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Financial interlinkages and risk of contagion in the Finnish interbank market

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Mervi Toivanen

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Financial interlinkages and risk of contagion in the Finnish interbank market

Bank of Finland Research
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Abstract

Using the maximum entropy method, this paper estimates the danger of contagion in 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 of ten deposit banks 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 in the Finnish interbank market.

Keywords: contagion, interbank markets, Finland, maximum entropy

JEL classification numbers: G21, G01

Tartuntariskit pankkien välisillä rahamarkkinoilla Suomessa

Suomen Pankin keskustelualoitteita 6/2009

Mervi Toivanen
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tutkimuksessa estimoidaan pankkien välisillä markkinoilla esiintyviä tartuntariskejä Suomessa vuosina 2005–2007 ja pankkikriisin aikana käyttämällä entropian maksimointi -menetelmää. 1990-luvun tartuntariskien analyysi osoittaa, että entropian maksimointi -menetelmä kykenee erottelamaan markkinoilla toimineista pankeista ne, jotka joutuivat kriisissä suurimpiin vaikeuksiin. Vuosien 2005–2007 simulaatioiden tulokset osoittavat, että kymmenestä suurimmasta talletuspankista viisi pankkia voi aloittaa tartuntariskien leviämisen. Tosin pankkimarkkinoihin kohdistuvien vaikutusten suuruus riippuu siitä, mikä pankeista menee ensiksi konkurssiin. Suurten liikepankkien lisäksi myös keskisuuret pankit voivat olla ketjureaktion alkuunpanijoita. Viimeisten vuosien aikana tartuntariskien negatiiviset vaikutukset Suomen pankkimarkkinoilla ovat keskimäärin pienemmät kuin 1990-luvun alussa. Tartuntariskien esiintyminen pankkien välisillä markkinoilla on Suomessa epätodennäköistä.

Avainsanat: tartuntariskit, pankkien väliset markkinat, Suomi, entropian maksimointi

JEL-luokittelu: G21, G01

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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 is deteriorated by US sub-prime crisis that undermines trust in the financial markets, increases market speculations, makes banks reluctant to lend to each other and tightens lending policies in interbank markets. As times of instability are highly undesirable, it is essential to understand the functioning of interbank markets, involved risks 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 does not hold open positions with the initially failing bank. More profound understanding on these contagion mechanisms and channels may help supervisors to focus limited resources and confine financial crises. Also, increasing knowledge of potential contagion may encourage market participants to pay more attention to risk prevention and lessen the danger of ‘moral hazard’, ie careless lending and disregard towards the counterparty’s credit limits and the creditworthiness.

This paper is related to studies that use interbank lending as a basis for contagion analyses and it contributes to academic literature by expanding the contagion analysis to Finnish interbank market using Finnish data for 2005–2007. It also tests the method of maximum entropy by using Finnish banking crisis data. As banking crisis’ main consequences for Finnish banking sector are known it is interesting to test whether contagion analysis can separate the problematic banks before the crisis hits.

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

Academic literature comprises both theoretical models that analyze specific aspects of contagion, and empirical analyses of markets. One of the theoretical frameworks is presented by Allen and Gale (2000). They show that the spreading of financial crisis depends crucially on the pattern of interconnectedness of the banking sector. 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. Then, the initial impact of financial crisis may be felt strongly in neighbouring regions.

The empirical research on contagion focuses most commonly on so called financial (aka direct) contagion through linkages between banks.¹ Linkages consist of financial exposures in banking sector. Contagion may occur through two effects: Problems of one bank may cause losses to creditor banks ('exposure contagion channel'). Alternatively, problems may jeopardize the liquidity of a potential debtor, ie, of a bank which finds that a credit line it holds with the troubled institution has dried up ('credit line contagion channel'). (Blåvarg and Nimander, 2002: 20; Müller, 2006: 38).

Empirical studies concentrate on national banking systems. Two different methodological approaches are used. The first approach simulates effects of a failure of a bank. Upper and Worms (2004) were the first to use the method of maximizing the entropy to estimate the distribution of individual banks' interbank loans and deposits and to analyse the possibility of contagion in German banking sector. Their methodology has been widely adapted and similar studies are performed with Swiss (Sheldon and Maurer, 1998), Belgian (Degryse and Nguyen, 2007), English (Wells, 2002 and 2004), Dutch (van Lelyveld and Liedorp, 2006) and Italian (Mistrulli, 2007) interbank markets. In general, all authors found potential for significant contagion effects but regard a substantial weakening of the whole banking sector as unlikely. The effects of the worst-case scenarios differ according to loss-given-defaults. With smaller values of loss-given-default the effect of contagion is lower. If loss-given-default is 100%, the contagion seems to be the most severe in the Netherlands (73–96% of national banking sector's balance sheets affected by contagion). The effect is the least severe in Belgium provided that a Belgium bank fails first. The contagion in other countries varies from 13% to 42%.

A second approach estimates contagion by considering a wider variety of risks and factors. Müller (2006) tests general stability of Swiss interbank market by developing a simulation approach. The emphasis of the paper is less on individual banks but more on the banking system's exposure to aggregate risk stemming from market's network structure. Possibility of contagion is evaluated by solving a clearing problem of multilateral, complex bank network model with the help of recursive algorithm. Elsinger, Lehar and Summer (2002) use standard risk management techniques in combination with a network model of interbank exposures to analyse the consequences of macroeconomic shocks for bank insolvency risk. They consider interest rate shocks, exchange rate and stock

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 and Nimander, 2002; Müller, 2006).

market movements as well as shocks related to the business cycle. Gropp, Lo Duca and Vesala (2006) use distance-to-default -indicator, multinomial logit model and ‘coexceedances’ to study contagion risk in the European banking market. In addition, Blåvarg et al (2002) have published a descriptive analysis on 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’. With maximum entropy method and with available data of banks’ balance sheets and counterparty exposure data one constructs Finnish banks’ bilateral exposure matrices. Then, 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 markets. In addition to big commercial banks middle-sized banks are also able to incur systemic wide contagion. The analysis of the banking crisis era shows how the risk of contagion increases a priori to the crisis. In the light of the 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: Finnish banking sector in general and interbank market in particular are described in section 2. Methodology for constructing bilateral matrices and simulating contagious effects are clarified in the section 3. Section 4 concentrates on description of the data sets, on choice of simulation parameters and on results of analyses. Section 5 concludes.

2 Banking sector in Finland

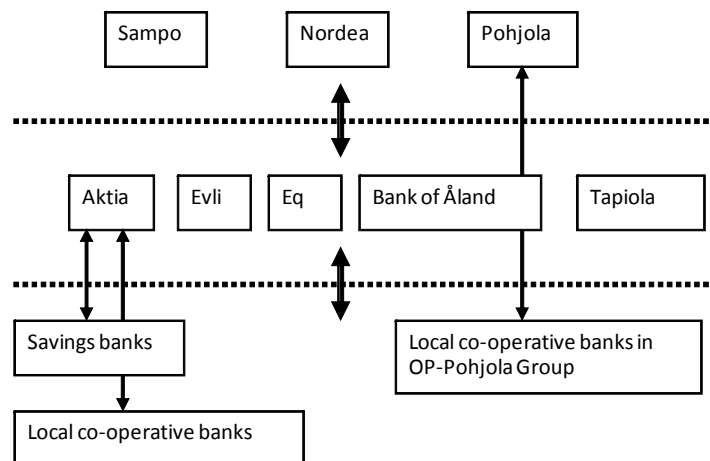
Finnish banking market consists of about 360 individual credit institutions. Several of these institutions are, however, part of a bigger consolidated corporation. According to the balance sheets the main banking groups in Finland are Nordea Bank Finland, Sampo Bank, OP-Pohjola Group, savings banks (incl. 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. Also, the business of mortgage banks has increased.

The linkages between Finnish banks can be roughly portrayed with Figure 2.1. Finnish interbank sector is, in principle, three layered. The biggest banks (Nordea, Sampo and Pohjola) have a possibility to act either on domestic or on international money markets. Ability to access international capital markets reduces their dependence on 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 bigger banks which act as financiers for other Finnish banks. Middle-sized institutions can also (to lesser extent than bigger banks) take benefit from international markets. Finally, the third layer is formed from small, local banks that use other banks as their central financing institution. For example, local savings banks and local co-operative banks use Aktia as their central financial institution. In a similar fashion, Pohjola plc finances local co-operative banks that belong to OP-Pohjola Group.

Figure 2.1

Interbank linkages on the Finnish banking market



Before the banking crisis during the 1980s 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 biggest ones and fierce rivals. The third biggest banking group were Savings banks for which Skopbank acted as a central financial institution. OKO Bank financed local co-operative banks that belong to OP Bank Group, Postbank was government-owned while the remaining banks were rather small. Finnish banking market was already then highly concentrated.

Table 2.1 shows banks' total assets as well as interbank liabilities in proportion to banks' total assets in 1988 and in 2006. At maximum, interbank

liabilities are approximately one fifth of total assets. But the share varies across institutions. Percentage shares have stayed in similar levels during the years although there are currently fewer banks whose exposures exceed 10% of total assets. In 1980s interbank lending used to be mainly domestic as individual banks used to hold quite large interbank positions in other Finnish banks.

Table 2.1 **Finnish deposit banks' total assets and a 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 interbank lending has become more international in nature. Finnish banks' unsecured receivables from financial institutions have been rising steadily from 2006 to 2007 (Table 2.2). In June 2007 the share of Finnish counterparties was exceptionally low and at the same time the share of Norwegian, Danish and Icelandic counterparties has 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 2.2

**Finnish banks' unsecured receivables classified
by countries**

	EUR Million	Share of countries of total assets in EUR million.						Banks from USA
		Finnish banks	Swedish banks	Other Nordic banks	German banks	English banks	Other European banks	
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

As researchers do not usually have complete information on individual banks' actual counterparty loan exposures, the data of bilateral lending relationships is estimated in order to fulfil gaps in data sets. 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. Estimation methodology is based on the concept of maximizing the entropy.² The concept originates from information theory where it denotes the most likely outcome given the a priori knowledge about the event. In the present context, it corresponds to the most likely structure of lending given all a priori pieces of information on interbank market. Maximizing the entropy includes the idea that banks spread their lending as evenly as possible between other banks in the market. (Upper, 2007: 5).

² More information on the estimation method can be found in Blien and Graef (1998).

Figure 3.1

N*N matrix of interbank loans and deposits

$$X = \begin{array}{cccccc}
 & & & & & \Sigma_i \\
 & & & & & a_1 \\
 & & & & & \vdots \\
 & & & & & a_i \\
 & & & & & \vdots \\
 & & & & & a_N \\
 \Sigma_j & l_1 & \dots & l_j & \dots & l_N
 \end{array}$$

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 3.1). Let this matrix be named 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 and column 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 to be zero, since no bank lends to itself. (Upper, 2007: 4). If researcher has some kind of a priori knowledge about individual interbank relationships and their magnitude, the knowledge is gathered into a priori matrix C that is also N * N matrix and resembles matrix X.

Censor and Zenios (1997: 237, 242, 245) pose the problem of maximizing the entropy more theoretically 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'. Frequently, matrix C is required to be adjusted so that the row (a = assets) and column (l = liabilities) totals equal fixed positive values, ie. row and column totals of matrix X. Maximizing the entropy yields a unique estimate of matrix X. More formally, the problem is as follows

$$\text{Min}_{x_{ij}} \sum_{i=1}^n \sum_{j=1}^n x_{ij} \log \frac{x_{ij}}{c_{ij}} \tag{3.1}$$

$$\text{s.t.} \quad \sum_{i=1}^n x_{ij} = l_j, \quad i = 1, \dots, n \tag{3.2}$$

$$\sum_{j=1}^n x_{ij} = a_i, \quad j=1, \dots, n \quad (3.3)$$

$$x_{ij} \geq 0 \quad (3.4)$$

If bilateral exposures are estimated from the balance sheet data, a requirement for maximum entropy estimation is 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).

3.2 Simulating contagion

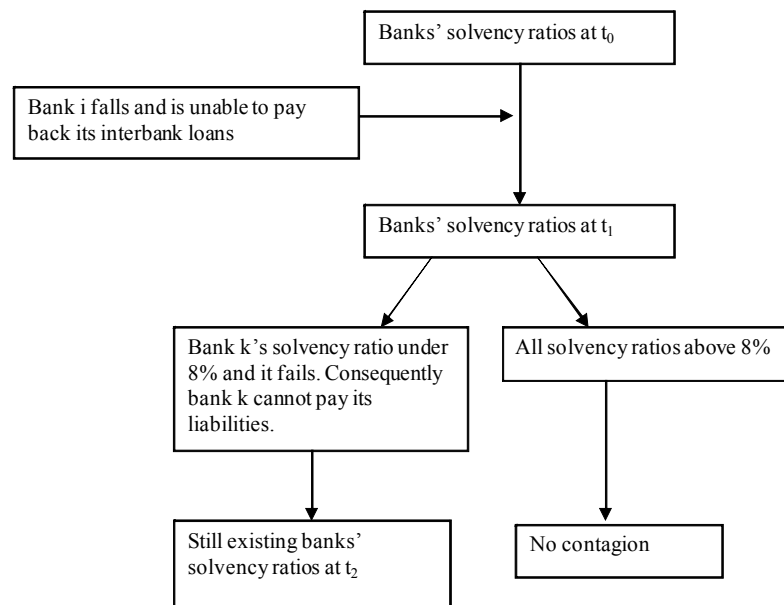
Once the matrix of interbank linkages is in place, the researcher has to specify the type of the shock that triggers the contagion (Upper, 2007: 7). Usually, the scope of contagion is estimated by letting banks go bankrupt one at a time and measuring the number of banks that fail owing to their direct or indirect exposure to the failing bank. Usually, if the amount of the losses suffered by banks lending to the failed bank is greater than lenders' own capital, lenders default. Contagion need not be confined to such first-round effects, but a failure of the first bank can potentially trigger a whole chain of consequent 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 , $b = 1, \dots, N$, in banking sector. All these banks hold capital c_b as well as an exposure x_{bb} versus another bank. Contagion simulation involves the following steps (Figure 3.2):

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

Figure 3.2

Algorithm for contagion simulations



4 Estimating the danger of contagion on the Finnish interbank market

4.1 Data description

The basic analysis of Finnish interbank market is based on counterparty exposures, balance sheet and liquidity risk data. Counterparty exposures data give accurate snapshot of interbank business, but the data fails to cover connections between all banks in the Finnish interbank market.³ At the end of 2007 six Finnish deposit banks' receivables from ten biggest counterparties were 28% of all banks' total receivables from financial institutions. In order to get the whole picture on 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 deposits. These instruments are

³ Data collection by Finnish Financial Supervision includes deposit banks whose balance sheet total exceed 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 group level and includes information on unsecured and secured loans. Unsecured claims of banking groups are divided into sub-groups like lending and securities (including certificates of deposits), settlement, shares and derivatives. Repurchasing agreements are singled out from all secured claims.

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 exposures data is used in matrix C to give more accurate estimations of relationships between the six Finnish banks. Further, liquidity risk data is used to clarify relationship between small local banks and their central financial institutions in matrix C. The data set includes information about central bank activities between Aktia and local co-operative banks and savings banks as well as between Pohjola Bank and co-operative banks in OP-Pohjola Group. It is noteworthy that analysis on banking crisis is based only on balance sheet data since counterparty exposures and liquidity risk data were not collected at the time.

Contagion analyses for 2005–2007 and for banking crisis period (1988–1990, 1994 and 1996) include major Finnish deposit banks.⁴ In order to obtain a closed system where, in principle, all interbank deposits and loans add up to zero, only lending between domestic banks is considered, ie all business with foreign banks are excluded. Subtracting international interbank lending leads, in practise, into a situation in which discrepancies between total assets and liabilities of the Finnish banking sector arise. Although this is in a way normal as banks can be either a net lender or a net borrower in the interbank market, it complicates running of the data estimation algorithm. For this reason, the individual liabilities positions were scaled so that their sum matches 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 different data points the highest share of domestic assets and liabilities were 100% while the lowest share for assets was 8% and that for liabilities 0%.

With maximum entropy method the balance sheet data permits to compute altogether four different matrices of bilateral exposures. After having constructed bank-to-bank matrix for each exposure category, these matrices are added up to total domestic exposure matrix.⁵ This added-up matrix is then 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. Analyses do not cover exposures arising from the payment or security settlement systems or exposures due to the cross-holdings of securities. Due to the data limitations, counterparty risks that are not recorded in the balance sheet are not captured either.

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 for 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 solvency ratio

The key parameters in determining the existence of contagion are the loss-given-default (LGD) ratio and solvency ratio (usually congruent with capital adequacy requirements). LGD-ratio refers to the share of assets that cannot be recovered in the case of bankruptcy. Solvency ratio is a limit for a default.

The choice of LGD-ratio is by no means obvious. Upper et al (2004: 838–839) trace back several episodes of banking crisis and find that the ratio varies significantly. For example, in the mid-1980s an average loss realised was 30% of the book value of the banks' assets in the United States. In the case of the bankruptcy of 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 of interbank claims vis-à-vis other creditors. The Finnish balance sheet data does not, unfortunately, provide information on collateralisation of loans. According to 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 LGD. In practise, 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 at interbank market. In reality, banks seldom go bankrupt out of the blue but there are at least some rumours about the difficulties before hand. 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, ie 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 as unrealistic due to the fact that contagion may occur over 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 one wants to

concentrate into maximal negative effect in the interbank market and into contagion effects of a short time period, it is assumed that regulators do not have time to react in a 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 bigger consolidated corporation. In addition to the banking arm the group of companies may also include, for example, insurance business, investment funds and real estate business. Thus, in a case of 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 fulfill their obligations related to solvency ratio. As the simulations are static in nature one assumes that corporations do not have enough time to raise required funding and save their banking arm. It is also assumed that there is no extra funding available from interbank markets. In addition, in analyses there are no other forms of safety nets to which banks could rely on case of problems.

Simulations focus on gross exposures and do not take netting into account. As one search for a maximum exposure and assume contagion to proceed without delays; netting is not an option. Also in Finland banks cannot net interbank claims that can be used as collaterals for central bank funding. What happens after all contagion rounds and a bankruptcy of a bank is outside the scope of this paper.

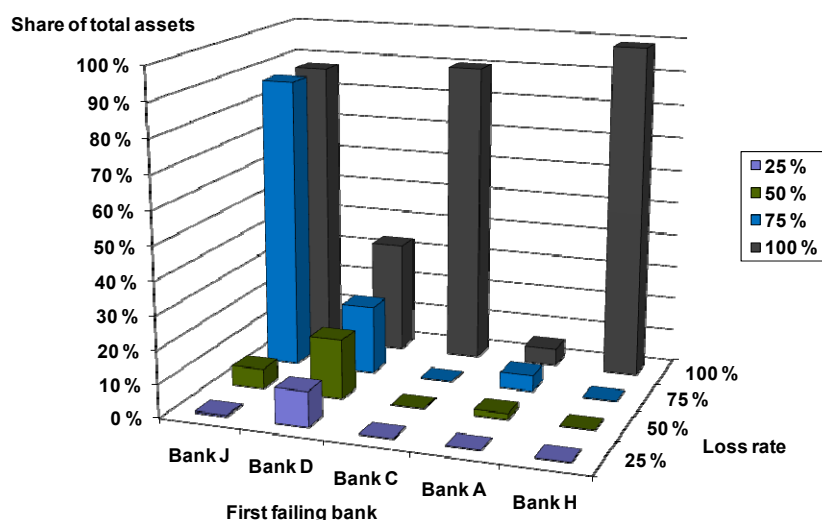
4.3 The risk of contagion

According to simulations for 2005–2007 the contagion may occur on the Finnish interbank market (Figure 4.1 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 big commercial banks there are also middle sized banks that are capable to produce 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 loss-given-defaults bank D is systematically riskier as it is able to affect negatively 10–30% of the banking market.

⁶ Local co-operative banks and local savings banks are both merged in groups.

Figure 4.1

Contagion on the Finnish banking system at the end of December 2007



The five banks that are identified to be a starting point for contagion remain the same from 2005 to 2007. Bank D is potentially the most contagious in 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 lesser extent, banks C and A can cause also problems in 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 enter 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 of overall banking sector due to this new set-up is negligible. Depending on the loss rate, the difference between the first and second set-up's magnitude of contagion varies from 0% to 2.5%.

From the perspective of local people and local communities the issue is not so trivial. Table 4.1 shows how large 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 fail over 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 relation to the first set-up in which all local co-operative banks were judged insolvent. The gap between results diminishes when the loss-given-default increases.

Table 4.1

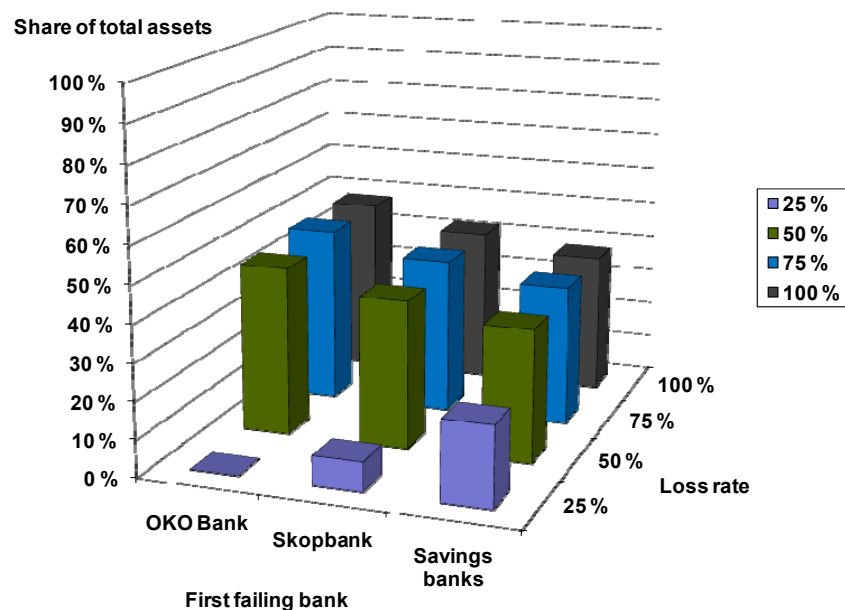
**Failing local banks' total assets in the second set-up
in relation to total assets of local banks**

	Loss ratio			
	25%	50%	75%	100%
local co-operative banks	6.0%	44.0%	82.2%	94.3%
local savings banks	5.3%	45.7%	71.9%	96.3%

The liberalization of Finnish financial market that began at the beginning of 1980s planted the seeds of banking crisis as it increased loan demand and loan stock started to expand rapidly as banks competed fiercely over market shares in household and corporate lending. At the same time, interbank market was opened 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, banking crisis was triggered by depression, collapse of export to Soviet Union, devaluation of the Finnish currency and rising interest rates.⁷

Figure 4.2

**Contagion on the Finnish banking system
at the end of 1990**



During the years 1988–1990 and on the edge of the banking crisis there were three banks that were able to trigger contagion, namely Skopbank, Savings banks and OKO Bank. (Figure 4.2 and Appendix 1) At the beginning of 1980s Skopbank

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

and Savings banks oriented themselves to market related activities. Their lending increased aggressively and as restrictions in money markets were lessened they resorted to acquire more funding in addition to deposits. Skopbank's and Savings banks' strategy was to acquire funding from short term money markets and invest in long-term assets. Interbank loans were both Finnish and foreign currency denominated. 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 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 banking sector's total assets.

The fact that the analysis unfolds OKO Bank as the most severe source of contagion during 1988–1990 is some sort of revelation. The OP Bank Group did have troubles during the crisis but it is generally acknowledged that the group was able to survive due their more conservative strategy and Group's joint responsibility over loan losses. The results are most likely driven to some extent by the fact that OKO Bank acts as a central financial institution for 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. So, if they had not been joint responsibility in the Group, OKO might have encountered problems.

In the light of the historic knowledge maximum entropy method is able to separate the most troublesome banks in the banking sector.⁸ When the overall economic situation weakened, banks' loan losses started to accumulate and their situation worsened rapidly. Growing market based funding increased the risk of contagion on the Finnish banking sector from 1988 to 1990. Skopbank's strategy was highly dependent on availability of market funding and as Skopbank's loan losses scored, markets became highly suspicious on Skopbank's ability to respond its obligations. The lack of confidence in national money market about the bank's operational preconditions increased and finally Skopbank's liquidity collapsed on 19th September 1991 when other banks refused to buy Skopbank's certificates of deposit. To prevent the whole banking system to collapse Bank of Finland stepped in and took Skopbank over.

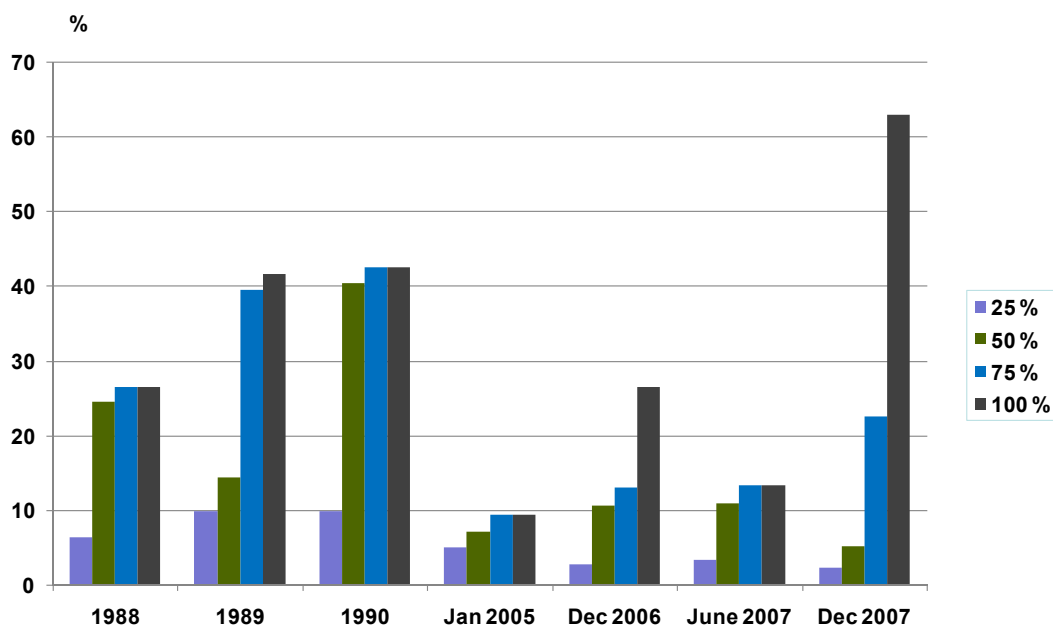
Savings banks situation worsened when loan losses doubled and the costs of market funding increased due to rising interest rates. Ultimately, savings banks

⁸ The contagion analysis is also replicated with 1994 and 1996 data. Yet, 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 make substantial losses during 1991–1995. At the end of 1994 only OKO Bank and Postbank are able to incur contagion while at the end of 1996 possible sources of contagion are OKO Bank, Postbank and Merita Bank. OKO Bank's exposure is due to its position as central monetary institution. Postbank's position is not, in reality, worrisome since Postbank was owned by the state. Merita Bank was the biggest bank in the market formed in a merger between KOP and SYP (Unitas).

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.

Analysis does not indicate KOP and SYP (Unitas) as possible sources of contagion. It is noteworthy that the banks' interbank lending related to their total assets is not as large as in other banking groups (Table 2.1). Still, KOP and SYP were the main banks in Finland and active in interbank market. Thus, intuitively they should be a prominent source for contagion. In fact, the analysis is hindered as one cannot identify domestic certificates of deposits from foreign ones. Certificates of deposits were, however, widely used instruments on the Finnish interbank market in 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 including bonds that are reported in banks' balance sheets to interbank assets and liabilities. When money market related instruments are included in the figures, all banks except STS-Bank and Bank of Åland cause wide spread contagion. With 100% loss ratio the effect of contagion varies from 51.5% to 92.1% depending 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.

Figure 4.3 **Average contagion with different loss ratios**



Based on the simulations the danger of contagion is a possibility on the Finnish interbank market. It appears also that the magnitude of contagion⁹ was higher in early 1990s than in 2005–2007 (Figure 4.3). The only exception is the end of 2007 when the effect of average contagion with 100% loss-ratio is the most profound. Yet, the results of December 2007 may be affected by structural changes in banking market.

Operational environment of banks in early 1990s and years 2005–2007 bear several similarities. Loan stock has been growing for several years and interest rates have mainly increased. Also, the banking sector is highly concentrated and there are only few big players at the market. However, there are also notable differences between the periods. The current interest rate level is not near that of early 1990s and corporate sector is not so badly indebted than before. Interbank markets are more international in nature and the network of interbank markets has 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 have been, on average, more limited in 2005–2007 than in early 1990s.

In simulations, speed of contagion and the importance of 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 on the subsequent contagion rounds is smaller. Typically, there are two or three contagious rounds after which contagion stops. Yet, the speed of contagion depends on the size of 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 LGD-ratio has an obvious effect on the results. This is intuitively appealing, since higher values of the ratio have a 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 maximum loss ratio is theoretically interesting since it gives ‘the worst case scenario’. In the case of 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, already the quite plausible 50% loss ratio seems to have measurable effects in 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. Finnish banking sector – like that of the Netherlands – is dominated by a few large banks. Respectively, the share of banking sector’s total assets affected by

⁹ The magnitude of contagion is measured as a percentage share of failing banks’ assets to banking sector’s total assets after all banks have been exposed to the effects of contagion. The assets of the first failing bank are not included in the figures. Individual charts for contagion at different time periods are in Appendix 1.

contagion is high especially when loss ratios are at an exalted level. At the same time, contagion seems to have somewhat milder effect in countries with multiple money-centre and two-tier systems (for instance, Italy and Germany). These results support findings of Allen et al (2000) as the level of contagion depends on the structure of interbank markets. On the other hand, Degryse et al (2007) find that Belgian banking sector's increasing concentration decreases the risk and impact of contagion. This outcome gets some support from Finnish case, since while concentration on the Finnish banking sector reduces, on average, the contagion grows.¹⁰ However, Finnish evidence is not decisive and more observations are needed to draw definitive conclusions. Also, when reviewing the country-level results the concentration of the banking markets does not seem to have such a clear cut connection with the level of contagion.

5 Conclusion

The present 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 (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 big commercial banks there are also middle sized banks that are capable to incur wide ranged contagion. Across the different time periods the five banks that are identified to be 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 historic knowledge the maximum entropy methodology is able to pick up the financial institutions that formed a systemic threat to Finnish banking system. Although banks' current operational environment resembles that of 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 have been, on average, more limited in 2005–2007 than in early 1990s.

However, as Upper (2007: 5) states that the entropy maximizing method is subject to important caveats. There is no account on any remedial action of banks when difficulties brake up, nor is there any allowance made for exposures in net

¹⁰ In Finland concentration (measured by Herfindahl index) and contagion (with 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.

terms. In addition, most of analyses are unable to make a distinction between uncollateralized and collateralized lending. There are also at least three reasons why maximizing the entropy might not be a particularly good description of reality. First, fixed costs for screening of potential borrowers and monitoring loans may render small exposures unviable. Secondly, relationship lending may limit the number of counterparties of any one bank and thus lead to a higher degree of market concentration than suggested by the maximum entropy method. Thirdly, maximum entropy results in the same portfolio structure for estimated counterparties. Maximum entropy biases the estimated matrix and raises the threshold for a shock leading to contagion.

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 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 contagion.

Based on the results of Mistrulli (2007) it seems clear that maximum entropy method biases the results on existing contagion, but the exact magnitude and the direction of distortion are not known exactly. Also, contagion analyses are based on static set-ups and on individual data observations. Therefore, the level of contagion should be taken as indication of possible effects in banking markets. New avenues for research could be to test how variations in exposures impact on the magnitude of contagion and to do 'stress-testing' analysis for banking sector.

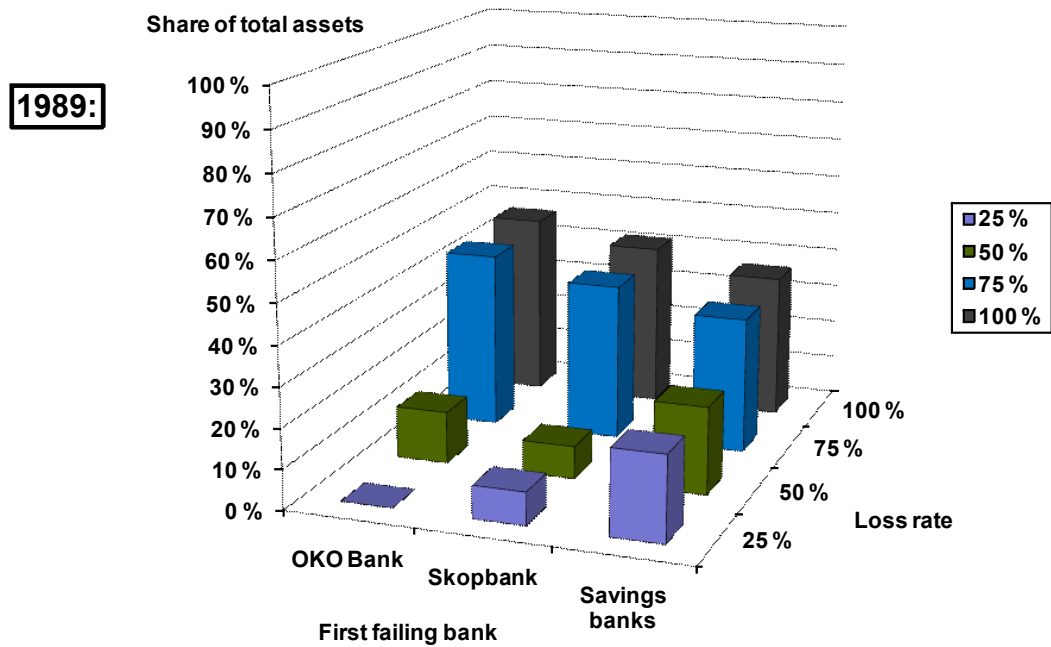
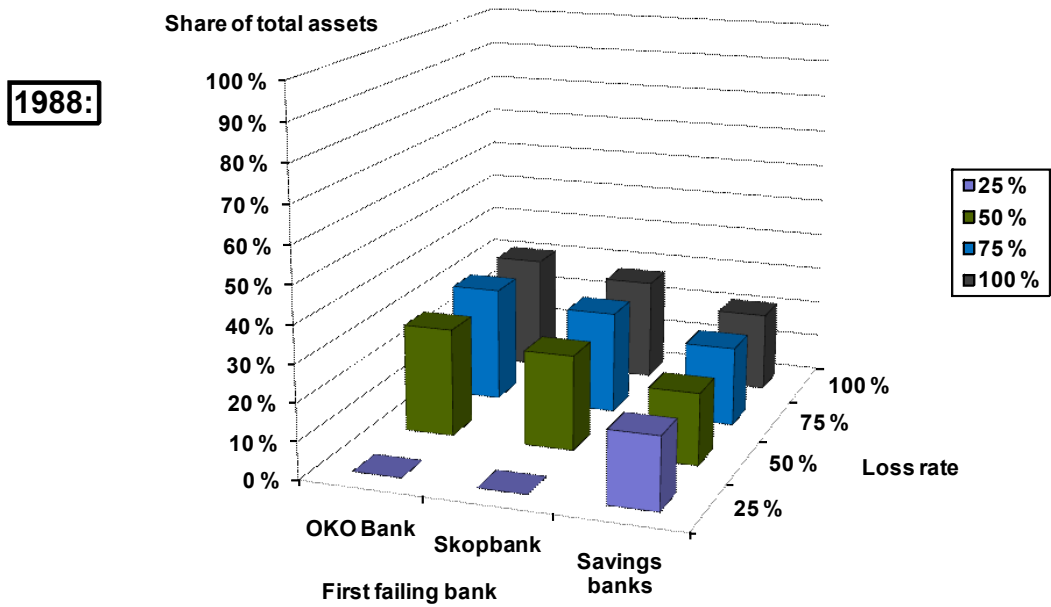
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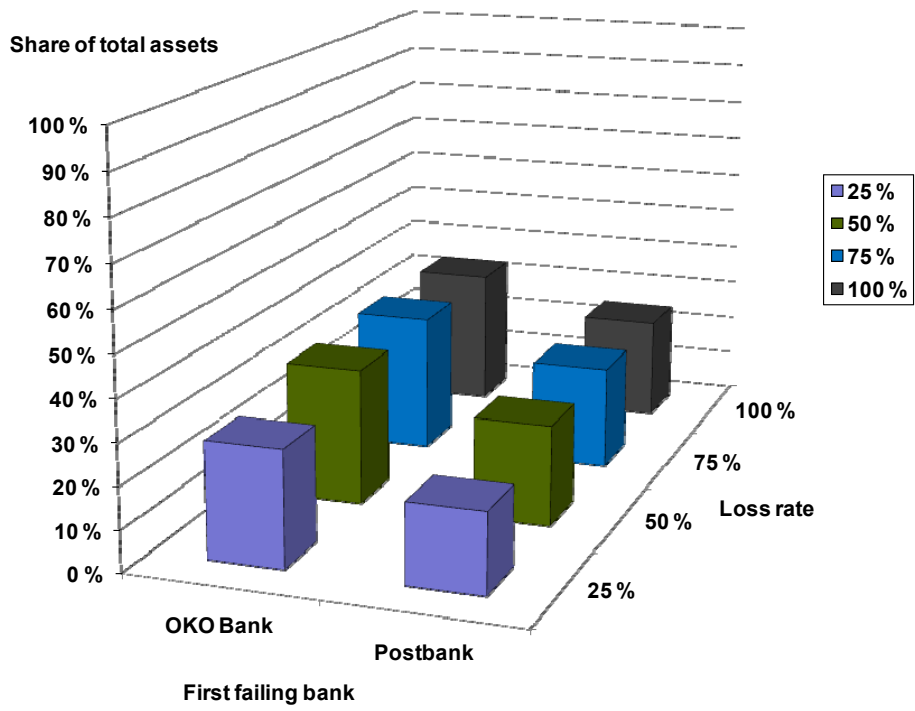
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Appendix 1

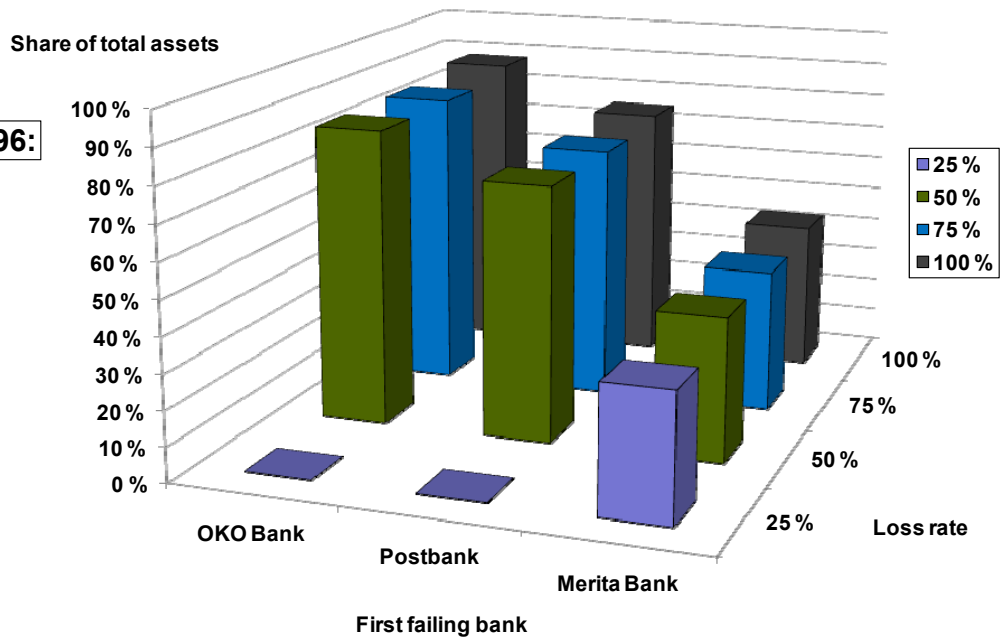
Contagion on the Finnish banking market

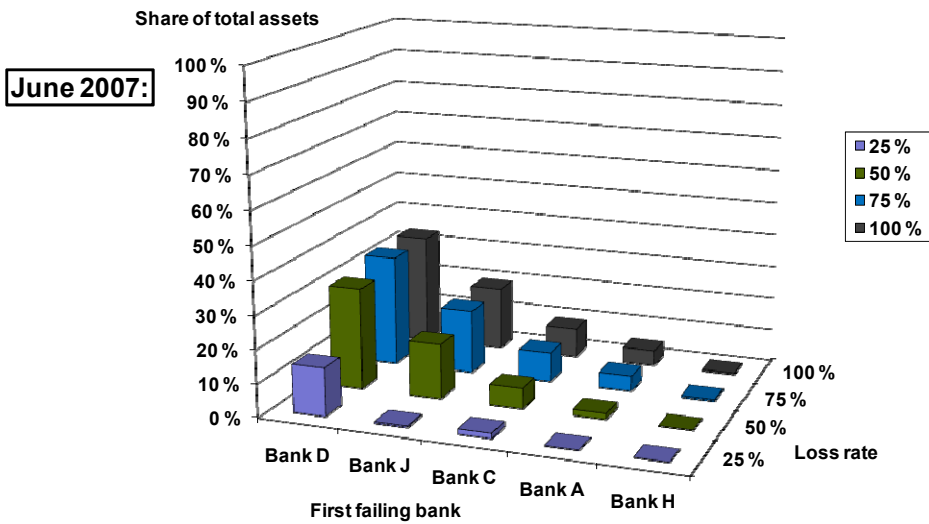
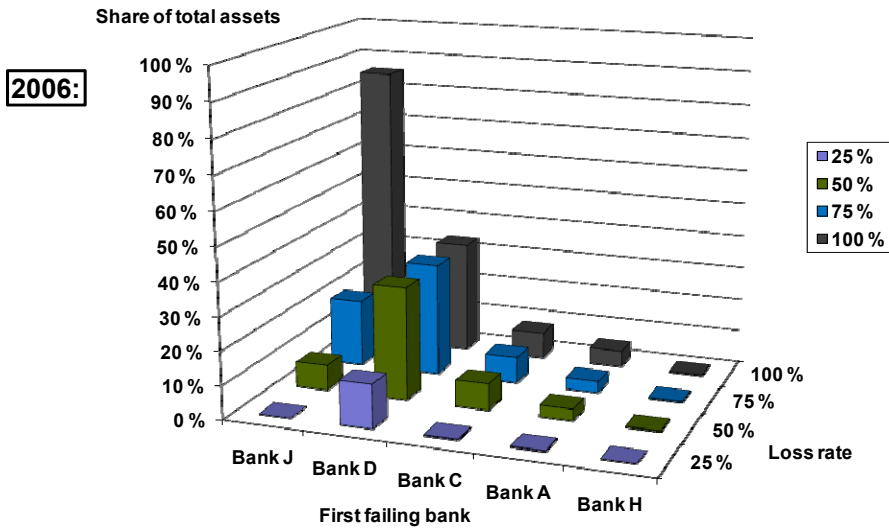
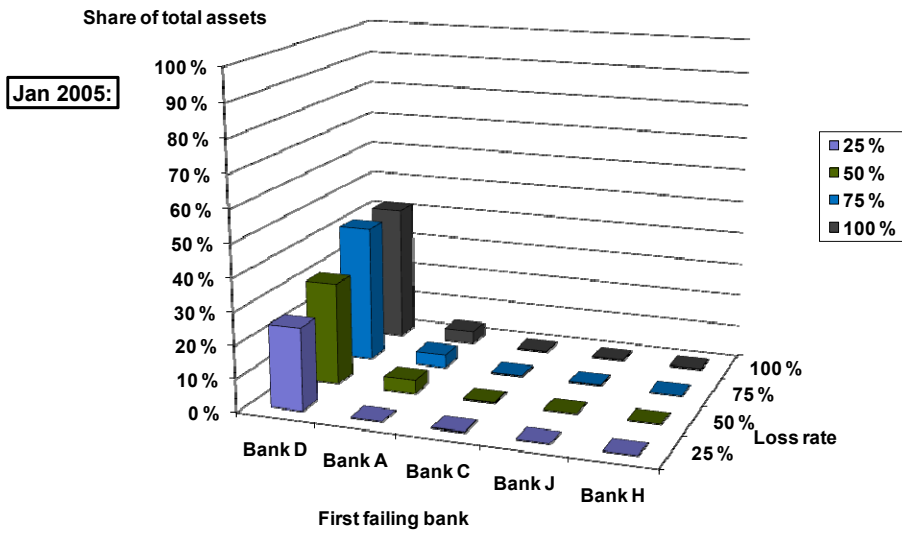


1994:



1996:





Appendix 2

Results for 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 (2008)	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 and Summer (2002)	Results show that 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 of 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 and Vesala (2006)	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 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 German banking sector. While 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 app. 40 %.
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, the fact that losses are shared among banks affiliated to a conglomerate, banking stability may even worsen due to new channel for 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 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 a 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 considerable impact on its 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. Bank's rate of assets, capital-to-asset-ratio and initial interbank lending affect the probability of the failure.
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 credit losses of banks are more severe. All in all, a single bank failure is rarely sufficient to trigger out 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 maintained assumptions about the distribution of interbank loans and the level of loss given default.

* With safety nets Upper et al. refer to 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.

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