second potential source of contagion is connected to the *channel of market expectations.* When one group of depositors face the withdrawal of other depositors, they also withdraw their deposits, which is motivated by the fear, that the later they withdraw, the less probable is that the bank can satisfy their claims. As a result, the market expectations can become self fulfilling. (Diamond – Dybving [1983].) Despite the significance of the topic I do not handle contagion related to bank panics and bank runs. *Mutual credit obligations* denote the third source of contagion. Under certain circumstances a failure of one bank can induce many other failures. In my paper I deal with this type of contagion, also called domino effect. If one insolvent or illiquid bank is not able to honour its interbank liabilities, could happen, that as a consequences of the non-repayment of interbank obligations the failing bank jeopardises the ability of creditor banks to meet their obligations. The initial non-repayment of interbank obligations can spread across the system, just like a domino-line collapses, when one of the dominos is fallen over. Whether the whole domino-line collapses, depends on the structure and the distance of the dominos. Similarly, the stability of the banking sector depends on the structure of the interbank market.

The severity of contagion depends on many institutional factors. At the level of the *individual banks* we can mention risk mitigation techniques, just like repurchase agreements, other collateralized loans, netting agreements and counterparty limits. *At the interbank market level* the structure of the interbank market influences the severity of contagion. According to Allen and Gale [2000] the structure of the interbank market can be complete, where banks are symmetrically linked to all other banks or incomplete, where banks are only linked to neighbouring banks. In their theoretical model they show, that complete market structures are less prone to contagion, however the level of connectedness is also important. Freixas, Parigi and Rochet [2000] distinguish another structure, named money centre. The money centre is symmetrically linked to other banks of the system, but those other banks are only linked together through the money centre.[1] In this case the failure of the money centre can cause subsequent failures. In banking systems multiple money centres could also exist, just like in Belgium. (Degryse – Nguyen [2004].) Another dimension of the structure of the interbank market is its dispersion. The exposures are dispersed if the interbank loans and deposits are equally spread over banks, which probably lead to lower contagion.[2] Finally, the last dimension of the interbank market is its concentration. However according to the literature the effect of concentration on contagion is not obvious. (Allen – Gale [2004], Carletti – Hartmann – Spagnolo [2003], Cifuentes [2003], Degryse – Nguyen [2004].)

The rest of the paper is organised as follows. In Section 2 the previous empirical literature is reviewed. In Section 3 the simulation methodology, just like the iteration-procedure of contagion, the necessary condition of the domino effect and the recovery rate is considered. In Section 4 next to the unique dataset key features of the Hungarian interbank market is presented and the structure of the interbank market is analysed on the basis of 50 days. In Section 5 results of the simulation are

[1] In Hungary the savings co-operative sector can be described as a structure with money centre. The role of the money centre is played by the Magyar Takarékszövetkezeti Bank (Takarékbank), as according to an agreement signed in October 1993, the savings co-operative institutions must put their free assets into the Takarékbank. (Katz [2003].)

[2] Formally this means that $x_{ij} = (a_i \cdot l_j) / \sum_{ij}^{NN} x_{ij}$, where x_{ij} is the interbank asset of bank *i* from bank *j*, a_i is the total interbank asset of bank *i*, and l_j is the total interbank liabilities of bank *j.* If the interbank exposures are dispersed, the relationship lending is ruled out.

summarized. Different default definitions are used, market expectations and multiple failures of banks with same risk profile are also captured. The severity of the contagion is measured by the number of banks failed, by the number of rounds in which contagion occurred and by the capital losses realised by the whole banking sector. In Section 6 drawbacks of the model are presented, then in Section 7 results of similar studies are compared. Section 8 concludes.

2. Literature review

The empirical models of contagion can be divided into three groups. One group of empirical models dealing with contagion put emphasis on different kind of macroeconomic shocks, just like the model of *Elsinger, Lehar and Summer [2002].* Authors assess the insolvency risk of banks for different scenarios of macroeconomic shocks, like interest rate shocks, exchange rate and stock market movements as well as shocks related to the business cycle. In each scenario banks face gains and losses due to market risk and credit risk, which influence the feasible payment flows between banks and net values of banks. The basic framework of the model is standard risk management techniques in combination with a network model of interbank exposures. The model explains feasible payment flows between banks endogenously from a given structure of interbank liabilities and net values of banks arising from all other bank activities. The model determines endogenously probabilities of bank insolvencies, recovery rates and a decomposition of insolvency cases into defaults that directly result from movements in risk factors and defaults that arise indirectly as a consequence of contagion. One of the contributions of the paper is a risk management model, which is able to handle that the probability of default vary greatly from bank to bank. However the model is based on special data sources, just like equity prices for banks, a major loan register or a database with time series of default rates for various industry branches. In many countries, including Hungary, this type of data is not available for researchers, as they simply do not exist.

The second group of empirical models concentrate exclusively on the impact of contagion and ignore shocks driven by macroeconomic factors. Researchers focus on credit risk associated with interbank lending, which may lead to domino effect, that is the failure of one bank results in failure of other banks not directly affected by the initial shock. Precise pattern of interbank linkages are also analysed, as recent works in economic theory suggest that risk of contagion depends on the structure of the interbank market. The main question of this second-type model is, whether due to the network of interbank exposures the failure of one bank can spread to other banks. These models can be viewed as stress tests, and solely capture the direct lending, that is the effect of non-repayment of interbank credits on the capital of creditor banks. Risks driven by the payment and settlement systems or cross holding of shares are ignored. Liquidity risk is also omitted. In my paper I also follow this analytical framework.

The study of *Furfine [1999]* exploits payment flow data from the Federal Reserve's large-value transfer system, Fedwire to simulate the impact of various failure scenarios. The data used uncover federal funds transactions on a bilateral basis. By means of a search algorithm Fufine identified bilateral positions of uncollateralized interbank loans, which represent a measure of interbank credit exposures. However, this measure is a pretty conservative measure, as according to Furfine it only captures approximately 14% of total interbank exposures. Between February and March 1998 the failure of the most significant bank, the failure of the second most significant bank, the failure of the 10th most significant bank and the joint failure of the two most significant banks are simulated. The risk of contagion is found to be economically small.

Upper and Worms [2002] used balance sheet information to test whether the breakdown of a single bank can lead to contagion. The analysis covers each 3246 German banks, and based on balance sheet data submitted to the Bundesbank every month. Both short and long term, and collateralized and uncollateralized assets and liabilities are considered. The matrix of the interbank exposures are estimated through an entropy optimalization procedure in two different ways. First aggregate balance sheet data is used and the dispersal of interbank assets and liabilities is assumed. Later the additional information given by the institutional categories and maturity breakdown of exposures are also taken into account.

Wells [2002] also focus on interbank exposures, as a possible source of direct contagion. The analysis is based on balance sheet data of UK-resident banks, that is UK-owned banks and branches or subsidiaries of foreign banks located within the United Kingdom. The data is collected regularly by the Bank of England. The simulation is conducted using exposures of 31st December 2000. Wells handle the 24 UK-owned banks individually, the remaining UK-owned banks are grouped together since they account for less than 1% of assets held by the UK banking system. The UK-resident foreign banks are grouped into 8 groups according to domicile. A matrix of bilateral exposures between these groups is estimated under two sets of stylised assumptions about how banks distribute their aggregate interbank lending and borrowing across other individual banks, or groups of banks. The first set of estimates assumes by ruling out the possibility of relationship banking that banks seek to spread their borrowing and lending as widely as possible across all other banks. The second model assumes that concentrations in the interbank market are reflected in the pattern of the large exposures data, which data detail the size and counterparty for each of the bank's 20 largest exposures and any other exposures exceeding 10% of its tier 1 capital.

Degryse and Nguyen [2004] investigate the evolution of risk and impact of interbank contagion based on balance sheet and large exposure data sources. Bilateral interbank matrices are estimated in three different ways. Next to the domestic interbank market composed of 65 Belgian banks the contagion exercise is extended to the foreign interbank market. Authors address the question whether contagion risk between Belgian banks evolved over time investigating the period from 1992 to 2002. Stress tests are used to capture potential anticipations by banks, expectations are incorporated by assuming that before the initial failure of a bank institutions are able to withdraw part of their interbank assets. As in the case of interbank loans the doctrine of "too-big-to-fail" may introduce implicit deposit insurance, Degryse and Nguyen also assumed that large Belgian banks would not be allowed to fail.

Table 1 summarises the features of data used in above mentioned previous papers. As the table shows the study of Wells [2002], Degryse and Nguyen [2004] contain not only the domino effect induced by a domestic bank, but also by foreign banks. The data obtained from Fedwire used by Furfine [1999] is the only one which is uncollateralized and bilateral although it is limited in scope.

Table 1: Features of data used

Author(s)	Institutions examined	Domestic vs. foreign banks	Sources of data used	Collateralized vs. uncollateralized transactions	Bilateral vs. aggregated data	Time
Craig Furfine	719 commercial banks (70% of total assets)	domestic	Interbank transactions realised through Fedwire	Uncollateralized	Bilateral	Febr.-March 1998
Christian Upper, Andreas Worms	3246 banks	domestic	Monthly data collected by the authority	Both	Aggregated	31. Dec. 1998
Simon Wells	24 big banks, the others are grouped into one group	foreign as well (8 groups)	Data collected by the authority, large exposures statistic	Both	Partly aggregated	31. Dec. 2000
Hans Degryse, Grégory Nguyen	65 banks	foreign as well (2 groups)	Data collected by the authority, large exposures statistic	Both	Aggregated	31. Dec. 1992 -2002. (two times a year)
Ágnes Lublóy	39 banks	domestic	Bilateral data collected by the National Bank	Uncollateralized	Bilateral	50 days in 2003

Finally, the third group of empirical models analyse the systemic risk of financial systems by applying results from general network theory. In this case the analysis relies on the idea that an interbank market can be interpreted as a network where banks form nodes and claims and liabilities between them define edges of the network. By using different measures from the network theory the empirical network structure of the banking system and the systematic relevance of different banks can be investigated. The main question of these studies is how the structure affects the stability of the network, that is, the stability of the banking system with respect to the elimination of a node in the network, i.e. a default of a single bank. (Boss et al. [2003], Müller [2003].)

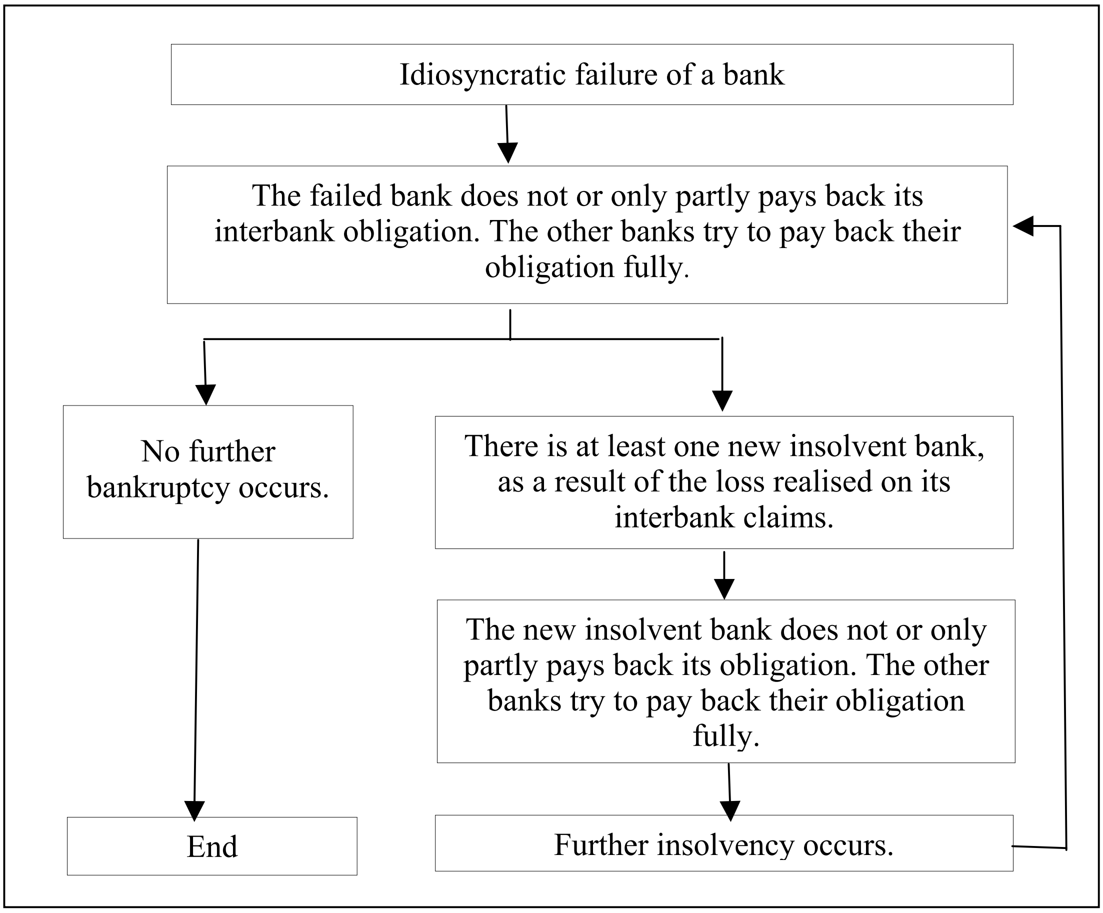
3. Simulation methodology

3.1. The procedure of contagion

Just like in the previous literature, the aim of this paper is to capture the domino effect of the interbank market related to mutual interbank credits. For this purpose simulation methodology is used. The research question is whether by assuming several recovery rates, failure of one bank would cause subsequent collapse of a large number of other banks. In order to capture the contagion effect only, the contagion is isolated from all kind of other macroeconomic shocks. In the base case of the simulation every bank goes bankrupt due to an idiosyncratic event, which means that the failed bank does not or only partly honours its obligation. One drawback of the model that because of the idiosyncratic nature of the initial failure the model can not capture the probability of different scenarios. Theoretically the loss given default can vary between 0-100%.

If there is no bank, which fails as a result of the initial failure, there is no contagion and the iteration stops. If there is contagion, which means that at least one other bank failed as a result of the initial failure, the bank failed in the first round of contagion does not or only partly pays back its liabilities. If there is no further contagion, the procedure stops. If there is again a bank, whose unpaid interbank claim is higher than its tier 1 capital, a second round contagion occurs. As a consequence of this second round contagion, further – third, fourth, etc. round – contagion can occur. The iteration starts from the beginning again, and stops if in the next round there is no insolvent bank. The methodology of the simulation is shown in Figure 1. The same simulation methodology was applied by Upper and Worms [2002], Wells [2002] and Degryse and Nguyen [2004], the effect of a failure by an individual institution is traced through the banking system.

Figure 1: The procedure of contagion



3.2. The necessary condition

The necessary condition for contagion to occur is that the realised loss suffered by a bank must be higher than the bank's tier 1 capital. Formally this means, that the idiosyncratic failure of bank *i* leads to contagion, if there exists any bank *j*, whose loss is higher than its c_j capital. The loss of bank *j* is equal to the product of x_{ji} exposure and θ loss given default.

$$x_{ji} * \theta \geq c_j$$

In the simulation in order to obtain internationally comparable results the c_j capital is equal to the value of the modified tier 1 capital of the bank *j*, given in the previous month. Thus, if for example the input for the simulation is the data of 20th March, the used capital is that of 28th February. The modification of the tier 1 capital is needed, as the main part of banks' profit after tax will be in form of net profit and general provisioning only part of their tier 1 capital after the general meeting and auditing. However the net profit is generated during the whole year. I modified the tier 1 capital of December 2002 with the cumulative profit after tax with the time proportionately. The dividend payment is also taken into account.

Precisely, I suppose that those 21 banks that did not paid dividend in the last three years will follow this practice in 2003 as well, and their whole cumulative profit after tax will be the part of their tier 1 capital. For those banks that have disclosed, but the general meeting has not accepted their dividend payment ratio (dpr), I acknowledge this preliminary ratio and the cumulative profit after tax is multiplied by (1-dpr). In the case of 8 banks that have paid dividend at least once in the last three years, I suppose that they will pay 35%, which is a proxy based on the average dividend payment ratio of the last three years. Thus the modification is equal to the 65% of the cumulative profit after tax. If profit after tax was negative banks' tier 1 capital is decreased by the bank's loss.

As a consequence of the failure of bank j bank k will go bankrupt if its loss, which equals the product of the sum of x_{ki} and x_{kj} exposures and the loss given default, is higher than its c_k capital. Generally, bank i fails if

$$\sum_j^N x_{ij} * \alpha_j * \theta \geq c_i$$

where α_j is a dummy variable. $\alpha_j = 0$, if bank j has not failed and $\alpha_j = 1$, if bank j has failed.

3.3. Loss given default

Another question to investigate is the value of θ, the loss given default. Based on previous studies Furfine [1999] refers to two different loss given defaults. According to James [1991] in the middle of 1980s in the United States the average value of θ was 30% of the book value of the banks' assets, and an additional 10% covered the administrative costs. Kaufman [1994] estimated a 5% loss given default based on the failure of Continental Illinois.

Upper and Worms [2002] referring to an article of Financial Times mention, that creditors preliminary assumed a loss given default of 90%, when the BCCI went bankrupt in 1991. According to an article of Frankfurter Allgemeine Zeitung several decades after the failure, creditors of Herstatt recieved 72% of their claims. Upper and Worms point out, that these examples show that it may not be the actual losses borne by the creditor banks that matter, but the expected losses at the moment of failure. Fundamentally the expected losses determine to which extent the exposure to the failing bank has to be written down, hence whether the creditor bank becomes technically insolvent or not.

In addition to the empirically observed loss given defaults it is worth mentioning the guidance provided by the revised Capital Accord of Basel II. Under the foundation IRB approach banks should only estimate internally the probability of default, a loss given default of 45% is set for senior claims on banks not secured by recognised collateral. For subordinated claims on bank a 75% LGD is assigned. (Basel II… [2004], 287-88. §.) If a transaction is covered with eligible financial collateral the Committee allows for the modification of the above mentioned loss given defaults. (Basel II… [2004], 289-294.§.)

We also can find defaulted banks in Hungary. The Ingatlanbank failed in 1991, the Ybl Bank in 1992, the Innofinance was liquidated in 1994. The Leumi Hitel Bank was carried through the market in 1995, the Iparbankház in 1996. Finally the Realbank was liquidated in 1998. (Várhegyi [2002].) After data collection and analysis a case study could be conducted to estimate a loss given default from the previous Hungarian failures. However given the limited number of bank failures, one could easily question the accuracy and soundness of the result. As the uncertainty about the proper value of the LGD would not diminish significantly I conduct my analysis in a similar manner than Furfine [1999], Upper and Worms [2002], Wells [2002], Degryse and Nguyen [2004]. However previous authors presented their results for a range of loss given defaults. In my paper due to the limited contagion effect I only assume a 100% LGD, and rather calculate the break even point of the loss given default.[3]

4. The Hungarian interbank market

4.1. The key features of the Hungarian interbank market

In developed countries in the interbank market there are three main types of interbank transactions: foreign exchange swaps (FX swaps), uncollateralized interbank transactions and repurchase agreements (repos). The turnover of the Hungarian interbank money market is growing form year to year, however less dynamically. Balogh and Gábriel [2003] argue in their study about the Hungarian interbank money market past and future trends that the market is dominated by FX swaps. In the second half of 2002 the turnover of FX swaps was two times higher than the turnover of uncollateralized interbank transactions. In Hungary the role of repos is fairly limited, however in the countries of EU15 since 2001 the repo market is the most significant segment. In Hungary the volume of collateralized interbank transactions (excluding repos) is also limited, in 2003 the daily average accounted for

[3] It is worth mentioning that netting agreements, an effective prudential regulation – by means of limiting the amount of (interbank) exposures, – and internal limit systems of the banks can lead to lower LGDs.

1,25% of the total volume of interbank exposures. However due to the general liquidity surplus of the banking system the market of central bank deposits with original maturity of one night or two weeks is pretty important in Hungary, as in many cases banks prefer passing part of their liquidity to the central bank. According to Balogh and Gábriel [2003] in 2003 central bank deposits accounted for one third of total interbank transactions.

In my paper I only deal with uncollateralized interbank transactions denominated in Hungarian forints and settled between Hungarian banks.[4] Foreign exchange swaps, repos and collateralized transactions are ignored. Due to data limitations interbank exposures denominated in foreign currencies and transactions settled with foreign banks are also excluded from this analysis. Financial experts argue that the volume of interbank exposures denominated in foreign currency is limited. Because of the counterparty limits set by banks institutions prefer not to contract in foreign currency, limits are hold for forint transactions. Additionally majority of the Hungarian banking sector is owned by foreign banks, and in several cases foreign exchange transactions with the mother bank are compulsory. According to the estimation of Balogh and Gábriel [2003] in 2002 about 15-20% of the uncollateralized transactions of the Hungarian banks are settled with foreign banks. However, it can happen that the distribution of this 15-20% is much more concentrated. A study by Manna [2004] shows, that cross border interbank transactions are mainly settled with neighbouring countries.

The data presented in this paper is from the FED database of the Hungarian National Bank. The data contains from May 2001 onwards all transactions denominated in forints and settled between Hungarian banks. Hungarian banks should report every day the volume of their transactions, their counterparty bank, the opening and the closing day of the transaction, the interest rate and the type of the transaction, which can be deposit or loan, and collateralized or uncollateralized. It is worth mentioning, that the data used is unique. In many European countries, just like Switzerland, Germany, United Kingdom or Belgium only aggregate exposures were given. (Sheldon and Maurer [1998], Upper and Worms [2002], Wells [2002], Degryse and Nguyen [2004].)

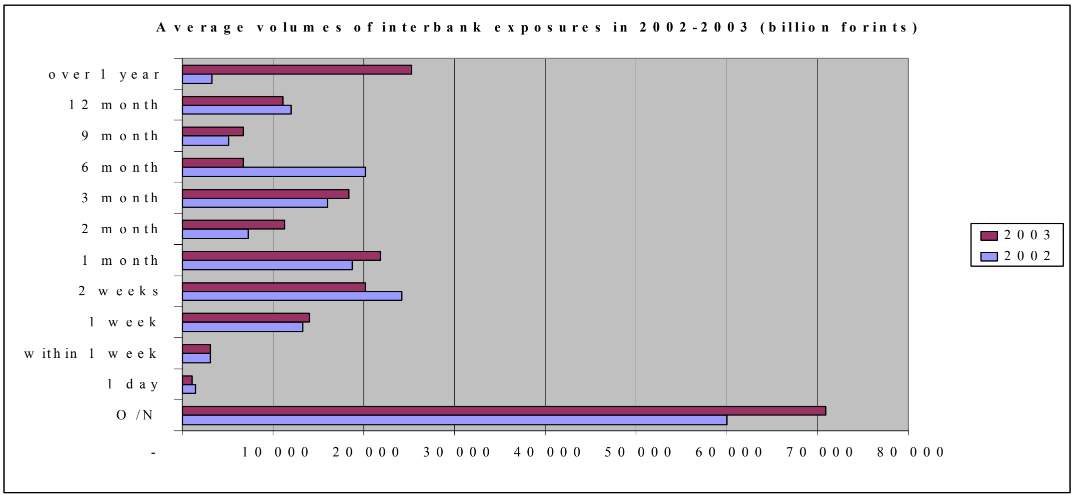
In spite of the present regulatory practice the analysis includes the Hungarian Development Bank (MFB) and the Export-Import Bank (Eximbank). On one hand the Hungarian Government guarantees the liabilities of MFB and Eximbank. On the other

[4] As a consequence, if not noted otherwise, when I refer to interbank transactions I mean uncollateralized interbank loans and deposits.

hand this guarantee is partly limited. Additionally as MFB and Eximbank could be significant institutions in the interbank market the exclusion of those two banks could bias the analysis of the interbank market structure and its systemic risk implications. Finally, as we have seen in section 3.3, the expected losses in some cases are more important than the realized losses. A long juridical debate about the insolvency and bailing out of MFB and Eximbank could result meanwhile in technical insolvency of other banks.

Figure 2 shows the pretty volatile volume of the average interbank assets[5] in 2002 and 2003 calculated from daily data. The average volume of the uncollateralized interbank assets was 184,4 billion forints in 2002, which increased to 208,7 billion forints in 2003, which accounts for 1,89 and 1,71% of total assets. Uncollateralized interbank assets total up to 19,64 and 19,05% of the modified tier 1 capital of the banking sector. Shown in Figure 2 interbank transactions are dominated by overnight transaction, but the amount of transactions with original maturity of one week, two weeks, one month and six months are also important. In 2003 there is a jump concerning the amount of transactions with maturity longer than one year, which is surprising in the light of the literature, which suggests that interbank transactions serve for liquidity management. However this deviancy can be explained basically with high volume of interbank assets of two banks, the Hungarian Development Bank and a "niche" bank mostly providing consumption loans.

Figure 2: Average volumes of interbank exposures

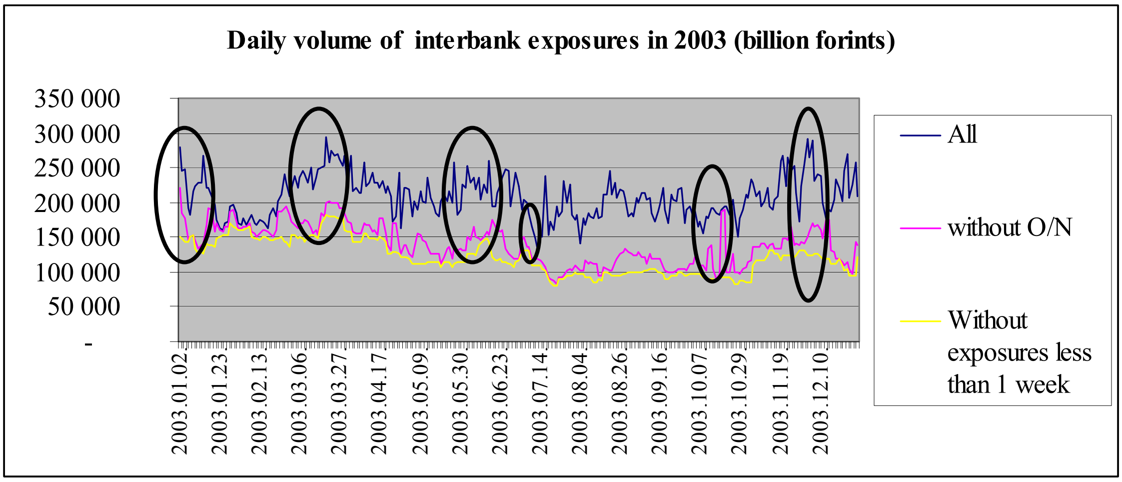


Source: FED database, Hungarian National Bank.

[5] Obviously, in this case the volume of the interbank assets equals to the volume of the interbank liabilities.

Figure 3 shows the volume of interbank assets for the working days of 2003. The maximum is reached in the middle of March, when not only the volume of total interbank assets is the highest, but the volume of overnight transactions, and transactions with maturity less than one week as well. However concerning the high volume of interbank assets, we can not say anything about the internal structure of those assets and its systemic risk implications. The distribution of lower volume of interbank transactions could be concentrated and as a result the probability and severity of domino effect could become more significant. For simulation purposes I selected six periods, containing altogether 50 days, which covers 20% of the working days.

Figure 3: Daily volume of interbank assets in 2003



Source: FED database, Hungarian National Bank.

In Figure 3 the selected turbulent and less turbulent periods are marked. The data of these days – 7-20 January, 19 March – 1 April, 13-26 June, 9-15 July, 15-20 October, 2-13 December – serves as an input for my simulation. The four ten-day periods are grouped among the days, where the volume of total interbank assets reached 250 billions, while the two five-day periods include days, where the volume of interbank assets was low.

4.2 The structure of the interbank market

One important dimension of the structure of the interbank market is the concentration of exposures, which can be measured by the market share of the most significant banks and by the Herfindahl-Hirschman index.

The concentration of the Hungarian interbank market is examined on the basis of the selected 50 days. Table 2 shows the minimum, mean and maximum of the cumulative market share of the most significant banks. As a consequence of the volatility of exposures and the dominance of transactions with short term maturity during the 50 day period the most significant institutions vary among different banks. The concentration of interbank assets and liabilities is nearly the same. Both in the asset and liability side the three most significant institutions cover 45% of the market, the five most significant banks own about 60%, meanwhile the ten most significant banks cover 80% of the market. In both market segments the fifteen most active institutions acquire more than 90% of the interbank market. Several banks share less than 1% of the market. Concerning interbank assets 7 banks did not settle any transaction, while on the interbank liability side 10 banks did not made any contract.

Table 2: Concentration in the Hungarian interbank market

Concentration in the intrbank mareket	Assets			Liabilities		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Market share of the 3 biggest banks	35,24%	45,16%	60,30%	36,65%	45,12%	51,78%
Market share of the 5 biggest banks	49,55%	58,50%	71,59%	49,38%	59,48%	67,41%
Market share of the 10 biggest banks	71,78%	78,94%	86,70%	72,59%	80,90%	87,27%
Market share of the 15 biggest banks	85,18%	90,30%	94,41%	87,74%	92,23%	96,85%
Market share of the 20 biggest banks	93,72%	96,76%	99,26%	94,88%	97,66%	99,72%

Source: FED database, Hungarian National Bank.

Based on the selected 50 days the market share of the biggest interbank lender is 23% on average, meanwhile the second most significant lender owns 12% of the market. There are two big banks with market share of 7,5% and 6%. In this way the four biggest bank owns circa 50% of the market, all with a strong residential customer base. On the other side, the market share of the biggest interbank borrower is above 20%. At the same time the second most important borrower has 10% of the market. The third biggest market player owns 8,3% of total interbank liabilities. The market share of two other big banks exceed 5% with their 7,5% market share.

Using the data of the selected 50 days the Herfindahl-Hirschman index (HHI) was calculated. The index shows the sum of the squares of the individual banks' market share. On the market of interbank asset the maximum of the HHI was 1581, on average 1045 and never fall under 729. Concerning the market of interbank liabilities the concentration is a bit lower, the maximum of the HHI was 1283, the mean accounted for 988, the minimum for 699. According to the Horizontal Merger Guidelines of the Hungarian Competition Authority the market is not concentrated if its HHI is under 1000, the market is moderately concentrated if its HHI is between

1000 and 1800, and the market is highly concentrated if its HHI is above 1800. In the highlight of numbers both segment of the Hungarian interbank market is moderately concentrated. (Horizontális Együttműködési… [2001].)

For further analysis of the structure of the interbank market and the domino effect bilateral interbank positions should be examined. Interbank assets and liabilities can be best captured by a matrix, shown in Figure 4. In the case of N domestic banks we get a matrix of N rows and N columns. The matrix *X* shows the bilateral exposures of banks, where x_{ij} is interbank assets of bank i from bank j, a_i is total interbank assets of bank i, and l_j is total interbank liabilities of bank j.

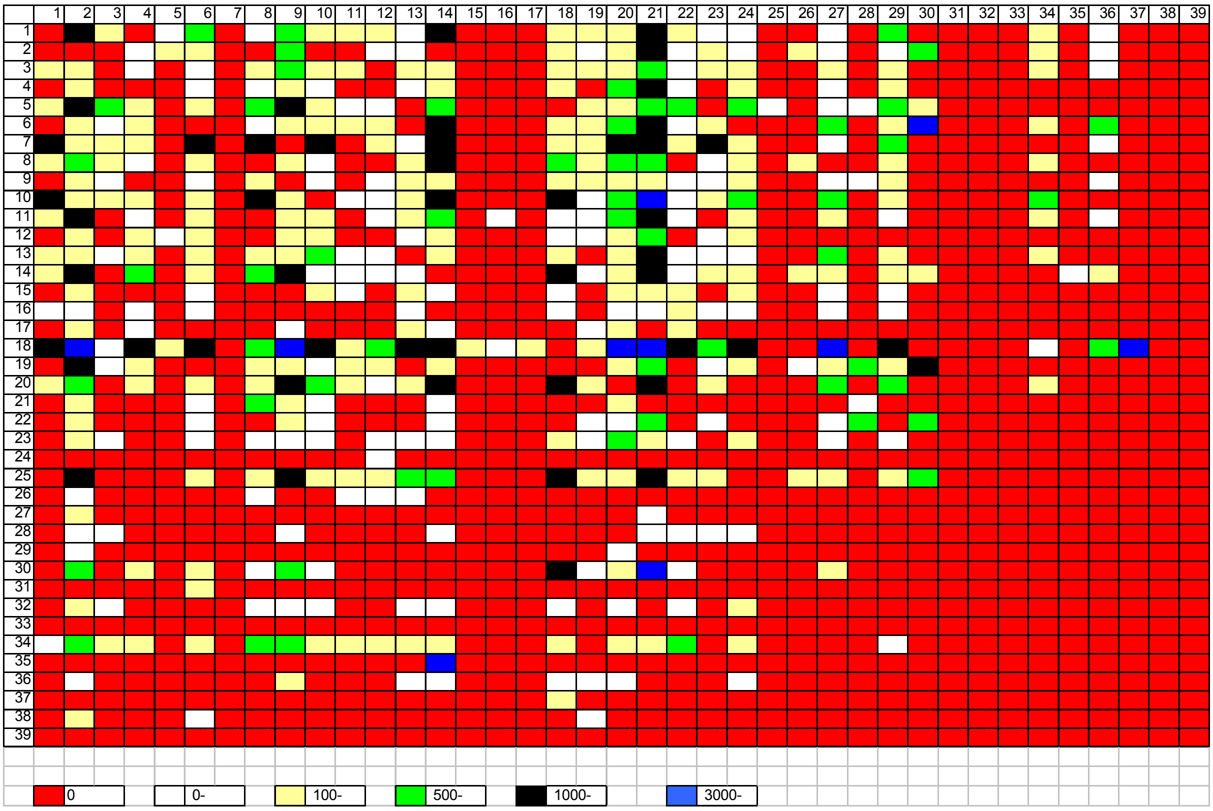
Figure 4: Matrix *X* of interbank exposures

Matrix X	1 2 3 … j … N	$\sum_j^N x_{ij}$
1		
2		
3		
…		
i	x_{ij}	a_i
…		
N		
$\sum_i^N x_{ij}$	l_j	

As bilateral positions of individual banks can not be disclosed Table 3 shows by means of six intervals the average size of interbank assets and liabilities for each bank. Banks are numbered from 1 to 39. For example the green cell in the intersect of first row and sixth column shows that the sixth bank borrowed funds from 500 to 1000 million forints on average from the first bank. The matrix indicates that many banks have no interbank assets or liabilities at all. 68,9% of the matrix equal zero, in 1021 from the potential 1482 interbank relations banks did not settle any transaction at all.[6] The Hungarian interbank market is not complete, there are many banks who do not transact with each other. In 9,3% of potential relations bilateral interbank exposures range an average from 0 to 100 million forints. In 15,2% of potential relations the average interbank exposure is between 100 and 500 million forints. Bilateral interbank exposures between 500 and 1000 can be found in 3,4% of potential relations. In 2,6% of potential relations bilateral interbank exposures range an average from 1000 to 3000 million forints. Average exposures higher than 3000 million forints can be found in 9 cases, representing 0,6% of potential relations.

[6] The number of potential relations is (39 * 39) - 39 = 1482, that is number of rows multiplied by the number of columns minus the number of elements in the diagonal, as a bank can not have interbank assets or liabilities from itself.

Table 3: The matrix of the Hungarian interbank market (Based on the selected 50 days from 2003, in million Forints)



Source: FED database, Hungarian National Bank.

In order to assess the structure of the Hungarian interbank market from an other point of view Table 4 presents the distribution of interbank assets and liabilities by means of banking groups. The 50 day average of interbank positions accounted for 251,7 billion forints in total. Banking groups are based on the asset size. The first group contains the five biggest banks, the second group from the 6th to 10th biggest banks, and so on. As the Hungarian banking sector consists of 39 banks, the last group only contains four banks. The value of 5,49% in the intersect of the second row and fourth column for example shows that 5,49% of the total interbank assets/liabilities are between banks of the first and third banking group.

By virtue of Table 4 the concentration of interbank assets and liabilities is interesting. On the asset side the market share of the first group is 47,32%, while on the liability side only 22,79%. This anomaly can be explained by the fact, that the banks of the first group funded a bank with a special role in the second group. Generally, on the liability side the market is more concentrated, than on the asset side. We can also see from Table 4 that there are only six relations from the 64, where the market share is higher than 5%. More than half of the interbank exposures are related to these six relations. In four cases this can be explained by liabilities of banks of the first banking group, while in two cases with liabilities of banks of the third banking group. We can find more than 1% higher market share in 17 cases, which covers altogether 36% of the market.

Table 4: Interbank market share of different banking groups

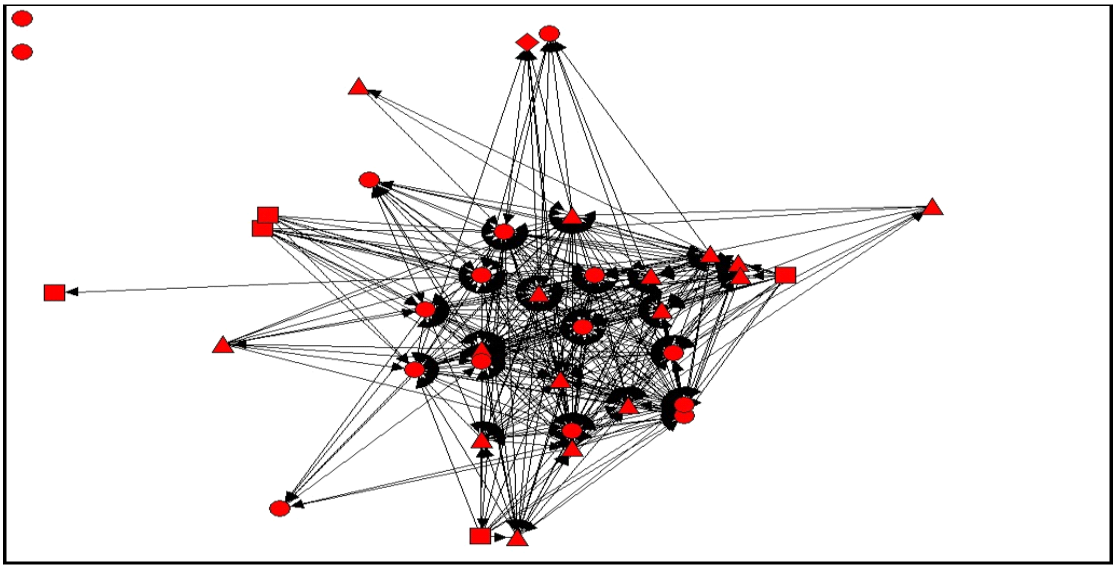
	1	2	3	4	5	6	7	8	Total assets	Cumulated assets
1	**8,32%**	**20,94%**	**5,49%**	**5,92%**	3,05%	3,06%	0,55%	0,00%	**47,32%**	**47,32%**
2	2,16%	2,37%	1,13%	0,57%	0,70%	0,05%	0,16%	0,06%	**7,21%**	**54,53%**
3	**5,63%**	**5,90%**	3,09%	2,05%	2,14%	0,00%	0,18%	0,00%	**18,99%**	**73,52%**
4	1,28%	1,69%	0,65%	0,65%	0,50%	0,34%	0,00%	0,36%	**5,47%**	**78,99%**
5	2,20%	2,88%	1,31%	1,26%	0,82%	0,86%	0,04%	0,29%	**9,66%**	**88,64%**
6	1,47%	3,64%	0,38%	0,45%	0,13%	0,00%	0,00%	0,00%	**6,07%**	**94,71%**
7	1,54%	1,72%	0,44%	0,51%	0,27%	0,29%	0,09%	0,00%	**4,86%**	**99,57%**
8	0,19%	0,06%	0,05%	0,12%	0,01%	0,00%	0,00%	0,00%	**0,43%**	**100,00%**
Total liabilites	**22,79%**	**39,20%**	**12,54%**	**11,53%**	**7,63%**	**4,59%**	**1,02%**	**0,71%**	**100,00%**	
Cumulated liabilities	**22,79%**	**61,99%**	**74,52%**	**86,05%**	**93,69%**	**98,27%**	**99,29%**	**100,00%**		

Source: FED database, Hungarian National Bank.

According to Table 4 the Hungarian interbank market can not be described with any clear structure. We come to the same conclusion if we group banks by their interbank importance, where the most important bank is the bank with the highest average asset and liability position. The structure of the interbank market is surely not complete, as there are many banks, with no interbank transactions. The structure of the interbank market is similar to a multiple money structure. The role of money centers are played by 15 big Hungarian banks, where money centers are linked either to other money centers or to other banks. The multiple money center structure of the Hungarian interbank market coincides with the experience of treasurers. In the opinion of financial experts in the interbank market there is a friendly, informal relationship among ten-fifteen banks. The market of this inner circle can be described with the principle of reciprocity. That is, if one of the counterparty banks requires additional liquidity, the others try to provide it under fair conditions and vice versa. 60% of interbank transactions are settled among the 15 largest bank, while in 95% of transactions at least one of the partners is among those 15 banks. However, if we compare the structure of the Hungarian interbank market with the Belgian interbank, we come to the conclusion, that the Belgian market is more similar to a multiple money center structure. Among the four largest Belgian bank – owning 85% of total banking assets – circa 35% of interbank transactions are settled, and in 90% of the transactions at least one of the partners is among those four banks. (Degryse – Nguyen [2004].)

However the structure of the interbank market is similar to a multiple money centre structure, it could be an excessive statement that in a banking system of 39 banks there are ten-fifteen money centres. In Figure 5 the graph of the Hungarian interbank market was prepared in UCINET from Analytic Technologies, which is a software used in social network analysis. (Borgatti – Everett – Freeman [2002].) The input data composed of a matrix showing bilateral interbank positions based on the turnover data of uncollateralized interbank transactions form year 2003. Two banks are situated in the left upper corner of Figure 5, those banks had no interbank transactions in 2003.

Figure 5: The graph of the interbank market



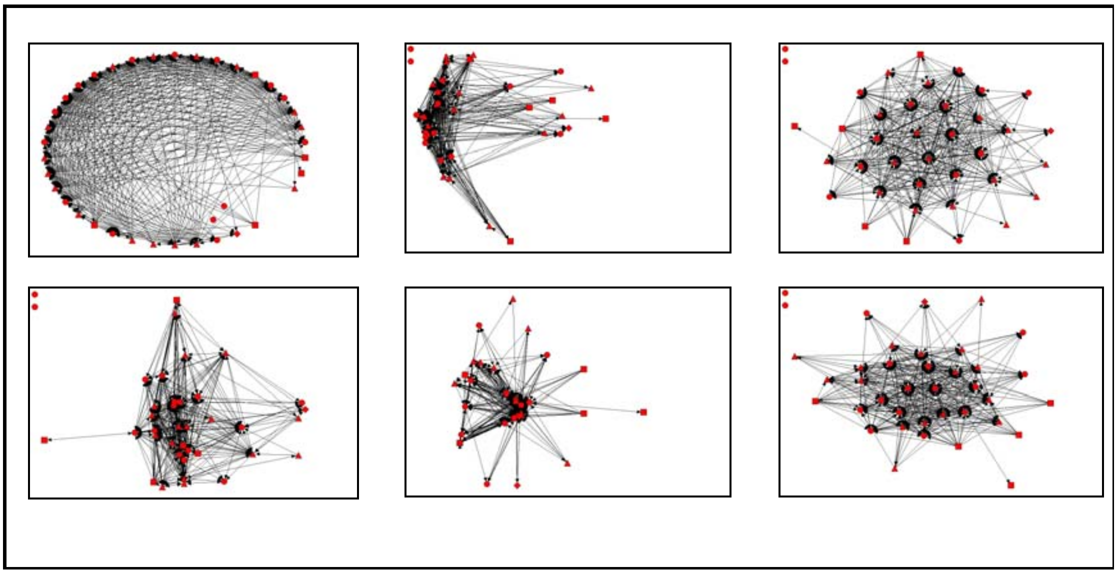
By virtue of Figure 5 half of the banks are strongly connected to each other, meanwhile the other half of the banks have relationships with few banks in the centre. As the graph is directed the figure also shows whether a bank is solely a borrower or lender in a given relationship. If the arrow points from bank *A* to bank *B*, it means that in 2003 solely bank *A* deposited its liquidity surplus at bank *B*. If the arrow points back and forth, than not only bank *A* deposited its liquidity surplus at bank *B*, but bank *B* also passed its liquidity surplus to bank *A*. In Figure 5 five banks are marked with square, which means that they were in every relationship net lender.[7] 16 banks marked with triangular was not in every relationship a net lender, but altogether the

[7] If a bank is marked with a square the arrows can point back and forth, which means that the bank not only lent to an other bank, but also borrowed money from that bank. However concerning the net bilateral interbank position of the banks, the bank marked with a square lent more funds, than borrowed.

bank lent more funds than borrowed. Banks marked with circle were altogether net borrowers. There is only one bank marked with diamond that was net borrower in every relationship.

Interbank assets and liabilities of the 39 Hungarian banks could be best captured in a 39 dimensional frame of reference. However the 39 dimensional frame of reference has many possible projections in two dimensions. 6 of them are shown in Figure 6.

Figure 6: Additional graphs of the interbank market



After the analysis of the structure of the Hungarian interbank market it is still an open question how the above mentioned money centre structure influences the probability and the severity of contagion. The results of the simulation exercise are presented in Section 5.

5. Simulation results

5.1. Base case

In the base case 1950 different scenarios were simulated.[8] A bank failed if it lost its modified tier 1 capital totally. The loss given default was 100%. One could argue that a 100% loss given default is unlikely high. However, if the number of contagious failures is still limited under this unrealistic assumption, than systemic risk implication of the Hungarian interbank market is surely also limited.

[8] 50 days x 39 banks = 1950 scenarios.

First round contagion occurred only in 11 cases, that is 0,55% of the scenarios. There was no second round contagion. The 11 first round contagious failures were due to the failure of a head institution of a banking group, which caused the failure of its subsidiary.[9]

In the worst case scenario, on 19th March, – one of those days, when contagion occured – the banking system lost 3,53% of its tier 1 capital. This is shown in the second and third column of Table 5. 9 banks suffered losses less than 10% of their tier 1 capital. Two banks lost between 10 and 20, and between 20 and 50% of their tier 1capital respectively. However the affected two banks account only for 3,88 and 1,61% of total assets of the banking system. The systemic importance of the failed bank is limited.

Table 5: The losses realized by the banking sector on 19th and 21st of March

	19th March		**21st March**	
Realized losses (in the percentage of the tier 1 capital)	**Number of banks**	**In percentage of total banking system assets**	**Number of banks**	**In percentage of total banking system assets**
ss than 10%	9	49,77%	12	71,96%
etween 10-20%	2	3,88%	1	0,49%
Between 20-50%	2	1,61%	4	4,75%
	0	0,00%	1	5,61%
Default	1	0,23%	0	0%

The break even point of the loss given default is 45,72%, which means, that if loss suffered by the subsidiary is less than 45,72% of its total exposure the subsidiary would not fail in the first round.

During the examined 50 days, the banking sector lost 0,53% of its modified tier 1 capital on average. However, it is worth mentioning, that on many days the banking sector realized losses higher than 3,53% of its tier 1. The highest losses, 7,58% of the tier 1 capital were realized on 21st March, when a big Hungarian bank failed. In this case the weakening of the banking sector is shown in the last two columns of Table 5.

[9] In Hungary there are three banking groups with a subsidiary: to the HVB Bank Hungary group belongs the Hypovereins Morgagebank, the Konzumbank is owned by the Magyar Külkereskedelmi Bank, and the Merkantil Bank, the OTP Building Society and the OTP Morgagebank belongs to the OTP group.

5.2. Modified default definition

Concerning this fairly limited contagion, I *modified the default definition* according to the Hungarian prudential regulation. In this case also systemic risk implications of an initial idiosyncratic failure were analyzed. However in this scenario contagious failure occurs if there exists at least one bank whose capital adequacy ratio falls below 4%. The initial definition of default is modified, now a bank fails if its regulatory capital is less than half of the minimum capital required. In the base case a bank defaulted if it lost 100% of its tier 1 capital, now a bank defaults if it operates with an insufficient regulatory capital base. At the majority of the banks the capital available for losses decreased, at the level of the banking sector by 30%, however in some cases even by 50-65%. However there exist several banks whose capital available for losses increased, as their tier 1 capital was lower than the difference between their actual regulatory capital and half of the minimum capital required.

Given a 100% LGD first round contagion occurred in 51 from the 1950 cases, that is 2,62% of the scenarios. Second round contagion never occurred. 43 first round contagious failures were due to the failure of a head institution of a banking group, which caused the failure of its subsidiary. Two contagious failures can be explained by an idiosyncratic failure of a big bank, a small bank failed on two different days. Five events of contagion are related to the failure of four different big banks, whose default caused the bankruptcy of two medium banks. In one case, a failure of a small bank led to a failure of a medium bank. Concerning the evolution of contagion over 2003, – neglecting the frequent failure of the subsidiary – contagion is still fairly limited and random. In January and June contagion occurred two times, in October one times, and in December three times.

On average the banking system lost 0,80% of its capital maximum available for losses,[10] the sector realized the highest loss, 10,87% on 21st of March. Concerning those days, when contagion happened, the maximal loss was 8,33%, the minimal 0,66%, and the mean 2,47%. The banking sector suffered the highest capital losses on a day, when no contagion occurred. Table 6 demonstrates the capital losses realized by the banking sector. The second and third column show the worst case scenario when contagion occurred. The fourth and fifth column show the distribution of capital losses in the absolute worst case, no contagion occurred, but the banking sector lost 10,87% of its capital.

[10] The capital maximum available for losses is the difference between the actual regulatory capital and half of the minimum capital required. If a bank's loss equals the capital maximum available for losses than the capital adequacy ratio is definitely 4%. It the bank's loss is higher than this, than the bank defaults as it capital adequacy ratio falls below 4%.

Table 6: The distribution of capital losses on 21st March

	Worst case			
	When contagion occured		When no contagion occured	
Realized losses (in the percentage of capital maximum available for losses)	**Number of banks**	**In percentage of total banking system assets**	**Number of banks**	**In percentage of total banking system assets**
Less than 10%	6	33,83%	10	66,74%
Between 10-20%	3	27,54%	3	5,71%
Between 20-50%	4	9,12%	4	6,02%
Above 10%	0	0,00%	1	5,61%
Default	1	0,23%	0	0%

The break even point of LGD is 68,69% in the case of the failure of the head institution of the banking group, while in other cases it is less, than 11,5%.

5.3. Market expectations

In reality the failure of a bank is not a sudden, unexpected event, it is rather a result of a process, e.g. bad credit policy. As a consequence, other banks can limit or even partly withdraw their interbank claims. By building this kind of *market expectation* into the model, I assume that the initially failed bank does not have any interbank obligation with original maturity less, than one week. This is basically the result of the behavior of market participants, who do not provide longer term loans to the bank which is to default. This part of the analysis focuses solely on those 51 scenarios, where contagion occurred.

Given a 100% LGD, and the modified default definition, contagion occurred only in 9 cases from the 51, mostly due to short term, 14 day claims. All of the contagious failures are related to the failure of the subsidiary. On the other hand this means, that all other contagion was a consequence of interbank exposures with original maturity less than one week. Having a further look at Figure 2, this is not surprising, as about 40% of the interbank exposures have an original maturity less than one week.

5.4. Multiple failures

Additionally I captured instead of the effect of an idiosyncratic failure the *effect of multiple bank failures with same risk profile*. Scenarios of joint failures are based on exposures stemming from concentrated credit portfolios, just like extended real estate project financing credits, agricultural credits and credits to financial enterprises.

The market of *real estate project financing* is fairly concentrated, two major banks own 50% of the market. Credits extended to the real estate sector account for 14% of total assets in both cases. The volume of real estate project financing credits is two times higher than banks' capital available for losses.

Assuming 100% loss given default, the joint failure of the above mentioned banks generated further contagion. Contagion occurred on 43 from the 50 days in the first round. However, just like under the assumption of modified default definition each failure was related to the initial failure of the head institution of the banking group. Second round contagion never occurred. The banking sector lost 3,03% of its capital maximum available for losses on average. The sector realized the highest loss, 9,67% on 21st of March. On the level of individual banks the highest loss measured by the capital maximum available for losses varied form 0% to 319,4%. The average of the ratio was 7,64%.[11]

Concerning the market of *agricultural credits* the four most significant creditors have nearly 70% market share and the three most significant banks own circa 60% of the market. In the case of three significant market player the agricultural credits account for 5-6% of total assets. In the case of two banks the volume of agricultural credits is significantly, nearly three times higher than the banks' capital available for losses. The scenario is based on the joint failure of the above mentioned two banks.

Contagion occurred only in two cases, on 12th and 13th of December, when a medium bank failed on two different days. The banking sector lost 3,07% of its capital maximum available for losses on average, the sector realized the highest capital loss, 6,83% on 4th of December. On the level of individual banks the highest loss measured by the capital maximum available for losses varied form 0% to 100,04%. The average of the ratio was 4,26%.

In Hungary it is a general tendency that banks finance their financial companies in a sophisticated manner. In 2002 *credits extended to financial companies* increased by 72%, in 2003 the volume of credits enlarged by 89%. And not only the volume of credits increased, but also its share in the portfolio. In 2003 the share of credits extended to financial companies was 15,8% of the corporate and residential credits, compared to 13% in 2002. The market of credits extended to financial companies is fairly concentrated, three major banks own more than 50% of the

[11] The above mentioned numbers are the minimum, maximum and mean of 1850 individual capital losses (37 banks * 50 days).

market. At five banks credits to financial corporations accounted for more than 15% of total assets. At three banks the volume of credits is significantly – 7 times, 5,3 times and 3,3 times – higher than the banks' capital available for losses. In this scenario the above mentioned thee banks fail jointly, as next to the high market share they are relatively badly endowed with capital.

The three initially failed banks altogether dispose 12,3% of total assets of the banking sector. However its systemic risk implication is considerably higher than in the previous scenarios, when the two failing banks owned 14% of total assets in both cases. On five days one bank, meanwhile on 18th of June two banks defaulted. Second round contagion was never generated, as the volume of interbank liabilities of additionally failed banks was not significant. On the level of individual banks the highest loss measured in the capital maximum available for losses varied form 0% to 149,16%, the mean was 6,02%.

5.5. Exchange rate shock

The aim of the stress testing carried out by the Hungarian National Bank is to capture the ability of the banking sector to absorb different kind of shocks. Stress tests address the implication of abnormal changes of risk factors, like exchange rates, domestic and foreign interest rates or quality of credit portfolio. The main objective is to re-evaluate the market value of bank portfolios and investigate the changes in tier 1 capital.

However the stress test in Hungary is not able to handle spill over and liquidity effects induced by the initial shock. As a consequence it may occur that the system-level credit and/or market risk is relatively moderate but, when the loss is concentrated among banks which are characterised by extensive interbank relations, then significant spill over effects may multiply the magnitude of the risk. In this section those banks are identified that in the case of an exchange rate shock could loose a significant part of their tier 1 capital. The identification is carried out on the basis of the outcome of stress tests. Systemic risk implications of a potential interest rate shock are ignored, as in this case losses suffered by the banking system is much more limited.

In this scenario I analyzed the joint failure of those banks whose foreign exchange exposure against the euro and the US dollar was significant on the last days of each quarter of 2003. Due to the substantial foreign exchange positions the joint 40% devaluation or appreciation of the euro and the dollar in several cases induced capital losses higher than the banks' tier 1 capital. The joint devaluation of the euro and the dollar resulted in several failures, but nearly in every quarter different banks defaulted. In the case of the joint 40% appreciation of the euro and the dollar there exist three banks whose capital loss exceeded the bank's tier 1 capital at the end of every quarter during the year 2003. The scenario of foreign exchange shock is based on the joint failure of the above mentioned three banks.

Initially failed banks processed 5,31% of total assets of the banking sector. The contagion is fairly limited in this scenario, as well on 20th and 31st March one big bank, while on 15-16th January one middle bank defaulted. The break even point of LGD is 95,43% in the first case, and 60,29% in the second case. That is, no first round contagion occurs if at least 4,57 and 39,71% of the interbank exposures recover. Second round contagion occurred in none of the scenarios. In the worst case the banking system lost 8,09% of its capital maximum available for losses, the sector realized the highest loss, 15,94% on 31st of March, on a day, when contagion occurred. The distribution of capital losses is shown in Table 7. On the level of individual banks the highest loss measured by the capital maximum available for losses varied form 0% to 165,86%. The average of the ratio was 7,82%.

Table 7: The distribution of capital losses on 31st March

Realized losses (in the percentage of capital maximum available for losses)	Number of banks	In percentage of total banking system assets
Less than 10%	7	27,53%
Between 10-20%	3	20,77%
Between 20-50%	4	28,81%
Above 10%	1	0,91%
Default	1	5,90%

6. International comparison

It is worth comparing the Hungarian outcomes and the results of previous studies using the same simulation methodology made in other European counties. Results are summarized in Table 8. The first column of Table 8 shows where the study was made and which year's data was used. The second column presents the value of LGD that was used in this comparison. Foreign banks in brackets refer to a scenario, where the initial defaulter was a foreign bank. The third column shows the maximal number of failed banks and the number of banks in the banking sector. The fourth and fifth columns capture the severity of contagion.

Simulation methodologies have many common features, however they are prepared for different point in time, the study of Wells [2002] and Upper and Worms [2002] are based only on end-year data. The Hungarian study is the only one, which handles a bilateral dataset of 50 days. If bilateral positions were not known, except for Hungary that was mostly the case assumptions about the distribution of interbank exposures were also different, either dispersed or modified with the data of the large exposures statistics. Finally, the way of interpreting result was also different. LGDs and the way of measuring the severity of contagion varied from study to study.

Table 8: Comparing the results

Country and the year of data used	LGD	Maximal number of failed banks (Total number of banks)	Maximal number of rounds, when contagion occured	Total assets of defaulted banks under the worst case scenario (in % of total assets of the banking sector)	Average/Median total assets of defaulted banks (in %of total assets of the banking sector)
Germany (1998)	40%	115 (3246)	3	5%	0,58%
	100%	2800 (3246)	8*	85%	0,85%*
Great Britain (2000)	40%	2 (33)	n. d.	0%	0%
	100%	4 (33)	n. d.	25,20%	8,80%
	40% (foreign bank)	3 (33)	n. d.	0,00%	0%
	100% (foreign bank)	9 (33)	n. d.	15,70%	0,10%
Belgium (2002)	40%	7 (65)	3**	2,74%	0,48%
	100%	21 (65)		4,38%	0,39%
	40% (foreign bank)	2 (65)	n. d.	20,01%	0,08%
	100% (foreign bank)	7 (65)	n. d.	18,08%	0,07%
Hungary (2003)	40%	1 (39)	1	0,23%	0,23%
	100%	1 (39)	1	0,23%	0,23%

* level of LGD is 75%
** level of LGD is 60%

Based on the study of Upper and Worms [2002], Wells [2002], Degryse and Nguyen [2004].

According to *Upper and Worms [2002]* assuming a loss ratio of 75%, the maximum number of bank failures caused by domino effect is 2 444 from the potential 3246, corresponding to 76,3% of total assets. With a loss given default of 100%, the initial failure could trigger the failure of up to 2 800 banks. With LGD = 75%, on average 30,3 banks were affected, corresponding to 0,85% of total assets. There is a striking difference between the contagion patterns of low and high loss ratios. The critical value of LGD is somewhere around 40-45%. For smaller LGDs the severity of contagion is limited even in the worst possible case. For LGD > 45% the contagion is sever, however with higher LGDs the marginal increment of the number of failing banks is limited. After incorporating safety mechanism into the analysis the authors found that contagion is much more limited in scope but still possible. For LGD in excess of 75%, about 100 banks were affected in the worst case of contagion, which corresponds to 15% of the banking system in terms of assets.

After estimating the matrix of bilateral exposures from the aggregate data *Wells [2002]* found that the contagion is rather exceptional than typical. One approach, which assumes banks seek to spread exposure as widely as possible, suggests that if multiple bank failure were to occur, it would most likely be triggered by the assumed insolvency of a large UK-owned bank. Even if none of the exposure is recovered (i.e. the LGD = 100%), the insolvency of a single bank triggers additional failures in only four of the 33 cases. The failures involve a relatively small percentage of banking assets, 8,8% in the median case of spill-over and 25,2% in the worst insolvency case. If LGD = 80% the percentage of affected banking assets decreases to 1% in the median case and 6,7% in the worst case. Assuming an LGD of 40% balance sheet assets affected decreases to zero in both cases. Incorporating the pattern of large exposures into the estimates of bilateral positions involves the possibility of group of foreign banks to trigger the direct failure of UK-owned banks. This increases the number of insolvencies that trigger additional failures, although the average size measured in terms of banking system assets affected is smaller. Under the extreme assumption of 100% loss-given-default, knock-on failures are experienced in nine of the possible 33 cases. But, in terms of size only 15,7% of balance sheet assets are affected in the worst case, meanwhile in the median case it reduces to 0,1%.

Based on 975 different scenarios (3 different matrix of bilateral interbank exposures, 5 LGDs and 65 banks) *Degryse and Nguyen [2004]* simulated first the contagion triggered by the default of a Belgian bank. The authors concluded that during the last decade the risk and impact of contagion has decreased and currently contagion risk appears fairly limited. Concerning the bilateral interbank matrix estimated on the basis of aggregate and large exposures and assuming a loss given default of 100% in the worst case 21 banks defaulted from the 65, in terms of banking system assets affected this corresponds to 4,38%. Under the assumption of 40% LGD, number of failed banks decreases to 7, affecting 2,74% of total assets. The number of rounds of contagion in the worst case scenario was 3 in 2002, meanwhile in 1995 with 11 rounds the worst-case scenario reached its maximum.

Under the assumption of 100% LGD the capital loss distribution of the Belgian versus the Hungarian banking sector in the worst case is shown in Table 9. As presented in Table 9 the contagion in Hungary is much more limited. The severity of contagion is smaller, not only in terms of number of failing banks or affected balance sheets, but also in terms of capital losses suffered by surviving banks.

Table 9: Capital loss distribution of the Belgian versus the Hungarian banking sector

	Number of banks		In percentage of total banking system assets	
Realized losses (in the percentage of capital maximum available for losses)	**Hungary**	**Belgium**	**Hungary**	**Belgim**
0%	24	14	44,51%	21,75%
Less than 10%	9		49,77%	
Between 10-40%	4	12	5,49%	38,57%
Between 40-70%	0	8	0,00%	20,78%
Above 70%	0	10	0,00%	14,54%
Default	1	21	0,23%	4,38%
Sum	39	65	100,00%	100,02%

Based on Degryse és Nguyen [2004].

Based on Belgian banks' large exposure data Degryse and Nguyen [2004] came to the conclusion that given a 100% LGD the default of one large foreign bank can lead to the failure of 7 Belgian banks whose assets account for 20% of total Belgian bank assets. The results also indicate that even for a LGD of 40%, the default of a foreign bank can in the worst-case scenario have a significant impact on Belgian banks: two banks defaulted, which affected 18,08% of total assets. Interestingly, contagion occurs less frequently, 13 times out of 135 cases, in the foreign bank failure simulations than in the simulations where the first domino is a domestic bank.

7. Drawbacks of the model

Before looking through the drawbacks of the simulation methodology I would like to highlight the advantages of the model. Firstly, it is able to capture systemic risk, and secondly the data used is available at central banks. Thirdly, the model itself is simple and instead of building a complicated model it is trying to read between the lines of the existing data. Finally the model, as shown earlier, is able to answer the "what happens if"-type of questions.

One of the most important drawbacks of the model is that most financial crisis affects multiple institutions and an idiosyncratic failure of one bank is rather improbable. Additionally, as the initial failure is idiosyncratic, the model can not capture any kind of probability. As nearly every model this general contagion exercise also involve biases, some of which tend toward underestimation and others toward overestimation of contagion risk. The sources of over- and underestimation of systemic risk is presented in Table 10.

In several points Wells [2002] and Degryse and Nguyen [2004] refer to the caveats of this type of model. In reality the failure of a bank is not a sudden, unexpected event, it is rather a result of a process. As a consequence, other banks can limit or even partly withdraw their interbank claims. I tried to overcome this critic by adding *market expectation* into the model. However the model is still static in the sense that I suppose that banks in trouble do not manage the source of the problem leading to bankruptcy, and banks does not raise capital either. This leads to the overestimation of contagion. Especially in Hungary where many banks are owned by big foreign banks. Except the model of Elsinger, Lehar and Summer [2002] all of the models are static concerning the loss given default, as the loss given default in each scenario is the same for every bank. This is surely far from reality.

Similarly to the banks neither regulatory authorities nor central banks take any steps in order to prevent contagion. Concerning the severity of contagion the role of regulatory bodies is important in preventing the contagion by means of limiting high exposures or stimulating the use of financial collaterals. Most of the models do not handle the stabilizing function of central banks, among others the systemic risk mitigation effect of lender of last resort. Building this type of intervention into the model would have although at least two drawbacks. First, the lender of last resort function is a discretional measure, which makes it difficult to add it to the model. Second, on the level of individual banks making lender of last resort explicit could lead to moral hazard. By ignoring the potential reaction of the regulatory bodies, the risk of contagion is overestimated.

Additionally the ignorance of netting agreements also lead to the overestimation of contagion, as the model captures exposures which could be netted in the case of default. In contrast, netting in not automatic, in many countries legally enforceable agreements are needed. According to Basle II where banks have legally enforceable netting arrangements for loans and deposits banks may calculate capital requirements on the basis of net credit exposures. (Basel II… [2004], 139. §. and 188. §.) The ignorance of netting basically results in higher loss given defaults. However by simulating systemic risk implications of an initial default by means of several LGDs, the effect of netting is partly captured. In my paper due to the limited contagion I assumed an LGD in excess of 100%, and rather calculated the break even point of LGDs. In previous studies the different loss given defaults made it possible to handle risk mitigation techniques, just like repos and collateralized interbank transactions. However in my study due to the unique dataset those transactions were excluded from the analysis.

Table 10: The sources of over- and underestimation of risk of contagion

Sources of overestimation of the risk of contagion	**Sources of underestimation of the risk of contagion**
Neglecting the potential reactions of banks (withdrawal of interbank exposures, raising capital)	Neglecting the risk stemming from the payment and settlement systems
Neglecting the potential measures of the regulatory authorities	Ignoring the off balance sheet items
Ignoring the reaction of the National Bank (to big to fail)	Ignoring the repo positions
Ignorance of netting agreements	Ignoring the systemic effect of cross-holding of shares
Non-consolidated data	
	Ruling out the imported contagion
	Assumption of dispersed bilateral exposures
	Definition of default (tier 1 capital)
	Using end year data

The effect of non-consolidated data is twofold. On one side the risk of contagion is overestimated as we assume that interbank transactions are not within a banking group, but between two different banks. This was the case in my simulation as well. Basically between a subsidiary and a mother bank no collateral is needed and no limits exist. On the other side it could happen that both the subsidiary and the mother bank borrowed funds from the same bank. In this case the potential default of the creditor bank depends on the joint failure of banks belonging to the same banking group. As this type of joint default is not taken into account, the risk of contagion is underestimated.

The underestimation of contagion is related to the fact that credit risk stemming from interbank loans and deposits is the only source of interbank contagion. The interlinkages through payment and settlement systems, derivative and other off balance sheet exposures, just like undrawn facilities, guarantees are ignored. Similarly the systemic effect of cross holding of shares is also not captured. Systemic risk implications of the above mentioned exposures are complex, the risk of contagion is probable underestimated.

Among others one of the most crucial sources of underestimation of risk is the ignorance of the contagion imported from abroad. However, in a small open economy, like Hungary and with an international banking sector the effect of imported contagion could not be neglected. In contrast, in the case of UK and Belgian banks the opposite, the analysis of exported contagion should be carried out, as many English and Belgian banks are important market players in many other interbank markets.

It is worth mentioning, that except the Hungarian model the previous European studies estimate the matrix of bilateral interbank positions from aggregate data reported to the regulatory authorities.[12] According to Degryse and Nguyen [2004] the distributional assumption of maximum dispersion of banks' interbank exposures leads to an underestimation of contagion risk. Furthermore, a conservative definition of bank failure is used, banks fail when their tier 1 capital is exhausted. However a bank could be unable to operate even if it suffers smaller capital losses than its tier 1 capital. Finally, foreign studies use end-year data, which also biases the outcome of the simulation.

The results reported below should be interpreted in much the same spirit as those of a stress test. In spite of several caveats, with this type of models we can capture the quantitative assessment of interbank contagion risk. Moreover, because this type of exercise has also been undertaken by other authors, as shown in the previous section it allows for some international comparisons. Furthermore, a consistent use of the methodology with time-series data allows estimating the evolution of contagion risk over time.

8. Concluding remarks

The risk and severity of contagion is mostly influenced by country specific factors, just like the volume of interbank transactions and structure of the interbank market. Systemic risk implications of the Hungarian interbank market even under unrealistic assumptions are fairly limited both in absolute and relative terms. This can be explained with the low volume of interbank exposures measured by total assets or tier 1 capital of the banking sector.

As we have seen in Section 4, in 2003 the volume of average interbank assets was 208,7 billion forints, corresponding to 1,71% of total assets. However on the level of individual banks slight differences are observable. There exists a bank, whose average interbank assets of the examined 50 days is 34% higher, than its end-year total assets. Generally speaking smaller banks have higher volume of interbank assets measured by percentage of total assets. From the study of Degryse and Nguyen [2004] it is known, that at the end of 2003 in Belgium interbank assets were 176 billion euros, presenting 22,28% of total assets, and interbank liabilities were 228 billion euros, presenting 28,65% of total assets.[13] However, those data contain exposures to both domestic and foreign banks, and both collateralized and uncollateralized

[12] The sources of underestimation mentioned in this paragraph is shown in Table 10 in italics, as arguments are solely related to foreign models.

[13] In the Economic and Monetary Union at the end of year 2001 the above mentioned ratios of commercial banks accounted for 22,6 and 26,2% respectively. (Degryse and Nguyen [2004].) In Hungary, concerning balance sheet data at the end of year 2003 interbank assets and liabilities represented 10,92 and 10,30% of total assets.

positions are captured. If we only consider uncollateralized exposures to domestic banks, the share decrease to 3,28% and 4,14% respectively. As we also know that 50,5% of total exposures are collateralized, percentage shares are even smaller. The difference between the Belgian and Hungarian data is only surprising for the first sight.

The 208,7 billion forints uncollateralized interbank assets total up to 19,05% of the modified tier 1 capital of the banking sector. Only in four cases are average interbank liabilities higher than the banks' tier 1 capital, and in six cases higher than the capital maximum available for losses. However this is the necessary condition for contagion to occur. The average of the ratio of uncollateralized exposures over modified tier 1 capital on the level of individual banks is 53,18%, which highlights the fact, that smaller banks have relatively higher volume of interbank assets measured by their tier 1 capital. However higher ratios are not common in Hungary. According to Upper and Worms [2002] in Germany 2758 banks, that is 85% of banks have a higher interbank exposure than banks' tier 1 capital. In Germany the average ratio of interbank credits over tier 1 capital is 2,96, meanwhile in Hungary the ratio is only 0,45. The difference if surely remarkable, as in Hungary a bank with a higher interbank exposure than its tier 1 capital is rather exceptional.

Next to the volume of interbank exposures, the structure of the interbank market is also playing an important role. Shown is Section 4, the structure of the interbank market is similar to a money centre structure, however much less concentrated that in Belgium.

As a result of low interbank exposures and moderately concentrated structure of interbank claims and liabilities, the limited risk of the contagion in Hungary is not surprising. Not only the probability, but also the severity of the domino effect is low. In contrast to other countries where contagion is a low probability – high impact event, in Hungary the domino effect can be seen as a *low probability – low impact* event.

As a result of this analysis the Hungarian regulatory authorities could feel comfortable, the domino effect has a limited impact on the banking sector. However more research is needed in order to be able to asses the proper regulatory and policy consequences of contagion. As the analytical framework is simple the critical volume and concentration of exposures could also be investigated. Looking forward, by joining the Economic and Monetary Union, the role of the Hungarian interbank market supposed to be appreciated, as Hungarian banks can take a credit denominated in the domestic currency from many other banks. It should be seen clearly that this together with the existence of regional money centres could increase the severity of contagion.

Bibliography

ALLEN, F.– GALE, D. [2000]: Financial Contagion. *Journal of Political Economy*, Vol. 108. No. 1. p. 1-33.

ALLEN, F.– GALE, D [2004]: Competition and Financial Stability. *Journal of Money, Credit and Banking,* Vol. 36. No. 3. p. 453-481.

BALOGH, CS. – GÁBRIEL, P. [2003]: The Interbank Money Market Past and Future Trends. MNB Occasional Papers, No. 2003/28.

BASEL II…[2004]: Basel II: International Convergence of Capital Measurement and Capital Standards: a Revised Framework. Basel Committee Publications No. 107.

BORGATTI, S.P.– EVERETT, M.G. – FREEMAN, L.C. [2002]: Ucinet for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.

BOSS, M. – ELSINGER, H. – SUMMER, M. – THURNER, S. [2003]: The Network Topology of the Interbank Market. Österreichische Nationalbank Financial Stability Report, Issue 7. June 2004. p. 77-87.

CARLETTI, E.– HATMANN, P. – SPAGNOLO, G. [2003]: Bank Mergers, Competition and Liquidity. European Central Bank Working Paper, No. 292.

CIFUENTES, R. [2003]: Banking Concentration: Implications for Systemic Risk and Safety Net Design. Central Bank of Chile Working Paper, No. 231.

DEGRYSE, H. A. – NGUYEN, G. [2004]: Interbank Exposures: An Empirical Examination of Systemic Risk in the Belgian Banking System. National Bank of Belgium Working Paper, No. 43.

DIAMOND, D. W.– DYBVING, P. H. [1983]: Bank Runs, Deposit Insurance and Liquidity. *Journal of Political Economy*, Vol. 91. No. 3. p. 401-419.

EISENBERG, L. – NOE, T. [2001]: Systemic Risk in Financial Systems. *Management Science*, Vol. 47. No 2. p. 236-249.

ELSINGER, H. – LEHAR, A.– SUMMER, M. [2002]: Risk Assessment for Banking Systems. Österreichische Nationalbank Working Paper, No. 79.

ELSINGER, H.– LEHAR, A. – SUMMER, M. – WELLS, S. [2004]: Using Market Information for Banking System Risk Assessment. Mimeo. http://www.vwl.uni-muenchen.de/ls_marin/hmoeller/summer.pdf. Downloaded on 3. January 2005.

FREIXAS, X. – PARIGI, B. M. – ROCHET, J. C. [2000]: Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank. *Journal of Money, Credit and Banking*, Vol. 32. No. 3. p.661-638.

FURFINE, C. [1999]: Interbank Exposure: Quantifying the Risk of Contagion. Bank for International Settlements, BIS Working Papers, No. 70.

Horizontális Együttműködési…[2001]: Horizontális Együttműködési Megállapodások. A Bizottság Közleménye. Az EK-Szerződés 81. cikkének a horizontális együttműködési megállapodásokra való alkalmazhatóságáról szóló iránymutatás. 2001/C 3/02.: http://www.gvh.hu/ index.php?id=3482&l=h. Downloaded on 25. September 2004.

JAMES, C. [1991]: The Losses Realised in Bank Failures. *The Journal of Finance*, Vol. 46. No. 4. p. 1223-1242.

KAUFMAN, G. [1994]: Bank Contagion: A Review of Theory and Evidence. *Journal of Financial Services Research*, Vol. 8. p.123-150.

KATZ, D. [2003]: Egy szövetkezeti hitelintézet kilátásai, fejlesztésének lehetőségei. http://www.pszfz.bgf.hu/konyvtar/polvax/972katz1.htm. Downloaded on 7. June 2004.

LUBLÓY, Á. [2004]: Systemic Risk Implications of the Hungarian Interbank Market. MNB Working Papers, No. 2004/10.

MANNA, M. [2004]: Developing Statistical Indicators of the Integration of the Euro Area Banking System. European Central Bank Working Paper, No. 300.

MÜLLER, J. [2003]: Two Approaches to Assess the Potential Contagion in the Interbank Market. http://www.sgvs.ch/pdf_basel_04/C1-MuellerJ.pdf. Downloaded on 2 December 2004.

SHELDON, G – MAURER, M. [1998]: Interbank Lending and Systemic Risk, *Swiss Journal of Economics and Statistics*, No. 134. p. 685-704.

STRESS TEST… [2001]: Stress test. Assessing Market and Credit Risk from the Viewpoint of the Financial Stability of the Banking Sector. In: Report of Financial Stability, Studies. February 2001. p. 50-66.

UPPER, C. – WORMS, A. [2002]: Estimating Bilateral Exposures in the German Interbank Market: Is there a Danger of Contagion? Deutsche Bundesbank Discussion Paper, No. 9.

VÁRHEGYI, É. [2002]: Bankvilág Magyarországon. Helikon Kiadó. Budapest.

WELLS, S. [2002]: UK Interbank Exposures: Systemic Risk Implications. Bank of England Financial Stability Review. December 2002. p. 175-182.