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Financial Interlinkages and Risk of Contagion in the Finnish Interbank Market

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ABSTRACT

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Using the maximum entropy method, this paper estimates the danger of contagion on the Finnish interbank market in 2005–2007 as well as the existence of contagion during a Finnish banking crisis. The contagion analysis of the early 1990s is able to predict the most troublesome and defaulting banks in the banking sector. The simulation results for 2005–2007 suggest that five deposit banks out of ten are possible starting points for contagious effects. The magnitude of contagion is conditional on the first failing bank. In addition to large commercial banks, middle-sized banks also cause damaging domino effects. Over the last few years, the negative effects of contagion on the Finnish banking sector have been, on average, more limited than those of the early 1990s. The contagion is currently a low probability event on the Finnish interbank market.

KEY WORDS: contagion, interbank markets, Finland, maximum entropy

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1. INTRODUCTION

Crises in banking sectors occur from time to time and generally incur negative effects and expenses for the whole national economy. Recently, financial stability has deteriorated globally due to the US sub-prime crisis, which has increased market speculation, made banks reluctant to lend to each other and tightened lending policies in interbank markets. As instability is highly undesirable, it is essential to understand the functioning of interbank markets, the risks involved and the transmission mechanism of such risks.

One of the possible transmission channels for financial risks is contagion between financial sector intermediaries. Credit risk associated with interbank lending may lead to domino effects, where the failure of a bank results in the failure of other banks even if the latter are not directly affected by the initial shock or do not hold open positions with the initially failing bank. A more profound understanding of these contagion mechanisms and channels may help supervisors to better focus their limited resources when attempting to confine emerging financial crises. Moreover, increasing knowledge of potential contagion effects may encourage market participants to pay due attention to risk prevention and lessen the danger of "moral hazard", i.e. careless lending and a disregard for the counterparty's credit limits and creditworthiness.

This paper is related to studies that use interbank lending as a basis for contagion analyses. The contagion analysis outlined here focuses on the Finnish interbank market using Finnish data for 2005–2007. It also tests the method of maximum entropy by using Finnish banking crisis data for 1988–1990. As the main consequences of the banking crisis for the Finnish banking sector are known, it is interesting to test whether contagion analysis could have identified the problematic banks before the crisis hits.

In the literature, there is a considerable amount of ambiguity concerning the definition of contagion: no theoretical or empirical identification procedure exists on which scholars agree (Pericoli & Sbracia 2003: 572). Nevertheless, contagion in banking markets is generally defined as a crisis that spills over from one institution to another. Since banks act in the very centre of the financial system, they are usually the main target of research and analysis.

The academic literature on this topic comprises both theoretical models for analyzing specific aspects of contagion, and empirical analyses of markets. One of the theoretical frameworks is presented by Allen & Gale (2000). They show that the spreading of a financial crisis depends crucially on the interconnectedness of the banking sector and its patterns. If the interbank market is complete and each region is connected to all other regions, the initial impact of a financial crisis in one region may be attenuated. If the interbank market is incomplete, each region is connected with a small number of other regions. In that case, the initial impact of a financial crisis may be felt strongly in neighbouring regions.

The empirical research on contagion focuses most commonly on so-called financial contagion through linkages between banks.[1] Linkages consist of financial exposures in the banking sector. Contagion may occur through two channels. Firstly, the problems of one bank may cause losses to creditor banks (the "exposure contagion channel"). Secondly, problems may jeopardize the liquidity of a potential debtor, i.e., of a bank which finds that a credit line it holds with the troubled institution has dried up (the "credit line contagion channel"). (Blåvarg & Nimander 2002: 20; Müller 2006: 38)

Empirical studies have so far concentrated on national banking systems, using two methodological approaches. The first approach simulates the effects of a bank failure. Upper & Worms (2004) were the first to use the method of maximizing entropy to estimate the distribution of individual banks' interbank loans and deposits and to analyze the possibility of contagion in the German banking sector. Their methodology has been widely adapted and similar studies have been carried out on the Swiss (Sheldon & Maurer 1998), Belgian (Degryse & Nguyen 2007), English (Wells 2002 & 2004), Dutch (van Lelyveld & Liedorp 2006) and Italian (Mistrulli 2007) interbank markets. In gen-

[1] Contagion can also be indirect. In that case, contagion is driven by information or by the sale of illiquid assets by distressed banks to meet regulatory capital requirements. Moreover, the failure of a large number of banks could as well be the result of a macroeconomic shock that affects institutions exposed to a common risk more or less simultaneously. (Blåvarg & Nimander 2002; Müller 2006)

eral, all these authors found the potential for significant contagion effects but regarded a substantial weakening of the whole banking sector as unlikely. The effects of the worst-case scenarios differ according to the losses-given-defaults. With smaller values of the loss-given-default, the effect of contagion is lower. If the loss-given-default is 100%, the contagion seems to be the most severe in the Netherlands (73–96 % of the national banking sector's balance sheets affected by contagion). The effect is the least severe in Belgium, provided that a Belgian bank fails first. The contagion in the other countries varies from 13% to 42%.

A second approach estimates contagion by considering a wider variety of risks and factors. Müller (2006) tests the general stability of the Swiss interbank market by developing a simulation approach. The emphasis of the paper is less on individual banks and more on the banking system's exposure to aggregate risk stemming from a market's network structure. The possibility of contagion is evaluated by solving a clearing problem of a multilateral, complex bank network model with the help of a recursive algorithm. Elsinger, Lehar & Summer (2002) use standard risk management techniques in combination with a network model of interbank exposures to analyze the consequences of macroeconomic shocks for bank insolvency risk. They consider interest rate shocks, exchange rate and stock market movements as well as shocks related to the business cycle. Gropp, Lo Duca & Vesala (2006) use the distance-to-default indicator, a multinominal logit model and "coexceedances" to study contagion risk in the European banking market. In addition, Blåvarg et al. (2002) have published a descriptive analysis of the Swedish banking sector's counterparty risks.

Since Finnish banks do not have to disclose their counterparties, very little is known about the actual structure of bilateral exposures on the Finnish interbank markets and how these relationships affect the danger of contagion. Therefore, one has to use identifying approximations to estimate bilateral exposures. The present paper follows the methodology of Upper et al. (2004), who estimate a distribution of interbank loans and deposits by "maximizing the entropy". Finnish banks’ bilateral exposure matrices are constructed by using available data on bank balance sheets and counterparty exposures.

The danger of contagion is assessed by letting every bank go bankrupt one at a time and computing the effect of this failure on the other banks.

The analyses for 2005–2007 suggest that contagion is currently a low probability event on the Finnish interbank market. In addition to large commercial banks, middle-sized banks are also capable of triggering broad, systemic contagion. The analysis of the banking crisis era shows how the risk of contagion increases the crisis a priori. In the light of historic knowledge, the maximum entropy methodology is able to pick up the financial institutions that formed a systemic risk to Finnish banking system.

The rest of the paper is organised as follows: the Finnish banking sector in general and interbank market in particular are described in section 2. The methodology for constructing bilateral matrices and simulating contagious effects is clarified in section 3. Section 4 concentrates on a description of the data sets, on the choice of simulation parameters and on the results of the analyses. Section 5 concludes the paper.

2. BANKING SECTOR IN FINLAND

The Finnish banking market consists of about 360 individual credit institutions. Several of these institutions are, however, part of a larger consolidated corporation. According to their balance sheets, the main banking groups in Finland are: Nordea Bank Finland, Sampo Bank, OP-Pohjola Group, savings banks (incl. Aktia), local cooperative banks and Bank of Åland plc. The Finnish banking sector is highly concentrated, as the three main players account for more than 90% of the total market. However, many new credit institutions such as Tapiola Bank have been established in Finland in recent years. Although these new banks are rather small players in the market, they have been able to expand their business gradually. In addition, the business of mortgage banks has increased.

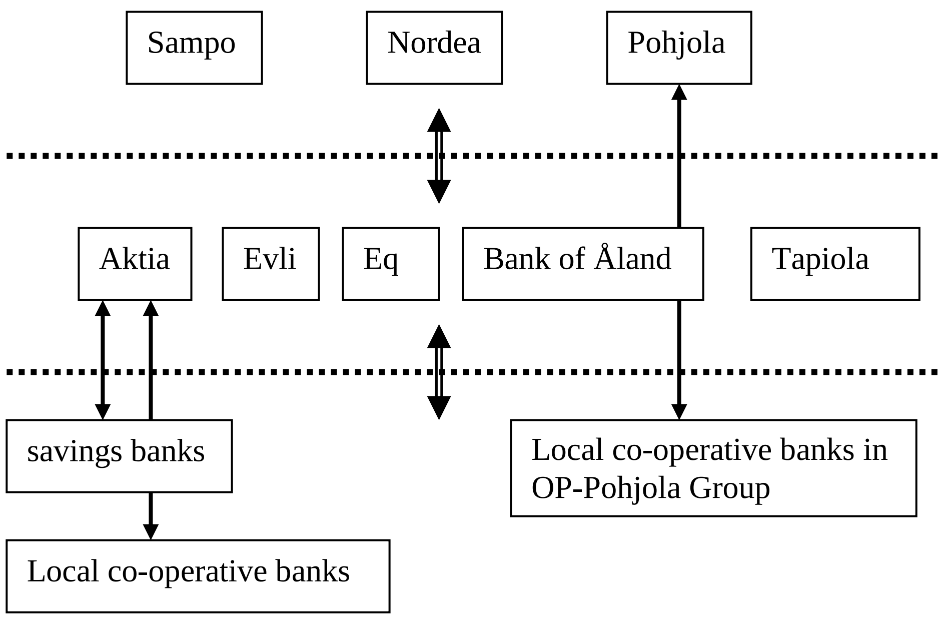

Figure 1. Interbank linkages on the Finnish banking market.

The linkages between Finnish banks are roughly portrayed in Figure 1. The Finnish interbank sector is, in principle, three-layered. The largest banks (Nordea, Sampo and Pohjola) have the room to manoeuvre either on domestic or on international money markets. The ability to access international capital markets reduces their dependence on the national interbank market. They can also interact with each other by loaning and depositing funds with each other. The second layer is formed by middle-sized institutions like Aktia and Bank of Åland. These banks can acquire funding from larger banks which act as financiers for other Finnish banks. Middle-sized institutions can also (to a lesser extent than larger banks) take benefit from international markets. Finally, the third layer is comprised of small, local banks that use other banks as their central financing institutions. For example, local savings banks and local co-operative banks use Aktia as their central financial institution. In a similar fashion, Pohjola finances local co-operative banks that belong to the OP-Pohjola Group.

Before the banking crisis that occurred in the 1980s, the Finnish banking market consisted of ten major deposit banks, namely KOP, SYP (Unitas), savings banks, OKO Bank, Postbank, Skopbank, STS Bank and Bank of Åland. Among these institutions, KOP and SYP were the largest ones and fierce rivals. The third largest banking group comprised savings banks, for which Skopbank acted as a central financial institution. OKO Bank financed local co-operative banks that belonged to the OP Bank Group. Postbank was government-owned and the other banks were rather small. The Finnish banking market was already then highly concentrated.

Table 1 shows the total assets of Finnish banks as well as interbank liabilities in proportion to the banks' total assets in 1988 and in 2006. At a maximum, interbank liabilities were approximately one fifth of total assets in 2006. But the share varies across institutions. Percentage shares have remained at similar levels over the years although there are currently fewer banks whose exposures exceed 10% of total assets. In the 1980s, interbank lending was predominantly domestic, and individual banks held quite large interbank positions in other Finnish banks.

Table 1. Finnish deposit banks' total assets and share of interbank liabilities in 1988 and in 2006.

	1988		2006	
	Total assets, EUR million	Interbank liabilities relative to total assets, %	Total assets, EUR million	Interbank liabilities relative to total assets, %
KOP	24 322	1.2 %	-	-
SYP (Unitas)	22 305	0.5 %	-	-
Savings banks	16 643	14.5 %	5 648	1.0 %
Postbank	12 582	0.7 %	-	-
Skopbank	10 681	11.5 %	-	-
OKO (Pohjola) Bank	7 375	16.2 %	24 196	4.5 %
STS -Bank	1 832	10.2 %	-	-
Bank of Åland	462	11.1 %	2 189	2.8 %
Nordea Bank Finland	-	-	130 985	22.3 %
Sampo Bank	-	-	26 627	1.8 %
Aktia plc	-	-	5 492	16.2 %
Local co-operative banks	-	-	3 467	0.2 %
Evli Bank	-	-	698	10.7 %
eQ Bank	-	-	627	0.0 %
Tapiola Bank	-	-	546	0.0 %

Source: banks' annual reports

Nowadays, Finnish banks' interbank lending has become more international in nature. Finnish banks' unsecured receivables from financial institutions rose steadily from 2006 to 2007 (Table 2). By June 2007, the share of Finnish counterparties was exceptionally low and at the same time the share of Norwegian, Danish and Icelandic counterparties had grown. Nordic, German and English banks are the main international counterparties for Finnish banks and thus they are the potential channels through which international contagion or market disturbances may spread to Finland.

Table 2. Finnish banks' unsecured receivables classified by country.

	EUR Million	Share of countries of total assets in EUR million.						
		Finnish banks	Swedish banks	Other Nordic banks	German banks	English banks	Other European banks	Banks from USA
December 2006	14 621	26.9 %	9.7 %	13.6 %	15.3 %	20.4 %	8.3 %	5.8 %
June 2007	16 853	6.0 %	5.9 %	32.9 %	20.0 %	17.5 %	9.5 %	8.1 %
December 2007	19 169	16.5 %	5.3 %	35.5 %	11.4 %	13.4 %	9.7 %	8.1 %

3. METHODOLOGY FOR CONTAGION RESEARCH

3.1. Constructing bilateral matrices

The data on bilateral lending relationships is most often estimated, as researchers do not usually have complete information on individual banks' actual counterparty loan exposures. The available data is usually obtained from balance sheets, large exposures and credit register reports that banks have to submit to authorities, but the availability of data differs across countries and over time periods. In order to fill in the gaps in these data sets, the estimation methodology has been based on the concept of "maximizing entropy". (Upper 2007: 5)

The concept of entropy maximization originates in information theory, in which entropy is a measure of the average information content of a random variable (or similarly a measure of the uncertainty associated with a random variable). The greater the entropy of the message, the greater the information the message contains.

Maximizing entropy means setting up probability distributions on the basis of partial knowledge and thus, it denotes the most likely outcome given the a priori knowledge about the event. Mathematically, a discrete random variable X can take on possible values {x: i = 1, …, n} and the entropy is defined as

(2.1.) $$H(X) = -\sum_{i=1}^{n} p(x_i)\log p(x_i)$$

where $p(x_i)$ is the probability mass function of outcome x_i. (Jaynes 1957; Shannon 1948) The lower the probability $p(x_i)$, i.e. $p(x_i) \rightarrow 0$, the higher the uncertainty, i.e. $-\log p(x_i) \rightarrow 0$, for the outcome x_i. When the probability of the outcome is maximized, the uncertainty diminishes. And when the probability is high and the uncertainty is small, estimates for parameters x_i are close to real values of x_i. Thus, the maximum entropy estimate is the least biased estimate that can be made on the basis of the available information.

The concept of the entropy maximization gives a building block to solve the problem of data inconsistency. These problems are also known as balancing the matrix or minimizing the relative entropy. Matrix is defined to be balanced if it satisfies the given set of linear restrictions of the problem. The problem of matrix estimation (and the entropy minimization) is posed as: "Given a matrix C, determine a matrix X that is close to matrix C and satisfies a given set of linear conditions on its entries". These doubly constrained minimum-information models are obtained into the use of economics. (Censor & Zenios 1997: 237, 242, 245; Blien & Graef 1998)

$$
\begin{array}{ccc}
 & & \Sigma_i \\
X = & \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{1N} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} \end{bmatrix} & \begin{matrix} a_1 \\ \vdots \\ a_i \\ \vdots \\ a_N \end{matrix} \\
\Sigma_j & \begin{matrix} l_1 & \cdots & l_j & \cdots & l_N \end{matrix} &
\end{array}
$$

Figure 2. N*N matrix of interbank loans and deposits.

Suppose that there are N banks that may lend to each other. In this case, the interbank lending relationships can be presented in the N * N matrix (Figure 2). Let this matrix be referred to as X. The row and column sums are bank i's total claims on other banks and bank j's liabilities in the interbank market, respectively. The row (a = assets) and column (l = liabilities) sums are received from data sets. As there is usually no knowledge on individual interbank loans and deposits, individual x_{ij}:s are unknown. The diagonal of the N*N matrix is usually set at zero, since no bank lends to itself. (Upper 2007: 4)

If a researcher has some kind of a priori knowledge and/or data on actual individual interbank relationships and their magnitude, the knowledge is gathered into an a priori matrix C that is also an N * N matrix and resembles matrix X. Frequently, matrix C is needs be adjusted so that the row and column totals equal fixed positive values, ie. the row and column totals of matrix X. Balancing the matrix yields a unique estimate of matrix X. More formally, the problem is as follows:

(2.2.) $$\underset{x_{ij}}{Min} \sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} \log \frac{x_{ij}}{c_{ij}}$$

(2.3.) s.t. $$\sum_{i=1}^{n} x_{ij} = l_j \qquad , i = 1, \dots , n$$

(2.4.) $$\sum_{j=1}^{n} x_{ij} = a_i \qquad , j = 1, \dots , n$$

(2.5.) $$x_{ij} \geq 0$$

If bilateral exposures are estimated using the balance sheet data, a requirement for the estimation is the availability of balance sheets of all potential counterparties for a given balance sheet item. In practice, this has limited the use of this method to lending between domestic institutions. (Upper 2007: 5)

The entropy will be maximized when the probability distribution is uniform. Thus, in the present context of the paper, maximizing the entropy includes the idea that banks spread their lending as evenly as possible between other banks in the market. And maximizing the entropy corresponds to the most likely structure of lending given all a priori pieces of information on the interbank market. (Upper 2007: 5)

3.2. Simulating contagion

Once the matrix of interbank linkages is in place, the researcher has to specify the type of the shock that triggers the contagion (Upper 2007: 7). Usually, the scope of contagion is estimated by letting banks go bankrupt one at a time and measuring the number of banks that fail owing to their direct or indirect exposure to the failing bank. A lender defaults if the amount of the losses suffered by lending to the failed bank is greater than the lender's own capital. Contagion need not be confined to such first-round effects, but a failure of the first bank can trigger a whole chain of failures (the domino effect).

The simplest approach is a simple sequential (or round-by-round) algorithm for simulations. As in several earlier studies the algorithm is also used in this paper. At the beginning, there are several banks b, b = 1,…,N, in the banking sector. All these banks hold capital c_b as well as an exposure x_{bb} towards another bank. Contagion simulation involves the following steps (Figure 3):

1. By assumption, bank i fails at t_0.
2. Any bank j fails if its exposure towards bank i, x_{ji}, multiplied by an exogenously given parameter for the loss rate (LGD aka loss-given-default), exceeds the bank j's capital c_j. So, bank j fails if $LGD * x_{ji} > c_j$ at t_1.
3. A second round of contagion occurs for any bank k for whom $LGD * (x_{ki} + x_{kj}) > c_k$ at t_2. Contagion stops if no additional banks go bankrupt. Otherwise, a third round of contagion takes place. (Upper 2007: 7)

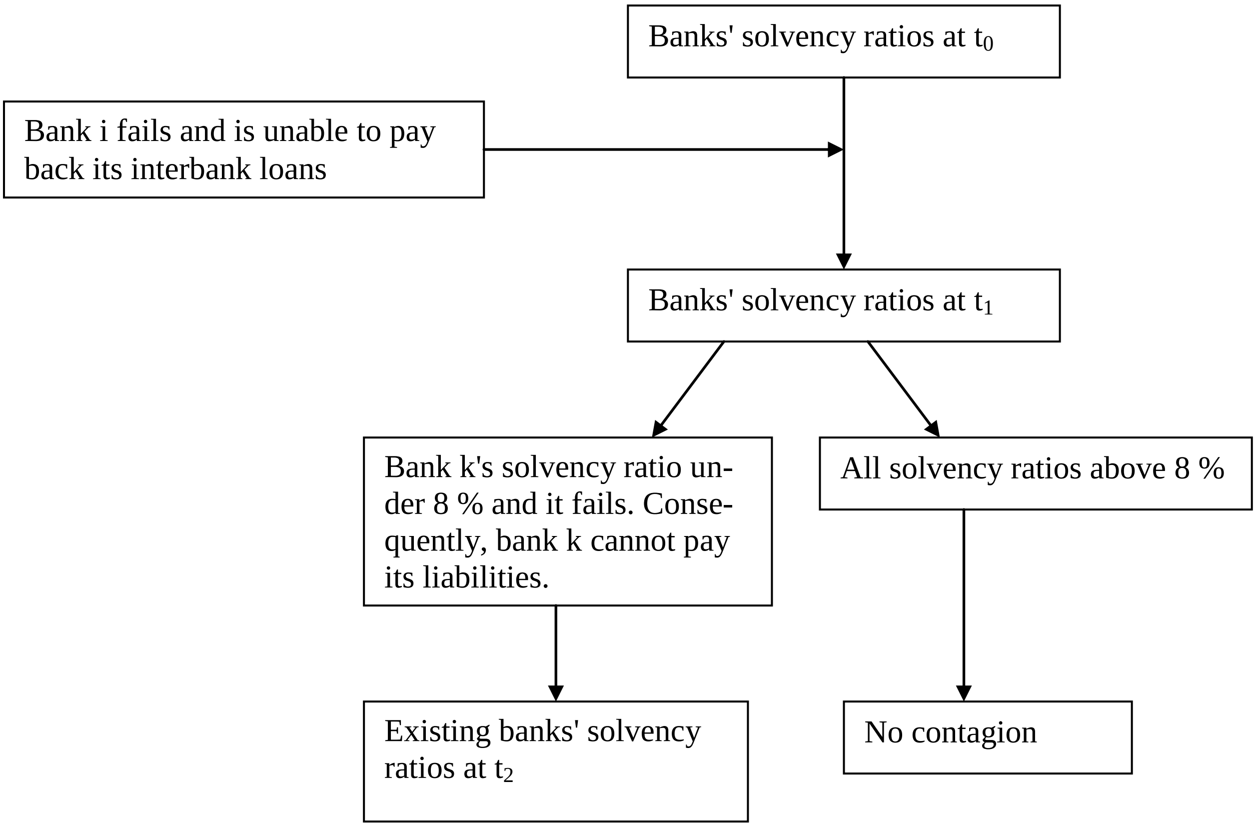

Figure 3. Algorithm for contagion simulations.

4. ESTIMATING THE DANGER OF CONTAGION ON THE FINNISH INTERBANK MARKET

4.1. Data description

The basic analysis of the Finnish interbank market presented here is based on counterparty exposure, balance sheet and liquidity risk data. Counterparty exposure data give an accurate snapshot of interbank business, but the data fails to cover connections among all banks in the Finnish interbank market.[2] At the end of 2007, six Finnish deposit banks' receivables from the ten largest counterparties comprised 28% of all banks' total receivables from financial institutions. In order to get the whole picture of the interbank market, one needs to rely also on balance sheet data. Balance sheets include quarterly information on loans and receivables to and from financial institutions as well as on bonds and certificates of deposit. These instruments are divided into domestic and foreign items that facilitate the contagion analysis by letting one concentrate on domestic exposures. Thus, balance sheet information is used for total claims and total liabilities in matrix X while counterparty exposure data is used in matrix C to give more accurate estimations of relationships among the six Finnish banks. Further, liquidity risk data[3] is used to clarify the interbank relationship among small local banks and their central financial institutions in matrix C. The analysis of the banking crisis in 1988–90 is based only on balance sheet data, since counterparty exposures and liquidity risk data were not yet collected at the time.

[2] Data collection by the Finnish Financial Supervision Authority includes deposit banks whose balance sheet total exceeds 1 billion euros or that have more than 100 million euros worth of certificates of claims eligible for central bank financing. Thus, only six deposit banks (namely, Nordea Bank Finland, Sampo Bank, Pohjola Bank plc (former OKO plc), Aktia Savings Bank, Bank of Åland and Evli plc) report information on their 10 largest counterparties that are financial institutions and 10 largest counterparties that are non-financial firms and communities. The bi-annual data refers only to interbank loans and deposits and does not include single household customers. The data set is on the group level and includes information on unsecured and secured loans. Unsecured claims of banking groups are divided into subgroups like lending and securities (including certificates of deposit), settlement claims, shares and derivatives. Repurchasing agreements are singled out from all secured claims.

[3] The data set includes information on interbank deposits and loans among Aktia on one side and local cooperative banks and savings banks on the other side. There is also similar data for Pohjola Bank and cooperative banks in the OP-Pohjola Group.

Contagion analyses for 2005–2007 and for the banking crisis period (1988–1990) include major Finnish deposit banks.[4] In order to obtain a closed system in which, in principle, all interbank deposits and loans add up to zero, only lending between domestic banks is considered, i.e. all business with foreign banks is excluded. Subtracting international interbank lending leads, in practice, to a situation in which discrepancies between the total assets and liabilities of the Finnish banking sector arise. Although this is in a way normal, as banks can be either net lenders or net borrowers in the interbank market, it complicates the running of the data estimation algorithm. For this reason, the individual liabilities positions were scaled so that their sum fits with that of the total asset positions. In December 2006, 66% of all interbank assets and 58% of liabilities were with Finnish deposit banks. Among the observations, the highest share of domestic assets and liabilities was 100% while the lowest share for assets was 8% and that for liabilities 0%.

Using the maximum entropy method, the balance sheet data permits us to compute two matrices of bilateral exposures. These sub-matrices are formed for loans and receivables and for bonds and certificates of deposit. After having constructed a bank-to-bank matrix for the sub-categories, these matrices have been combined to total domestic exposure matrix.[5] This composite matrix has then been used to test the possibility of contagion on the Finnish interbank market. It is important to note that the analysis concentrates exclusively on contagion due to credit exposures in the interbank market. The analyses do not include exposures arising from payment or security settlement systems or exposures due to the cross-holding of securities. Due to the data limitations, counterparty risks that are not recorded in the balance sheet are not captured either.

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[4] Nordea Bank Finland, Sampo Bank, Pohjola plc (former OKO plc), Aktia Savings Bank, Bank of Åland, Evli plc, eQ Bank, Tapiola Bank, local co-operative banks and local savings banks for January 2005, December 2006, June 2007 and December 2007. KOP, OKO Bank, SYP (Unitas), savings banks, Postbank, Skopbank, STS Bank and Bank of Åland are included in the banking crisis period.

[5] Bilateral matrices could also be formed on the basis of aggregated interbank assets and liabilities. It is, however, unappealing, since bank's positions in different instrument categories can differ substantially. Aggregation may, therefore, level out individual positions and weaken estimation results.

4.2. The choice of loss-given-default and the solvency ratio

The key parameters in determining the existence of contagion are the loss-given-default (LGD) ratio and the solvency ratio (usually congruent with capital adequacy requirements). The LGD -ratio refers to the share of assets that cannot be recovered in the case of bankruptcy. The solvency ratio is a limit for a default. The choice of the LGD -ratio is by no means obvious. Upper et al. (2004: 838–839) trace back several episodes of banking crises and find that the ratio varies significantly. For example, in the mid-1980s the average loss realised in bank defaults was 30% of the book value of the banks' assets in the United States. In the case of the bankruptcy of The Bank of Credit and Commerce International (BCCI) the creditors first expected to suffer losses up to 90%. Eventually, they ended up recovering more than half of their deposits. The uncertainty about eventual recoveries, combined with the time it takes for creditors to get their money, suggest that it may not be the actual losses borne by the creditor banks but the expected losses at the moment of failure that matter.

The loss ratio depends also on the availability of the collateral on interbank claims vis-à-vis other creditors. The Finnish balance sheet data does not, unfortunately, provide information on the collateralization of loans. According to the counterparty exposure data, most of the loans reported are uncollateralized and the share of collateralized lending is almost non-existent. Since the purpose of the study is to find the maximum negative shock that could hit the Finnish banking market, it is assumed that most of the interbank loans reported in the balance sheet are indeed unsecured. Given the difficulties in determining the appropriate loss rate, the possibility of contagion is tested using the broad-ranging values for the LGD. In practice, the loss ratio receives four different values, namely 100%, 75%, 50% and 25%. The loss ratio remains constant across banks.

The 8% solvency ratio is one of the limits for bank default. It is a limit defined by regulatory authorities and it shows if a bank is — for the time being — solvent enough to fulfil its obligations towards other remaining banks in the interbank market. In reality, banks seldom go bankrupt out of the blue; there are at least some rumours about the difficulties beforehand. Therefore, regulatory powers may be ready to take action if needed. As Upper et al. (2004: 842–843) state, it may be possible to stop the most severe scenarios with relatively low costs at an early stage, i.e. before the dramatic wave of bank failures sets in. A bank can be either closed down or refinanced through special financing operations. However, domino effects take place instantaneously. This preventive closure may be deemed unrealistic due to the fact that contagion may occur in a very short time period, which precludes regulatory action. In practice, it may take some time before banks realise the losses they have incurred but, even so, late rounds can occur quickly after the initial shock. This means that there may be virtually no possibility for a regulator to react to a process once it has started. As the focus here is on the maximal negative effect in the interbank market and on the contagion effects occurring in a short time period, it is assumed that regulators do not have time to react to the collapse of a bank.

In the simulations, bank institutions stand alone. In reality this may not always be the case, since several Finnish banks are part of a larger consolidated corporation. In addition to the banking arm, the group of companies may also include insurance business, investment funds and real estate business. Thus, when facing difficulties, a corporation may direct funding to its problematic banking business. This funding can extend the bank's ability to sustain market turbulence and restrain contagion. Nevertheless, banks need to fulfil their obligations related to the solvency ratio. As the simulations are static in nature, it is assumed here that corporations do not have enough time to raise the required funding and save their banking arm. It is also assumed that there is no extra funding available from interbank markets. In addition, in the analyses presented here there are no other safety nets on which banks could rely in case of problems.

Simulations focus on gross exposures and do not take netting into account. As we are searching here for a maximum exposure and assume that contagion proceeds without delays, netting is not an option. Moreover, in Finland banks cannot net interbank claims that can be used as collateral for central bank funding. What happens after all contagion rounds and the bankruptcy of a bank is outside the scope of this paper.

4.3. The risk of contagion

According to simulations for 2005–2007, contagion may occur on the Finnish interbank market (Figure 4 and Appendix 1). However, contagion is a low probability event. During the estimation period, five banks out of the ten may trigger contagion in the market.[6] In addition to the large commercial banks, there are also middle-sized banks that are capable of producing negative effects. The volume of contagion depends greatly on the bank that goes into bankruptcy first. If the loss rate is 100%, banks J, C and H are systematically so important that they can threaten the whole banking system. Contagion caused by banks C and H vanishes if the loss rate decreases below 100%. With smaller losses given defaults, bank D is systematically riskier as it is able to affect negatively 10-30% of the banking market.

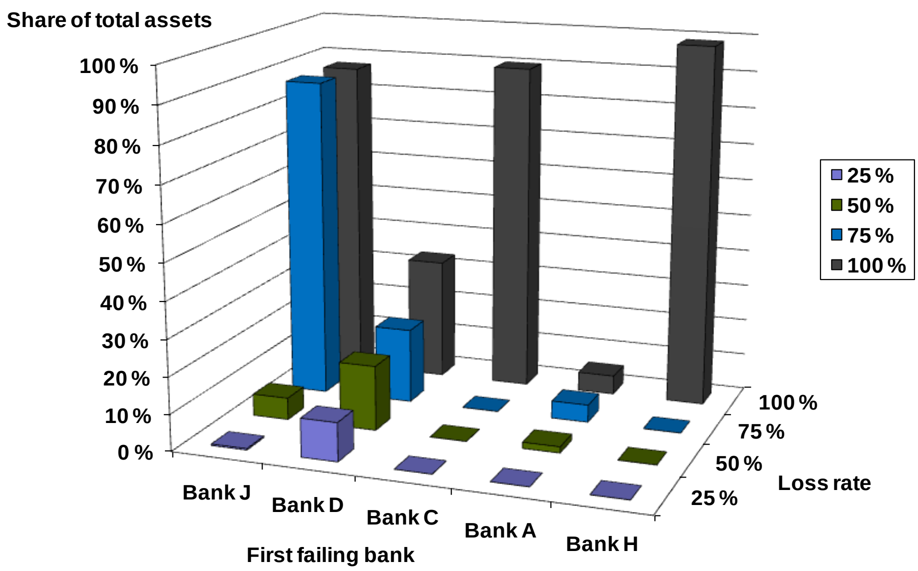

Figure 4. Contagion in the Finnish banking system at the end of December 2007.

[6] Local co-operative banks and local savings banks are both merged into groups.

The five banks that are identified as a starting point for contagion remain the same from 2005 to 2007. Bank D is potentially the most contagious in the Finnish banking system. It is able to cause mayhem in the market with the smallest loss ratio and, on average, it causes the largest share of the Finnish banking system to collapse. In the long run, bank J's importance has grown and currently it is systematically so important that it can threaten the whole banking system. To a lesser extent, banks C and A can also cause problems in the interbank market. Bank H's importance has grown only recently as the contagion originating from bank H had earlier only very limited effects on the Finnish banking system.

The effect of contagion on local communities is also estimated by letting local co-operative banks and local savings banks be entered into the calculations as individual banks. In reality, local co-operative banks and local savings banks are indeed not liable for each others' debts. In this set-up, there are 42 local co-operative banks, 39 local savings banks and 8 commercial banks. The change in the results on the overall banking sector due to this new set-up is negligible. Depending on the loss rate, the difference in magnitude between the contagion of the first set-up and that of the second varies from 0% to 2.5%.

Table 3. Failing local banks' total assets in the second set-up in relation to total assets of local banks.

	Loss ratio			
	25 %	50 %	75 %	100 %
Local co-operative banks	6.0 %	48.0 %	81.2 %	95.1 %
Local savings banks	5.8 %	25.2 %	64.4 %	67.5 %

From the perspective of local people and local communities, the issue is not so trivial. Table 3 shows how large a share of local co-operative and local savings banks fail in the second set-up in proportion to the first set-up, in which all local banks are deemed to collapse instantaneously. The difference in results is considerable with the smallest loss ratio. For instance, in the second set-up only 6% of local co-operative banks go into bankruptcy, in comparison to the first set-up, in which all local co-operative banks were deemed insolvent. The gap between the results diminishes when the loss-given-default increases.

The liberalization of the Finnish financial market in the middle of 1980s planted the seeds of the banking crisis as it increased the demand for loans and the loan stock started to expand rapidly as banks competed fiercely over market shares in household and corporate lending. The interbank market was opened up between Finnish banks in 1986 and banks started to finance their growing lending by acquiring funding from money markets. Thus, banks were exposed to increasing interest and loan loss risks. Finally, the banking crisis was trigged by the depression, the collapse of exports to the Soviet Union, the devaluation of the Finnish currency and steeply rising interest rates.[7]

During the years 1988-1990 and at the beginning of the banking crisis, there were three groups that were able to trigger contagion, namely Skopbank, savings banks and OKO Bank (Figure 5 and Appendix 1). At the beginning of the 1980s, Skopbank's and savings banks' lending increased aggressively and as restrictions in money markets were lessened, they turned to money markets to acquire more funding in addition to deposits. Their strategy was to acquire funding from short-term money markets and invest in long-term assets. At the same time, Skopbank acted as a central financial institution for the whole savings bank group. If Skopbank had failed in 1988, contagion would have affected 26% of banking sector assets (presuming a 100% loss ratio). At the end of 1990, Skopbank's failure would have affected 41% of total assets. In 1988 and in 1990, the failure of savings banks would have caused about 5 percentage points lower negative effects on the banking sector's total assets than the failure of Skopbank.

[7] The evolution of the Finnish banking crisis is described in detail in Nyberg & Vihriälä (1994).

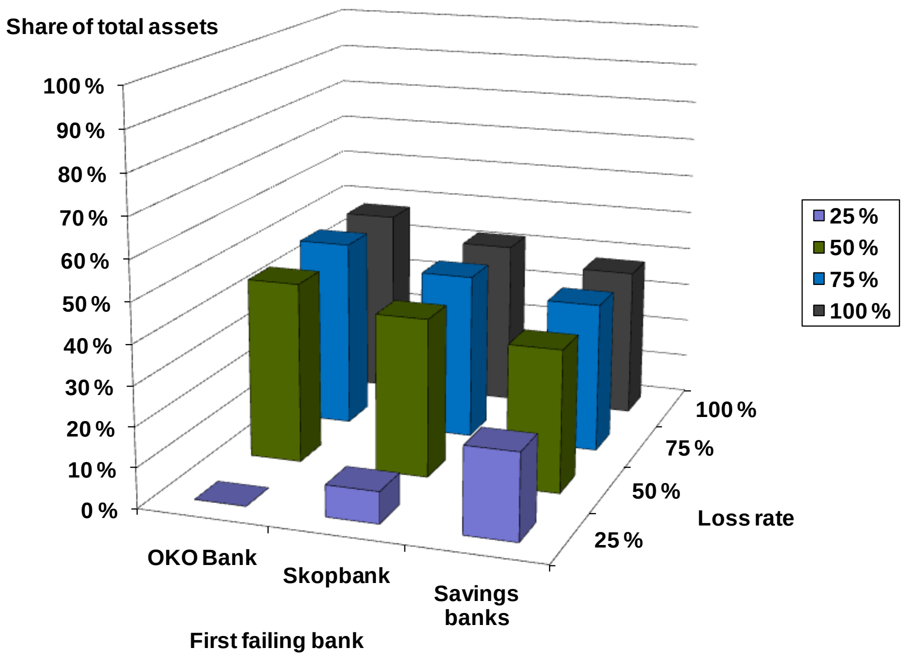

Figure 5. Contagion on the Finnish banking system at the end of 1990.

The fact that the analysis identifies OKO Bank as the most severe source of contagion during 1988–1990 is some sort of a revelation. The OP Bank Group did have trouble during the crisis but it is generally acknowledged that the Group was able to survive due to their more conservative strategy and the Group's joint responsibility in dealing with loan losses. The results are most likely driven to some extent by the fact that OKO Bank acts as a central financial institution for the co-operative banking group. But after the deregulation of financial markets, market funding began to constitute an increasing share of OKO's assets and liabilities. Therefore, if there had not been joint responsibility in the Group, OKO might have encountered problems.

In the light of the historic knowledge, the maximum entropy method is able to separate out the most troublesome banks in the banking sector.[8] When the overall economic situ-

[8] The contagion analysis is also replicated with 1994 and 1996 data. However, these data points are problematic, since banks received substantial subsidies from the government. Even though the overall economic situation improved little by little, banks continued to incur substantial losses during 1991–1995. At the end of 1994, only OKO Bank and Postbank were able to trigger contagion while at the end of 1996

ation weakened, banks' loan losses started to accumulate and their situation worsened rapidly. Growing market-based funding increased the risk of contagion in the Finnish banking sector from 1988 to 1990. Skopbank's strategy was highly dependent on the availability of market funding and as Skopbank’s loan losses soared, markets became highly suspicious of Skopbank’s ability to fulfil its obligations. The lack of confidence prevailing on the national money market in the bank's operational wherewithal increased and finally Skopbank’s liquidity collapsed on 19 September 1991 when other banks refused to buy Skopbank’s certificates of deposit. To prevent the whole banking system from collapsing, the Bank of Finland stepped in and took Skopbank over.

The savings banks' situation worsened when loan losses doubled and the costs of market funding increased due to rising interest rates. Ultimately, savings banks that were on the brink of collapse merged into the Savings Bank of Finland (SBF) in 1991. However, SBF was not able to follow its special recovery plan and its assets were thus sold to four domestic commercial banks (OKO Bank, KOP, Unitas and Postbank) in October 1993. The risky assets of SBF were transferred to an asset management company.

The analysis does not indicate KOP and SYP (Unitas) as possible sources of contagion. It is noteworthy that the banks' interbank lending relative to their total assets is not as large as in other banking groups (Table 1). Still, KOP and SYP were the main banks in Finland and active in the interbank market. Thus, intuitively they should be a prominent source of contagion. In fact, the analysis is hindered as one cannot distinguish domestic certificates of deposit from foreign ones. Certificates of deposit were, however, widely used instruments on the Finnish interbank market in the 1980s. Banks' exposures to short-term money markets were such that no bank would have survived the sudden dry-up of external funding. The analysis is replicated by adding bonds and certificates of deposit that are reported in banks' balance sheets to interbank assets and liabilities. Then, all banks, except for STS -Bank and Bank of Åland, cause wide spread contagion. With a 100% loss ratio, the effect of contagion varies from 51.5% to 92.1% depending

possible sources of contagion were OKO Bank, Postbank and Merita Bank. OKO Bank's exposure is due to its position as a central monetary institution. Postbank's position was not, in reality, worrisome since Postbank was owned by the state. Merita Bank was the largest bank in the market, formed from the merger of KOP and SYP (Unitas).

on the first failing bank. STS -Bank is so small that it is not able to cause system-wide effects. At the same time, Bank of Åland's business concentrated mainly in Åland and it did not have enough interbank relations with mainland banks to be a starting point for contagion.

It appears also that the magnitude of contagion[9] was higher in the early 1990s than currently (Figure 6). The only exception is the end of 2007, when the effect of an average contagion with a 100% loss ratio is the most profound. Yet, the results of December 2007 may be affected by structural changes in the banking market.

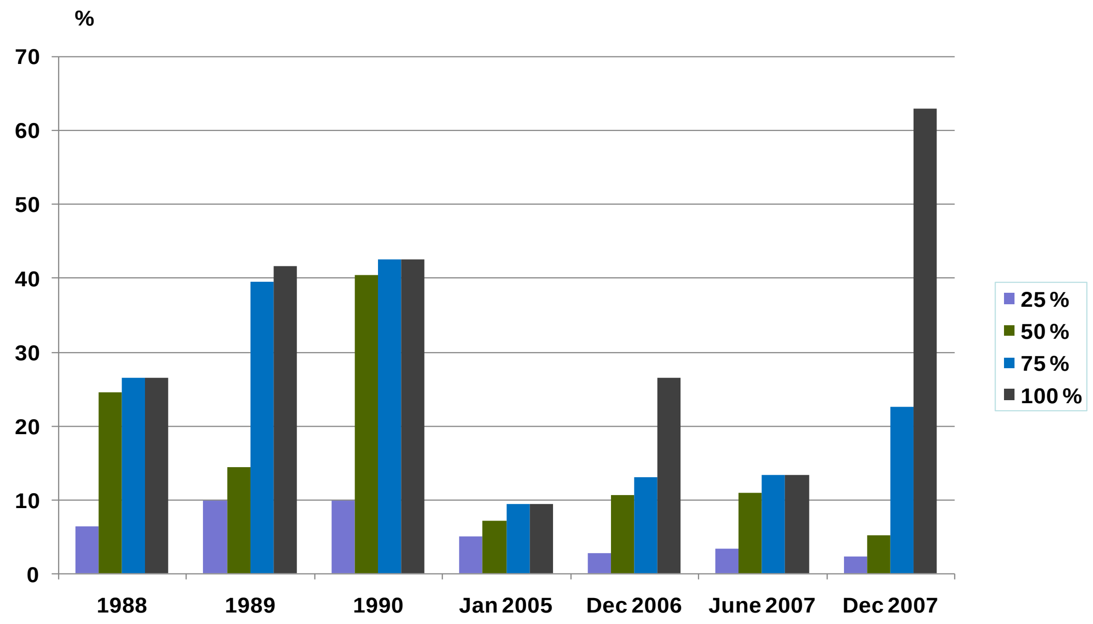

Figure 6. Average contagion with different loss ratios.

The operational environment of banks in the early 1990s and the years 2005–2007 bear several similarities. In both periods the loan stock grew and interest rates mainly increased. Also, the banking sector was highly concentrated and there were only a few large players in the market. However, there are also notable differences between the pe-

[9] The magnitude of contagion is measured as a percentage share of failing banks' assets of the banking sector's total assets after all banks have been exposed to the effects of contagion. The assets of the first

riods. The 2005–2007 interest rate level was nowhere near that of the early 1990s and the corporate sector was not as badly indebted as before. Interbank markets became more international and the network of interbank markets changed. Therefore, it is highly unlikely that the banking crisis would happen again. The analyses also suggest that the negative effects of contagion on the Finnish banking sector were, on average, more limited in 2005–2007 than in the early 1990s.

In simulations, the speed of contagion and the importance of the loss-given-default ratio follow similar patterns. At the beginning, the initial shock leads to a breakdown of several banks, but the number of failing banks in the subsequent contagion rounds is smaller. Typically, there are two or three contagious rounds after which contagion stops. However, the speed of contagion depends on the size of the loss ratio. With the smallest loss rate of 25%, contagion has only first- or second-round effects. When the loss given default is higher, there are at least two contagious rounds. The only case when contagion takes five rounds occurs in December 2007. The size of the LGD ratio has an obvious effect on the results. This is intuitively appealing, since higher values of the ratio have the potential to increase pressure in the system. At some point, a critical mass of losses is reached and the interbank market collapses. The case of the maximum loss ratio is theoretically interesting since it gives the "worst case scenario". In the case of an immediate and severe banking crisis, it portrays what could happen if everything goes badly. While the worst case scenario might be only a theoretical possibility, the quite plausible 50% loss ratio seems to already have measurable effects on the banking market.

The Finnish results are in line with previous studies (Appendix 2). Especially the results concerning the banking sector's structure and contagion are similar. The Finnish banking sector — like that of the Netherlands — is dominated by a few large banks. Respectively, the share of the banking sector's total assets affected by contagion is high, especially when loss ratios are at an exalted level. At the same time, contagion seems to have a somewhat milder effect in countries with multiple money-centre and two-tier systems (for instance, Italy and Germany). These results support the findings of Allen et

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failing bank are not included in the figures. Individual charts for contagion in different time periods are in al. (2000), as the level of contagion depends on the structure of interbank markets. On the other hand, Degryse et al. (2007) find that the Belgian banking sector's increasing concentration decreases the risk and impact of contagion. This outcome gets some support from the Finnish case: while the concentration in the Finnish banking sector diminishes, on average, the contagion grows.[10]

Appendix 1.

[10] In Finland, the concentration (measured by the Herfindahl index) and contagion (with a 100% loss ratio) were 2,730 and 9.3% in Dec. 2005, 2,560 and 26.5% in Dec. 2006 and 2,540 and 62.9% in Dec. 2007.

5. CONCLUSION

This paper investigates the possibility of contagion on the Finnish interbank market. Contagion is defined as a crisis in which the failure of one bank causes the failure of other banks not directly affected by the initial shock (the so-called domino effect). The simulations for 2005–2007 suggest that a danger of contagion is present on the Finnish interbank market but that contagion is a low-probability event. Five deposit banks out of ten are possible starting points for contagion although the severity of contagion is conditional on the first failing bank. In addition to large commercial banks, there are also middle-sized banks that are capable of triggering wide-ranging contagion. Across the different time periods, the five banks that are identified as a starting point for contagion remain the same.

The simulations are repeated with Finnish banking crisis data. The analysis shows how the risk of contagion increases in the banking sector from 1988 to 1990. In the light of the historical knowledge, the maximum entropy methodology is able to pick up the financial institutions that formed a systemic threat to the Finnish banking system. Although banks' operational environment in 2005–2007 resembled that of the early 1990s, there are also notable differences between the periods. Therefore, it is highly unlikely that the banking crisis would happen again. The analyses also suggest that the negative effects of contagion on the Finnish banking market were, on average, more limited in 2005–2007 than in the early 1990s.

Recently, Mistrulli (2007) has compared the results obtained by assuming maximum entropy with those based on actual bilateral exposures. The comparison of results indicates that the maximum entropy method tends to underrate the extent of the contagion. However, under certain circumstances, depending on the structure of the interbank linkages, the recovery rates of interbank exposures and banks' capitalisation, the maximum entropy method can overrate the scope of the contagion.

The area remaining for future research is broad. First of all, the results obtained by Mistrulli (2007) and the analysis of Upper (2007) show the maximum entropy method biases the results for existing contagion. The exact magnitude and direction of the distortion are not known exactly. Thus there is room for better analytical methods. Secondly, the current set-up would benefit from behavioural analysis. Allowing banks to take remedial action when difficulties appear or allowing them to make exposures in net terms, could enrich the analysis. In addition, the analysis could take into account: the fixed costs of screening potential borrowers and the monitoring of loans; relationship lending; and different portfolio structures. Thirdly, new avenues for research open up from testing how variations in exposures impact the magnitude of contagion. As current contagion analyses are based on static set-ups and on individual data observations, "stress-testing" analysis for the banking sector is needed to be able to see how variations in exposures affect the risk of contagion. Finally, more evidence on the relationship between the concentration of the banking market and the level of contagion is needed in order to draw definitive conclusions on possible interconnections.

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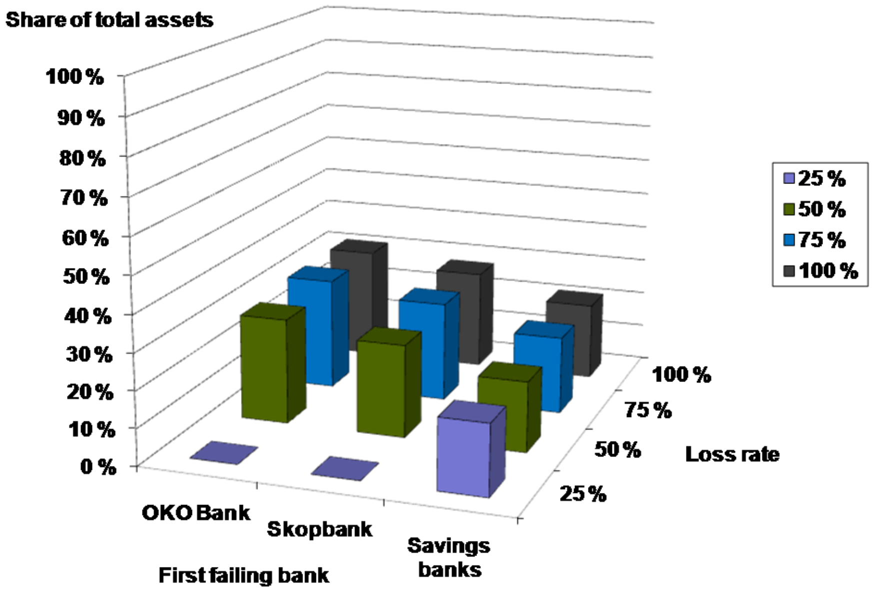
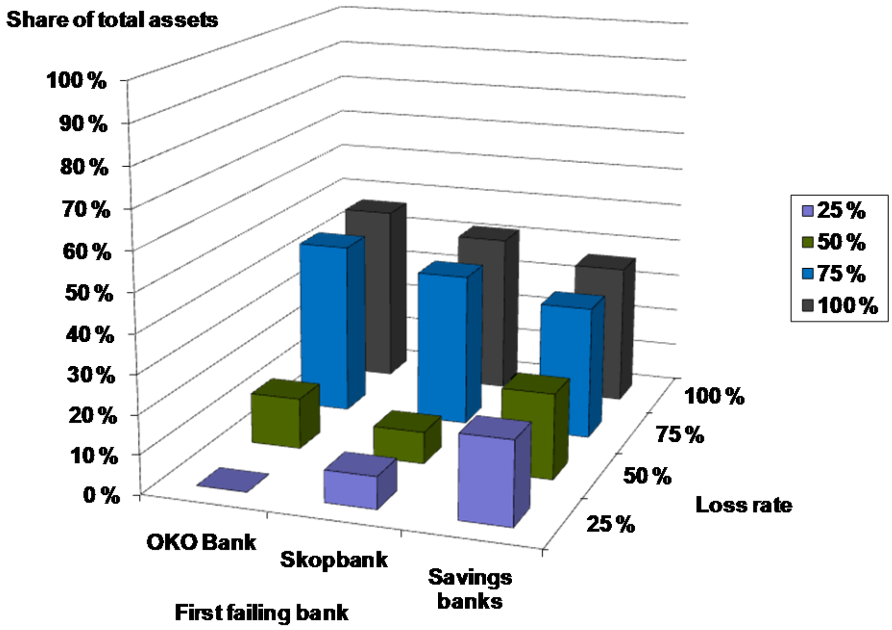
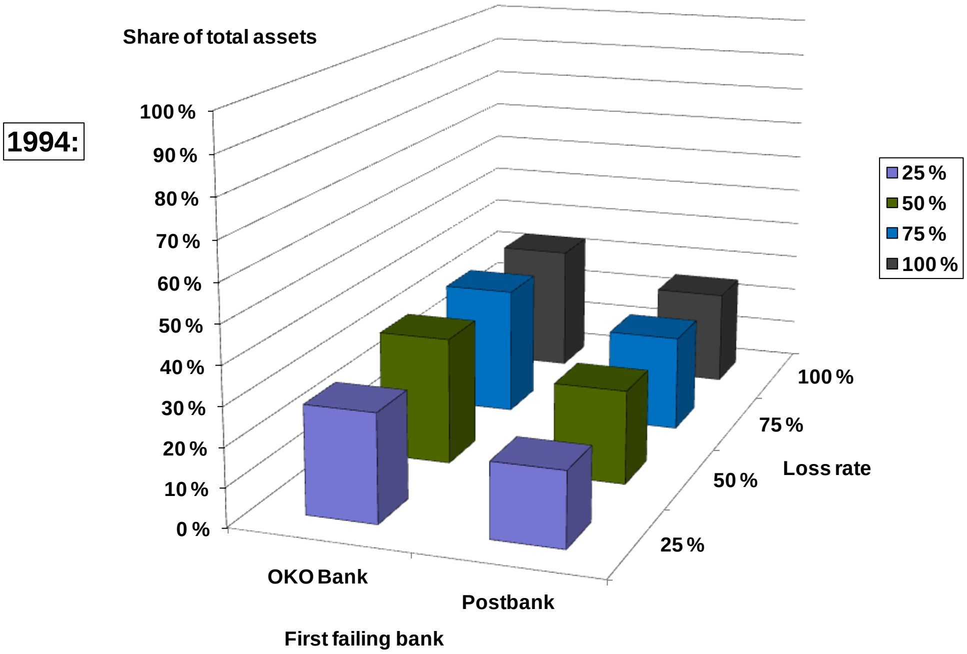
APPENDIX 1. Contagion in Finnish banking market

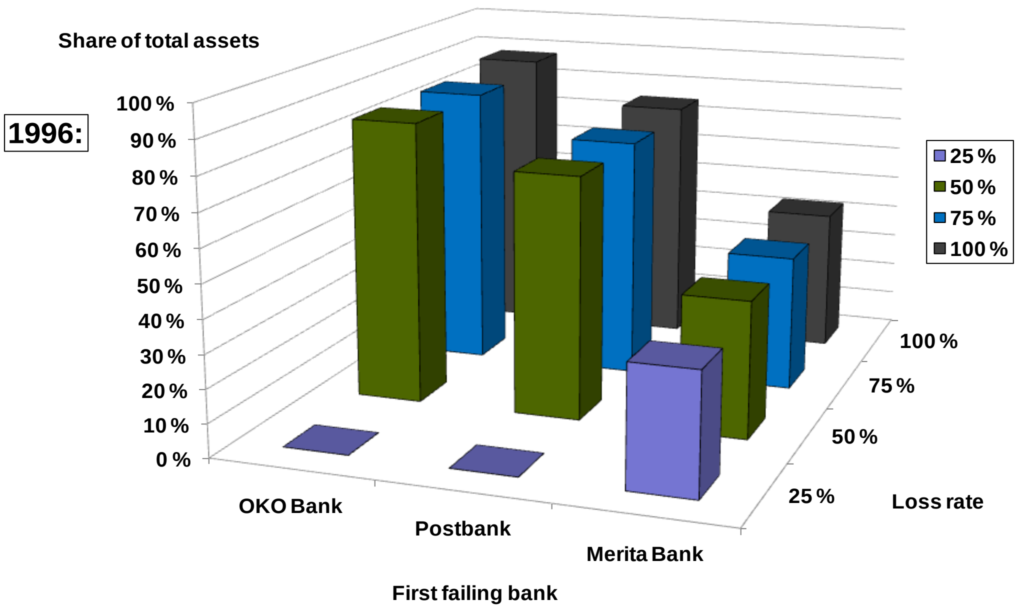
1988:



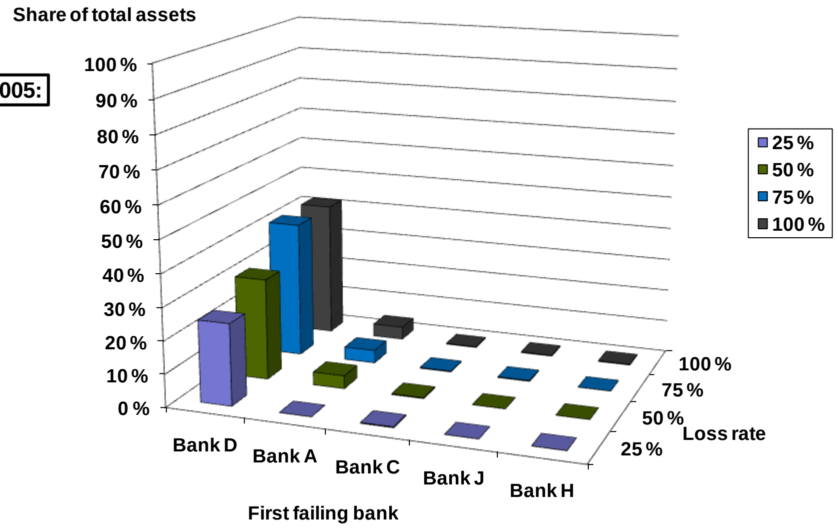
1989:



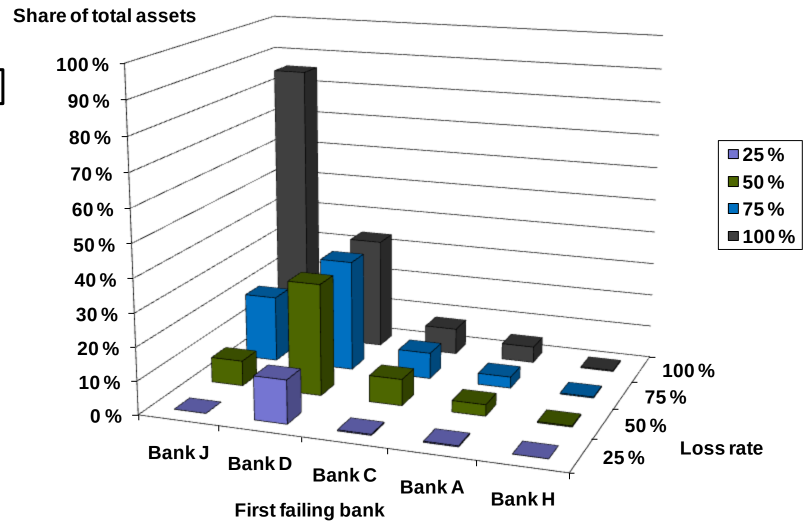

1994:
Share of total assets
100 %
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0 %
OKO Bank
Postbank
First failing bank
25 %
50 %
75 %
100 %
Loss rate
25 %
50 %
75 %
100 %


1996:
Share of total assets
100 %
90 %
80 %
70 %
60 %
50 %
40 %
30 %
20 %
10 %
0 %
OKO Bank
Postbank
Merita Bank
First failing bank
25 %
50 %
75 %
100 %
Loss rate
25 %
50 %
75 %
100 %

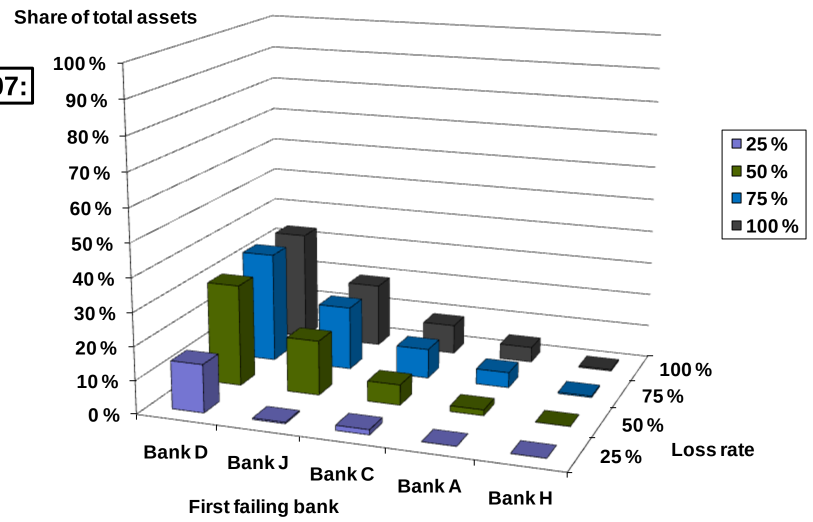
Jan 2005:



2006:



June 2007:



APPENDIX 2. Results of empirical studies on contagion

Results for worst-case scenarios of empirical studies on contagion: as a percentage of balance sheet assets affected by contagion (excluding assets of "first domino").

		Loss-given default									
		100 %	**80 %**	**75 %**	**60 %**	**50 %**	**40 %**	**25 %**	**20 %**	**10 %**	**5 %**
Germany	Gross exposures, no safety net	na	na	76.3 %	na	61.6 %	5.0 %	0.8 %	na	0.6 %	0.3 %
Upper & Worms (2004)	Netting, no safety net	na	na	8.2 %	na	1.1 %	0.9 %	0.6 %	na	0.3 %	0.3 %
	With safety net	na	na	13.5 %	na	3.0 %	0.8 %	0.8 %	na	0.5 %	0.0 %
Belgium *	Domestic contagion (2002)	3.8 %	3.8 %	na	3.3 %	na	3.0 %	na	0.5 %	na	na
Degryse & Nguyen (2007)	Domestic contagion (1993)	90.9 %	na	na	3.3 %	na	na	na	0.0 %	na	na
	Foreign contagion	20.0 %	20.0 %	na	18.2 %	na	18.1 %	na	0.1 %	na	na
United Kingdom	Model I: the benchmark case	25.2 %	6.7 %	na	6.7 %	0.0 %	0.0 %	na	0.0 %	na	na
Wells (2002 & 2004)	Model II: incl. large exposures data	15.7 %	15.7 %	na	15.7 %	0.0 %	0.0 %	na	0.0 %	na	na
	Model III: money-centre model	42.2 %	6.7 %	na	0.1 %	0.0 %	0.0 %	na	0.0 %	na	na
Holland	Large exposures data	96.0 %	na	90.0 %	na	2.0 %	na	2.0 %	na	na	na
van Lelyveld & Liedorp (2006)	Survey data	73.0 %	na	45.0 %	na	3.0 %	na	2.0 %	na	na	na
Italy	The benchmark case	15.9 %	15.2 %	na	7.9 %	7.9 %	7.9 %	na	3.5 %	0.5 %	na
Mistrulli (2007)	Conglomerate bail-outs	12.8 %	12.8 %	na	12.8 %	12.8 %	12.8 %	na	0.5 %	0.5 %	na
Finland	Banking crises (average 1998-90)	36.8 %	na	36.1 %	na	26.4 %	na	8.7 %	na	na	na
Toivanen (this paper)	Current period (average 2005-07)	28.0 %	na	14.5 %	na	8.4 %	na	3.3 %	na	na	na

na = not available

General results of empirical studies

Country	Author(s)	Results
Austria	Elsinger, Lehar & Summer (2002)	The results show that the Austrian banking system is very stable and default events are unlikely. The median default probability of an Austrian bank is below one percent and only a small fraction of bank defaults can be interpreted as contagious. The vast majority of defaults are a direct consequence of macroeconomic shocks.
Belgium	Degryse & Nguyen (2007)	The results of the survey show that a change in the Belgian interbank market from a structure in which all banks have symmetric links towards a structure in which money centres are symmetrically linked to some banks, but are not linked together themselves, decreases the risk and impact of contagion. The default of some large foreign banks has the potential to trigger significant domino effects in Belgium.
European Union	Gropp, Lo Duca & Vesala (2006)	The authors find some evidence in favour of significant cross-border contagion among the banking sectors of the largest EU countries. Contagion may have increased since the introduction of the euro and integrated money market. Combined with the finding that there is no contagion among small banks, the results point towards a "tiered" interbank structure at the cross-border level such that small banks only deal with domestic counterparties, leaving foreign operations to major international banks.
Germany	Upper & Worms (2004)	Without the safety net*, there is considerable scope for contagion in Germany and it could have an effect on a large proportion of the German banking sector. When a safety net is in place, it considerably reduces (but does not eliminate) the danger of contagion. Large-scale contagion can occur only if the loss rate on interbank loans exceeds a value of approx. 40%.

* Upper et al. use "safety nets" refer to the guarantee funds of savings and cooperative banks. In Germany, both the savings banks' and cooperative banks' associations operate funds backed up by mutual guarantees which serve to recapitalise member institutions in the event of insolvency.
In addition to guarantee funds, savings banks are also explicitly guaranteed by the relevant local or regional government. There are also a (small) number of public banks guaranteed by the federal government of Germany.

Country	Author(s)	Results
Italy	Mistrulli (2007)	The main results show also that Italian interbank market is conducive to financial contagion. However, even for high loss rates, the default of banks raising funds in the interbank market hardly triggers a systemic risk. Simulations also indicate that when conglomerates are allowed to recapitalise their affiliates, which otherwise would fail, the resilience to financial contagion of the banking system tends to improve. In some cases, however, due to the fact that losses are shared among banks affiliated with a conglomerate, banking stability may even worsen due to new channels of contagion. The comparison of results based on actual counterparty-information indicates that the maximum entropy method tends to underrate the extent of contagion. However, under certain circumstances, depending on the structure of the interbank linkages, the recovery rates of interbank exposures and banks' capitalisation, the maximum entropy method overrates the scope of contagion.
Netherlands	van Lelyveld & Liedorp (2006)	The results state that there exist considerable risks in Dutch interbank markets in case of a bankruptcy of one of the large banks or through foreign counterparties (especially European and North African). Bankruptcy will not, however, lead to a complete collapse of the interbank market. The contagion effects of the failure of a small bank are limited.
Sweden	Blåvarg & Nimander (2002)	The risk of contagion within the Swedish banking system is light and the effects on the Swedish system from abroad seem to be even smaller. The results show that financial institutions dominate banks' ranking list, that the largest exposures are in the foreign exchange settlement segment, that counterparties have high credit ratings and that the banking system is concentrated.
Switzerland	Müller (2006)	The main findings are, first, that there is substantial potential for contagion. Second, the exposure as well as the credit line contagion channel exists in Switzerland. Third, a lender of last-resort intervention could reduce spill-over effects remarkably. And fourth, the structure of interbank markets has a considerable impact on markets' resilience against spill-over effects: Centralized markets are more prone to contagion than homogenous ones.
Switzerland	Sheldon & Maurer (1998)	Although there seems to be a high probability of a bank failure, there is no significant evidence for systemic risk in the Swiss banking sector. A bank's rate of assets, capital-to-asset-ratio and initial interbank lending affect the probability of the failure.

Country	Author(s)	Results
United Kingdom	Wells (2002 & 2004)	The first model benefits from the aggregate data and assumes that banks seek to spread exposures as widely as possible. The results suggest that if a multiple bank failure were to occur, it would most likely be triggered by the assumed insolvency of a large UK-owned bank. Such a shock to the system is, however, deemed to be very unlikely. The second model incorporates large exposures data. It opens up the possibility that the insolvency of a large foreign bank could cause multiple bank failures in the UK system. However, when multiple failures do occur, the systemic implications seem to be somewhat less than under the first approach. The results of the third model are similar to those of model 1 and 2. The only exception is that for the higher loss-given-defaults, the credit losses of banks are more severe. All in all, a single bank failure is rarely sufficient to trigger the outright failure of other banks, but it does have the potential to weaken substantially the capital holdings of the banking system. In an extreme case, a single bank's insolvency could trigger knock-on effects, leading in the worst case to the failure of up to one quarter of the UK banking system. The results depend greatly on the assumptions maintained about the distribution of interbank loans and the level of loss given default.