

Interbank Exposures and Risk of Contagion in Crises: Evidence from Finland in the 1990s and the 2000s

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Abstract

By analysing the risk of interbank contagion during two distinctive crises, namely the Finnish banking crisis in the 1990s and the most recent financial crisis of the 2000s, this paper provides evidence on negative domino effects in a small open economy with a concentrated banking system. Simulations based on interbank exposures and maximum entropy estimations shed light on the magnitude of the contagion and the vulnerability to cross-border risks. The results show that just before the onset of the Finnish banking crisis the contagion would have affected almost half of the banking system, indicating that without the government bailout the implications for society would have been severe. In the 2000s the domestic contagion peaked after the collapse of Lehman Brothers and amid the sovereign debt crisis. The analysis suggests that the higher the concentration of the banking system, the more vulnerable it is to severe contagion. Moreover, strong interbank linkages with foreign banks increase the domestic risks.

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1 Introduction

The history of financial crises extends to the early 20th century and beyond, including incidences such as the Wall Street Crash of 1929 and the sub-prime crisis. Frequently, the crises impact negatively on the financial stability of the banking sector and are extremely costly for an economy as a whole. From the historical perspective, relatively little emphasis has, nevertheless, been placed on analysing how the crises spread across institutions and borders, although the recent financial crisis highlights the importance of the interconnectedness of financial institutions.

The interbank markets, in which banks borrow and lend funds, may act as transmission

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channels for shocks during crises. These linkages are especially vulnerable since banks can relatively easily reduce interbank lending should their confidence in counterparties deteriorate. In the worst case scenario, the losses from interbank loans may lead to contagion (or so-called domino effect), i.e. one bank failure leads to failures of other banks even if the latter are not directly affected by the initial shock or do not hold open positions with the first failing bank [1].²

This paper examines the possibility of contagion via banks' interbank exposures in a small open economy with a concentrated banking sector during two distinctive crises. Academic literature is enriched, firstly, from the focus on significant crises periods, namely the Finnish banking crisis in the 1990s, which is one of the "Big 5" banking crises [5], and on the recent financial crisis of the 2000s. Insights into similarities and differences in the two crises and into the patterns of contagion are provided for the estimation periods. The specific case of a small open economy such as Finland is interesting because of the vulnerability to cross-border risks, given the dependence on foreign trade: exports of almost 40% of GDP in 2010. Moreover, Finland's GDP decreased by 8% in 2009 and by 10% in 1991–1993, causing a severe stress to the banking system.

Secondly, the role of contagion in the Finnish banking crisis has not been discussed in previous literature. The systematic nature of the crisis in the 1990s forced authorities to bail out banks in order to save the rest of the banking system by limiting the effects of contagion. The contagion simulations shed light on the magnitude of problems that society would have faced if banks had been allowed to fail.

Thirdly, there is relatively little public information on network effects of the banking system, and during the last decade risk assessments have mainly concentrated on individual institutions. A deeper understanding of interbank linkages and transmission channels is therefore desirable to increase our knowledge of contagion and to help lessen the danger of "moral hazard", i.e. excessive risk-taking. Finally, cross-border vulnerabilities of the Finnish banking system from 2005 onwards are identified. The Finnish banking sector is highly concentrated and nowadays dominated by foreign banking groups, making Finland a prominent example for other similar banking systems. Banks' bilateral interbank lending is estimated by using the maximum entropy method and data on banks' balance sheets, interbank assets and liabilities. On the basis of these estimates, the effects of a bank failure in the Finnish interbank market are subsequently simulated.

The results suggest that during the banking crisis in the 1990s three banks were able to trigger contagion, while indicating five large and middle-sized banks as sources of contagion in 2005–2011. During the 1990s the contagion would have affected almost half of the banking system (assuming 100% loss ratio) and thus the implications for society would have been severe without the authorities' rescue measures. In 2005–2011, the negative shock caused by a failure of a foreign bank (with a 100% loss-given-default) affects 77% of the total assets of the Finnish banking sector, while contagion from a Finnish bank impacts 66% of the total assets of the sector. In addition, the estimations show that the higher the concentration of the banking system, the greater the system's vulnerability to contagion. This is worrying in terms of a country that has large

²Other contagion channels include information, sale of illiquid assets or joint macroeconomic shocks but they are beyond the scope of this paper. (See [2], [3] and [4])

cross-border exposures with foreign banks.

In terms of average contagion, the fragility of the banking system increases before the crisis irrespective of the original source (domestic/international) of the crisis. Although the interbank market exhibits higher risk levels in the current crisis than in the 1990s, a bad outcome has not materialized owing to the absence of a trigger. The macroeconomic shock was milder and more transitory in the 2000s than in the 1990s, banks' capital buffers are currently large, interest rates are lower than in the early 1990s and many borrowers and lenders have learned from the experience of the 1990s, and so acknowledge the dangers of over-borrowing.

The rest of the paper is organised as follows. The previous literature is reviewed in section 2, and section 3 describes the Finnish banking sector and the crisis periods. Section 4 presents the data and method of estimating bilateral exposures and simulating contagious effects. This section also briefly discusses the simulation parameters. The results are introduced in section 5 and section 6 concludes.

2 Previous Research

The Finnish banking crisis is dealt with in several papers, describing the boom and subsequent bust of the Finnish banks and economy in the early 1990s (see, for instance, [6], [7], [8] and [9]). No single, individual cause for the negative outcome can be identified, as several factors such as financial deregulation, abundant refinancing opportunities for banks, over-borrowing of firms and households, excessive risk taking, lack of adequate risk management, policy and supervisory measures, and negative macroeconomic shocks all played a role. Although the Finnish crisis shares common features with other financial crisis in general and with Nordic banking crises in particular (see [6], [7], [10], [11], [12], [13]), it is one of the worst banking crises (so-called "Big 5" crises) of the post-WW II era, as listed in [5]. Despite the extensive coverage, the role of contagion in the Finnish banking crisis has not yet been discussed.

Theoretical evidence on the consequences of the banking sector's structure for contagion is twofold. If all banks are connected with each other (i.e. the interbank market is complete), the initial impact of a financial crisis may be attenuated [14]. But if each bank is connected with a small number of other banks (incomplete interbank markets), the crisis may be felt strongly in neighbouring institutions. However, some papers provide evidence that an incomplete structure renders the banking system less vulnerable to contagion. [15], [16]

Empirical research finds potential for significant contagion effects but regards as unlikely a substantial weakening of the whole banking sector ([17], [18], [19], [20], [21], [22], [23], [24]). Other empirical studies have estimated contagion by considering a wider variety of risks and factors (see e.g. [3], [25], [26]). These studies support the above findings and also indicate significant cross-border contagion. Regarding cross-border contagion, [27] shows that the contagion is more widespread between countries geographically close to each other. Furthermore, they suggest that the risk of cross-border contagion has increased over the years.

3 The Finnish Banking Sector and the Crises

3.1 Banking Sector in Finland

In the 1990s the majority of Finnish banking market was dominated by KOP, SYP, savings banks, cooperative banking group, Post office bank and Skopbank. Of these institutions, KOP and SYP were the largest ones and were fierce rivals. The third largest banking group was the savings bank group, which comprised about 250 savings banks and Skopbank, which served as the group's central financial institution. OKO Bank financed the cooperative banks that belonged to the cooperative banking group, and Post office bank was a government-owned commercial bank. The Finnish banking market was already then highly concentrated, as the remaining banks were relatively small. ([6], [8])

According to the balance sheets, the main banking groups in Finland are currently: Nordea Bank Finland, OP-Pohjola Group, Sampo Bank, savings banks (incl. Aktia) and local cooperative banks. Nordea and Sampo banks are foreign-owned, and the Finnish banking sector is highly concentrated, as the three main players account for approximately 75% of total lending. All together, there are about 360 individual credit institutions in Finland, several of which belong to a larger consolidated banking group.

3.2 The Crises in the 1990s and 2000s

The deregulation of the Finnish financial market in the mid-1980s planted the first seeds of the Finnish banking crisis, as it expanded banks' choice set of assets and liabilities (for more details, see [7]). The interbank market was established in 1986, providing a new funding source for Finnish banks. Banks were no longer bound to traditional deposit funding but could finance the growing lending stock with market funding. At the same time, the private sector started to accumulate debt, as low real interest rates, a growing real economy and general optimism unleashed the demand that had been suppressed during the regulation era.

Moreover, banks competed fiercely over market shares in private sector lending. During the second half of the 1980s, Skopbank's and savings banks' lending increased aggressively, but other banks too were quick to react to the competition. Foreign currency loans were especially easy to sell owing to interest rate differentials and a pegged exchange rate regime.

When the overall economic situation weakened, banks' traditional loan losses started to accumulate and their situation worsened. Finally, the banking crisis was triggered by steeply rising interest rates, devaluation of the Finnish currency, and the collapse of the real estate bubble and exports to the Soviet Union. A severe depression followed, and GDP decreased by 10% in 1991–1993. The Finnish experience with financial liberalization, lending boom and systemic banking crisis resembles in many ways the crises that took place in Sweden and Norway in the 1990s although some differences remain. [6]

Turning to individual banks, Skopbank's strategy had been highly dependent on the availability of market funding and, as Skopbank's loan losses soared, the markets became sceptical as to Skopbank's ability to meet its obligations. The lack of confidence prevailing in money markets increased and finally Skopbank's liquidity collapsed in September 1991 when other banks refused to buy Skopbank's certificates of deposit. To prevent the whole banking system from collapsing, the central bank took over Skopbank.

In the first half of 1992, the savings banks that were on the brink of collapse merged to form the Savings Bank of Finland (SBF), but its financial standing deteriorated during the year as loan losses doubled and the costs of market funding increased. Ultimately, SBF was not able to follow its special recovery plan and the bank was split up between four competitors in October 1993.

The recent global financial crisis started in 2007 when the sub-prime mortgage market collapsed in the US and the value of mortgage backed securities plummeted, causing large losses for financial institutions that had invested in these instruments. As the crisis deepened, panic spread in financial markets and equity values declined. Lehman Brothers failed in September 2008, after which the financial crisis intensified. Several US and European banks were either bailed out by governments or merged with other companies. Iceland's banking sector was hit especially hard, while Swedish banks booked large loan losses on lending to Baltic States, and many small banks in Denmark faced difficulties. [13], [28]

The over-indebtedness of several European countries, along with a downturn in the global economy, bursting property bubbles, as well as investment and loan losses in the European banking sector, contributed to an unfolding of the European sovereign debt crisis. The crisis began at the start of 2010 when the magnitude of Greece's fiscal deficit was revealed. Amid fears of crisis escalation and downgrading of Greek sovereign debt, the situation in the international financial markets deteriorated in early May 2010. Since then, Ireland and Portugal have also received rescue packages.

Throughout the sovereign debt crisis the international money markets have remained extremely volatile, although several policy measures have been undertaken. The situation has remained fragile, and financial markets have been repeatedly hit by renewed worries related to the debt crisis. The financial markets continue to be divided into weak banks dependent on public support and strong banks still able to access markets on their own. With limited exposures to ailing governments' bonds and low traditional loan losses, the Finnish banks have been relatively well-placed compared to their European and Scandinavian peers in recent years.

4 Methodology

4.1 Data

Contagion analyses of the Finnish interbank market in 1988–1996 and 2005–2011 include the Finnish deposit banks.³ The analysis for 2005–2011 is based on balance sheet, counterparty exposure and liquidity risk data, whereas data were not collected on counterparty exposures and liquidity risk in the 1990s, so that only balance sheet data are used for the earlier crisis period.

Balance sheet information is based on data collected from banks' annual reports for the

³KOP, OKO Bank, SYP, Merita Bank, savings banks, Postbank, Skopbank, STS Bank and Bank of Åland in 1988–96 and Nordea Bank Finland, Sampo Bank, Pohjola (former OKO), Aktia Savings Bank, Bank of Åland, Evli, eQ Bank, Tapiola Bank, S-Bank, local co-operative banks and local savings banks in 2005–2011. Local co-operative banks and local savings banks are each combined into a separate banking group.

1990s and on data collected by the Finnish Financial Supervisory Authority (FSA) for the 2000s. Yearly data on aggregated interbank loans and receivables vis-à-vis financial institutions are available for the 1990s; for the 2000s we have quarterly data on interbank loans and receivables as well as on banks' bonds and certificates of deposit.⁴ Table 1 shows the total assets of Finnish banks as well as interbank liabilities relative to banks' total assets in 1988 and 2006. At a maximum, interbank liabilities were approximately one fifth of total assets in 2006 although there are differences between institutions. The share of interbank liabilities has diminished over the years, as there are currently fewer institutions with exposures exceeding 10% of total assets.

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

	1988		2006	
	Total assets, EUR million	Interbank liabilities over Total assets, %	Total assets, EUR million	Interbank liabilities over Total assets, %
KOP	24,322	1.2 %	-	-
OKO (Pohjola) Bank	7,375	16.2 %	24,196	4.5 %
Postbank	12,582	0.7 %	-	-
Skopbank	10,681	11.5 %	-	-
STS Bank	1,832	10.2 %	-	-
SYP (Unitas)	22,305	0.5 %	-	-
Savings Banks	16,643	14.5 %	5,648	1.0 %
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 %
Evli Bank	-	-	698	10.7 %
eQ Bank	-	-	627	0.0 %
Tapiola Bank	-	-	546	0.0 %
Local co-operative banks	-	-	3,467	0.2 %

Source: banks' annual reports

Counterparty exposure data give accurate quarterly snapshots of interbank business and provide information on unsecured and secured loans at the group level. However, the FSA's data set covers only the 10 largest domestic and foreign counterparties of each reporting bank and does not shed light on all exposures.

In order to fill in this gap, FSA's quarterly liquidity risk data are used to clarify the

⁴In principle, there is also information on bonds and certificates of deposits in 1990s but this is not included since breakdown between domestic and foreign items is not available. Foreign exposures are deducted from all balance sheet items to get a closed system. This is a standard procedure in the literature owing to the estimation method requiring that exposures of all potential counterparties should be available for a given time period.

bilateral interbank relationship among small Finnish local banks and their central financial institutions⁵. Cross-border contagion is assessed by using counterparty data on Finnish banks' interbank lending to foreign banks.

According to the counterparty exposure data most of the banks' exposures are unsecured. In 2005–2011 the unsecured receivables from both domestic and foreign financial counterparties fluctuated between EUR 12.0 billion and EUR 19.2 billion, constituting 73–113 per cent of the banks' total capital. In September 2008, amidst the international financial crisis, the main counterparties of Finnish banks were domestic ones. Since then the share of Finnish counterparties have gradually decreased, while the share of foreign banks has increased.

Based on the available data the Finnish interbank sector does not form a complete structure in the sense of [14]. All banks are nevertheless connected to each other via common counterparties. The three largest banks, in the heart of the interbank market, have room to manoeuvre in either the domestic or international money markets. The ability to access international capital markets reduces their dependence on the national interbank market, although they interact with each other and with other Finnish banks. Middle-sized institutions are also able to raise funding from international markets but also acquire funding from the largest Finnish banks. Finally, small, local banks use other Finnish banks as their central financing institutions and thus form 'satellites' around these banks. 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.

4.2 Estimating Bilateral Matrices

As balance sheets and large exposure data do not give complete information on individual banks' actual counterparty exposures, the method of entropy maximization has been used to fill the gaps in the data sets. Following [17] and [19], this paper assesses domestic and foreign contagion in the Finnish interbank market.

The problem of estimating the matrix for banks' bilateral exposures 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" (see [29] and Appendix). Matrix C contains all available statistical information on the bilateral unsecured exposures among Finnish banks as well as between foreign and Finnish banks, while balance sheet data on total interbank assets and liabilities provide the set of linear conditions for the estimation problem. The overall distribution of interbank loans and deposits (i.e. matrix X) is subsequently estimated by using the entropy maximization. This problem is easily solved using the RAS algorithm by [30].

The data permit us to compute two matrices of bilateral exposures. These sub-matrices are formed for loans and receivables as well as for bonds and certificates of deposit. After having estimated a bank-to-bank matrix for the sub-categories, these matrices are combined into the total domestic exposure matrix. This composite matrix is then been used to test the possibility of contagion.

⁵The data set includes information on interbank deposits and loans between Aktia, on one side, and local co-operative banks and savings banks, on the other side. Similar data exist for Pohjola Bank and co-operative banks in the OP-Pohjola Group.

4.3 Simulating Contagion

Once the matrix of interbank linkages is in place, the scope of contagion is simulated by letting banks go bankrupt one at a time and by computing the overall effect on the banking sector due to direct or indirect exposures to the first failing bank. The simulations follow a sequential (or round-by-round) algorithm ([2], [31]). At the start, there are several banks b , $b = 1, \dots, N$, in the Finnish banking sector. All these banks have capital c_b as well as an exposure x_{bb} towards another domestic bank. Contagion simulation involves the following steps:

1. By assumption, bank i fails at t_0 .
2. A lender defaults if the amount of losses from lending to the failed bank exceeds the lender's own capital. So, a bank j fails if its exposure towards bank i , x_{ji} , multiplied by an exogenously given parameter for the loss-given-default (LGD), exceeds the bank j 's capital c_j . So, bank j fails if $\text{LGD} * x_{ji} > c_j$ at t_1 .
3. Contagion need not be confined to such first-round effects, but a failure of the first bank can trigger a chain of failures (domino effect). A second round of contagion occurs for any bank k for which $\text{LGD} * (x_{ki} + x_{kj}) > c_k$ at t_2 . Contagion stops if no additional banks go bankrupt. Otherwise, a third round of contagion takes place.

The impact of the failure of a foreign bank is successively studied by letting each of the M foreign banks go bankrupt one at a time and simulating the contagion within the domestic interbank market with a given LGD.

In the simulations, bank institutions stand alone. In reality this may not always be the case, since several Finnish banks are members of a larger group. Thus, when facing difficulties, a parent corporation may provide funding to its banking subsidiary. This funding can extend the bank's ability to sustain market turbulence and restrain contagion. However, the recent financial crisis has shown that banks may not have time to react in a crisis. A sudden drying up of interbank markets and short-term funding or a lack of other forms of safety nets on which banks could rely in a case of problems may quickly squeeze the bank out of the interbank markets. Should the analysis take into account all ramifications of a bank failure such as adjustments by depositors the impact is likely to be even more devastating.⁶

Simulations focus on gross exposures and do not take into account netting. As the focus is on maximum exposure and contagion is assumed to proceed 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 beyond the scope of this paper.

⁶For instance, when prices are allowed to change, the systemic risk may be even larger than thought previously [32].

4.4 The Choice of Parameters

The key parameters in determining the existence of contagion are the loss-given-default (LGD) ratio and the solvency ratio. The LGD refers to the share of assets that cannot be recovered in the event of a bankruptcy. The choice of LGD is by no means obvious, as it can vary significantly. Historical evidence on the failures of international banks such as Continental Illinois, BCCI and Herstatt indicates that the loss ratio may range between 5–90% depending on the time period when losses are expected to materialize. ([2], [17]) The uncertainty about eventual recoveries suggests that it may not be the actual losses borne by the creditor banks but rather the expected losses at the moment of a failure that matter.

The loss ratio also depends on the availability of collateral for interbank claims vis-à-vis creditors. According to the Finnish counterparty exposure data, collateralized lending by Finnish banks is almost non-existent. Since the purpose of the study is to find the maximum negative shock that could hit the 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 a broad range of values for LGD, 25%, 50%, 75% and 100%, which remain constant across banks.

The solvency ratio forms a requirement for a bank's equity. The current minimum Tier 2 capital ratio is set at 8% by regulatory authorities. In reality, banks seldom go bankrupt out of the blue; there are at least some rumours about the difficulties beforehand. If the institution is too big or too systematic to fail, regulators are likely to take action to address the issue by closing the bank, by moving doubtful assets to a special financing vehicle or by providing liquidity for the bank. This kind of policy response was evident during the Nordic banking crises and during the latest financial crises when authorities bailed out the majority of significant banks, for instance, in Ireland and the UK. Nevertheless, as the focus here is on the maximal negative effect and the short-term contagion effects, it is assumed that regulators do not have time to react.

5 Estimating the Danger of Contagion on the Finnish Interbank Market

5.1 The Banking Crisis in the 1990s

In 1988–1990 contagion was triggered by savings banks, Skopbank and OKO Bank. The magnitude of contagion in each case increased steadily. (Figure 1) If savings banks had failed in 1988, contagion⁷ would have affected 26% of banking sector assets (assuming a 100% loss ratio) and the negative impact would have been somewhat smaller with lower LGDs. Two years later, just before the onset of the actual crisis, savings banks' failure would have affected 38% of the total assets of the banking sector.

The case of Skopbank is interesting, as it was actually taken over by the central bank in

⁷The magnitude of contagion is measured as the percentage of failing banks' assets in the banking sector's total assets after all banks have encountered the direct and indirect contagion effects. The assets of the first failing bank are not included.

1991. Simulations show that the bank's failure in 1988–1990 would have had a more profound impact on the markets than the failure of the savings banks. In 1988 and in 1989 the negative effect would have caused 31% and 48% of the banking sector to collapse, respectively. A year before the failure of the bank, contagion would have affected almost half of the banking system, indicating that without the bailout of the bank the implications for the society would have been severe. The contagion is somewhat milder with the lower loss-given-default (LGD) ratios.

Note: The y-axis represents the proportion of Finnish banking sector (measured by percentage of failing banks' assets in banking sector's total assets) that will run into problems as a result of a default of Savings banks, Skopbank or OKO bank, after all banks in the system have been exposed to the contagion. The extent of the effect is assessed for four different loss-given-default (LGD) rates. The assets of the first failing Finnish bank are excluded. A missing bar means that the failing bank does not trigger a domino effect.

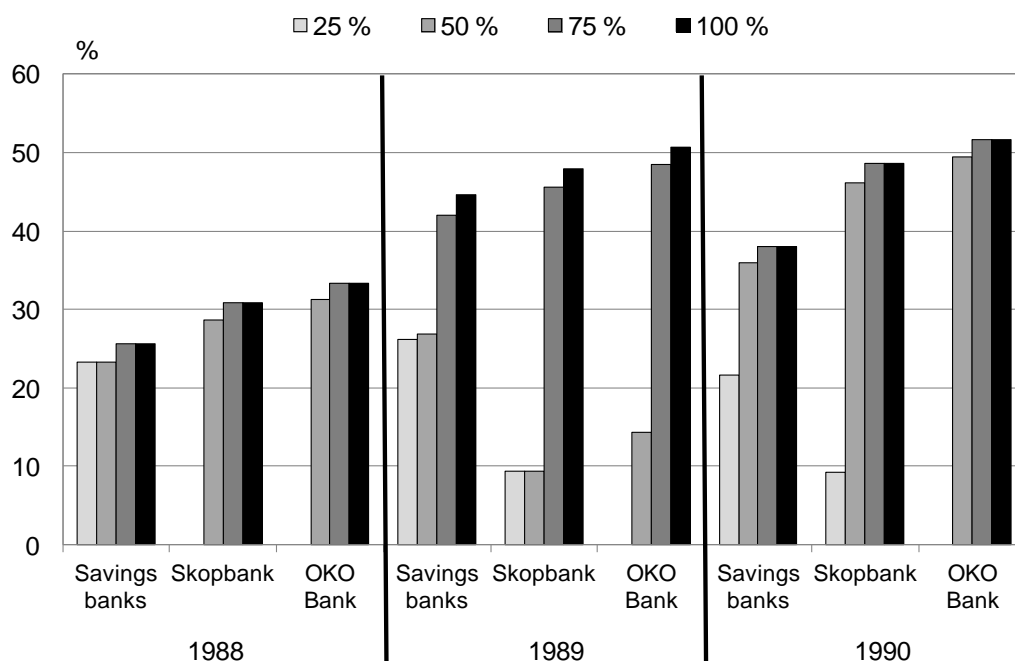


Figure 1: Contagion in Finnish banking system in 1988–1990, grouped by LGD

The fact that the analysis identifies OKO Bank as the most severe source of contagion during 1988–1990 is a new finding. The cooperative banking group did have problems 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 likely driven to some extent by the fact that OKO Bank acts as a central financial institution for the co-operative banking group, acquiring refinancing from the markets and passing on the funds to cooperative banks. And, market funding constituted an increasing share of OKO's balance sheet.

Another interesting result is that commercial banks KOP and SYP do not show up as possible sources of contagion, though they were the largest banks. Although they were active in the interbank markets their interbank lending relative to their total assets was not

as large as in other banking groups (see Table 1). If certificates of deposit, which were widely used instruments in the Finnish interbank market in the 1980s, are also included in interbank assets and liabilities, the results indicate that all banks' exposures to short-term money markets were such that no bank would have survived a sudden drying up of external funding.

The contagion analysis is replicated with data on the most severe recession year 1992, followed by the recovery years 1994 and 1996. However, these data points are somewhat problematic since by that time banks had received substantial subsidies from the government. Assuming a 100% loss ratio, the contagion would have impacted 14%, 33% and 53% of the banking sector's assets in 1992, 1994 and 1996, respectively. Owing to restructuring of the banking sector, the risk of contagion declined in 1992 but started to increase after that. During these years saving banks, OKO Bank, Merita Bank and Post office bank were possible contagion sources. The savings banks were still contagious in 1992, affecting 21% of the banking sector (with 100% LGD), but after the final resolution the group did not cause contagion in 1994 and 1996. OKO Bank's exposure is due to its position as a central monetary institution, while Merita Bank was formed in a merger of two large banks in 1996, and thus constituted a large share of the banking system. It should be noted that the Post office bank's position was not, in reality, worrisome since it was owned by the state.

In light of the historical knowledge, the estimations seem to be able to identify banks that were the most troublesome during the banking crisis. The evidence also indicates that banks with a significant share of interbank assets are more prominent sources of contagion than the others.⁸

5.2 The Recent Financial Crisis

According to simulations for 2005–2011, five out of the ten banks could trigger contagion in Finland. In addition to the large commercial banks, there are also middle-sized banks that are capable of producing negative spillover effects. The five banks that are identified as a starting point for contagion remain the same for whole estimation period.

On average⁹ and assuming 100% loss rate, 66% of banking sector assets would have been affected in 2005–2011 (Figure 2). Although the case of the 100% loss-given-default (LGD) is harsh, it is interesting as a “worst case scenario”, portraying the outcome if everything goes badly. The result is at the upper end of earlier estimates, which vary from 4% for Belgium to 96% for the Netherlands.

While the worst case scenario might be only a theoretical possibility, the quite plausible 75% and 50% loss ratios in the short-run seem to have already significant effects on the banking market. Over the estimation period, the average negative impact on total assets is 39% and 19%, respectively.

⁸This supports [2] arguing that direct contagion happens only if interbank exposures are large compared to the capital.

⁹A simple average for the banking sector over the estimation period for stated LGD.

Assuming 25 % loss-given-default, the average contagion affects 11% of banking sector assets.¹⁰

The LGD ratio has an obvious effect on the speed of contagion and the outcome. 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. For instance, the larger the LGD, the quicker the pace of contagion and the more severe the negative impact on the banking system.

Note: The y-axis represents the proportion of the Finnish banking sector (measured by percentage of failing banks' assets in banking sector's total assets) that will run into problems as a result of a default of a domestic bank, after all banks in the system have been exposed to the contagion. The extent of the effect is assessed for four different loss-given-default (LGD) rates. Results for each loss rate and each quarter are based on a simple average for the individual banks. The assets of the first failing Finnish bank are excluded.

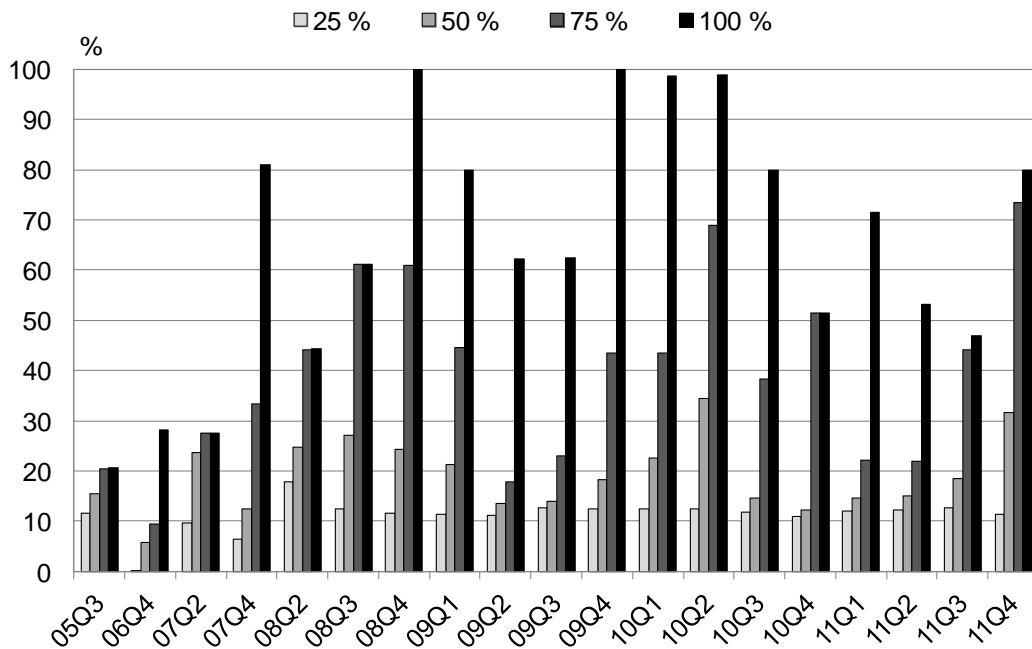


Figure 2: Contagion in Finnish banking system in 2005–2011, grouped by LGD

The volume of contagion also depends on the bank that fails first. Only one bank is extremely contagious in the Finnish banking system, being able to cause mayhem in the market already with the smallest loss ratio. With 25% LGD, around one half of the

¹⁰The effect of contagion is also estimated by letting local co-operative banks and local savings banks enter the simulations as individual banks instead of combining them into two representative banking groups. In this set-up, there are 42 local co-operative banks, 39 local savings banks and 8 commercial banks. The effect on the results is nevertheless negligible and the contagion is 0.1%–2.6% lower depending on the loss rate. However, in reality this difference may prove important for local communities and individual banks, as local co-operative banks and local savings banks are not liable for each others' debts.

Finnish banking system would collapse due to the problems of this bank. If the loss ratio is larger, this bank is a source of contagion that affects the whole banking system and ultimately causes the system to collapse. Of the other four banks identified as a source of the contagion, two banks are systematically important from June of 2008 onwards and with higher loss ratios. The contagion from the last two banks is usually limited in nature albeit some noticeable exceptions remain. Nevertheless, the negative effects imposed by these banks are almost non-existent if the loss rate is less than 100%. The limited number of contagious banks portrays the high concentration of the banking sector.

Turning to developments over the years, the aggregated¹¹ domestic contagion intensified at the beginning of the domestic and international crisis in both the 1990s and the 2000s (Figure 3). The magnitude of the contagion was relatively mild up to 2007, remaining under the levels of 1988–1990. For instance, in December 2006 the first failing bank would have caused around 11 % of Finnish banking sector to collapse. In the run-up to the banking crisis in 1990s as well as before the collapse of Lehman Brothers, the severity of contagion increased in Finland. The contagion risk peaked at the end of 2008 after the collapse of Lehman Brothers, when a first failing bank would have caused, on average, almost 50% of the banking system to collapse.

After the initial culmination of the crises, the magnitude of contagion decreased. Nevertheless, the positive development was reversed and the risk of contagion rose towards the end of 2009. The actual magnitude of Greece's fiscal deficit was revealed at the turn of the year 2010, triggering the sovereign debt crisis and raising the contagion risk in Finnish interbank market above the 50% impact level in June 2010.

After this peak the contagion risk declined until mid-2010 but started to increase again towards the end of the estimation period, possibly reflecting renewed worries related to the debt crisis and the changing pattern of interbank linkages. The freezing of money markets may have negatively impacted cross-border interbank lending, which has been – at least partially – replaced by lending between domestic institutions. Growing importance of domestic counterparties naturally increases the magnitude of domestic contagion.

¹¹Aggregation is based on a simple average over the individual banks and the loss-given-default ratios for each individual year.

Note: The y-axis represents the proportion of the Finnish banking sector (measured by percentage of failing banks' assets in the banking sector's total assets) that will run into problems as a result of a default of a bank, after all banks in the system have been exposed to the contagion. Aggregation for each time period is based on a simple average for the individual banks and the loss-given-default ratios. The assets of the first failing Finnish bank are excluded.

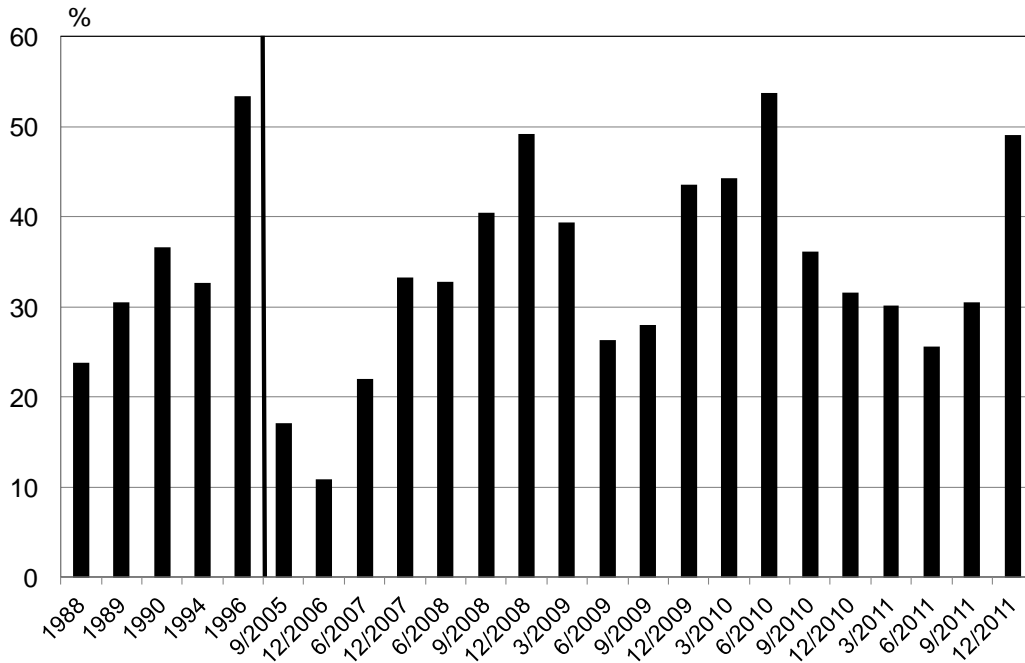


Figure 3: Aggregated contagion in 1988–1996 and 2005–2011

The results concerning banking sector structure and contagion suggest that an incomplete interbank market with highly concentrated banking sector correlates positively with contagion. In Finland, the concentration measured by the Herfindahl index¹² and contagion grew, respectively, from 2,730 and 17% in 2005 to 3,700 and 49% in 2011. The simple correlation between these two time series was 66% in 2005–2011, suggesting that there is a positive link between higher contagion and increasing concentration of incomplete markets.

This vulnerability to severe contagion gets support from previous studies, indicating that banking sectors dominated by a few large banks (such as the Dutch and Finnish banking sectors) exhibit high contagion risk. At the same time, contagion seems to have a somewhat milder effect in countries with two-tier systems and low concentration (such as Germany and Italy). ([17], [20], [23]) Furthermore, [19] finds that the change from complete structure towards a more decentralised structure reduces the risk and impact of contagion.

¹²Data for the index from Statistical data warehouse (SDW) of the ECB ([www.http://sdw.ecb.europa.eu/](http://sdw.ecb.europa.eu/)).

5.3 Cross-border Contagion

The analysis of this section concentrates on whether a failing *foreign* bank can trigger a default of a Finnish bank and whether there is a subsequent domino effect within the domestic banking sector. As no information on bilateral financial linkages between foreign banks is available, simulations cannot take into account the overall cross-border contagion, which hinders the analysis of second-round effects abroad and potential indirect impacts on Finnish banks after the initial failure of a foreign bank. This limitation affects all the literature on financial contagion. Only [27] investigates overall contagion across countries but the paper is limited to aggregate country level data, as it lacks data on individual banks.

Overall, the default of a foreign bank can trigger contagion in the domestic interbank market, leading in general to the immediate failure of a few (from zero to four) Finnish banks. On average¹³, the instant first-round impact of the failure of a foreign bank amounts to 8% of the total assets of the Finnish banking sector in 2005–2011. The magnitude of the effect varies over time, peaking at 17% in June 2007 and amounting to about 8.5% at the end of the estimation period (Figure 4).

Note: Line shows the share of Finnish banks' assets that initially go bankrupt in the first-round due to the failure of a foreign bank. Columns represent the aggregated percentage of failing Finnish banks' assets in the banking sector's total assets, after all banks in the Finnish banking sector have been exposed to the subsequent domestic contagion rounds after the initial impact. Aggregation for each quarter is based on a simple average over the individual banks and loss-given-default ratios.

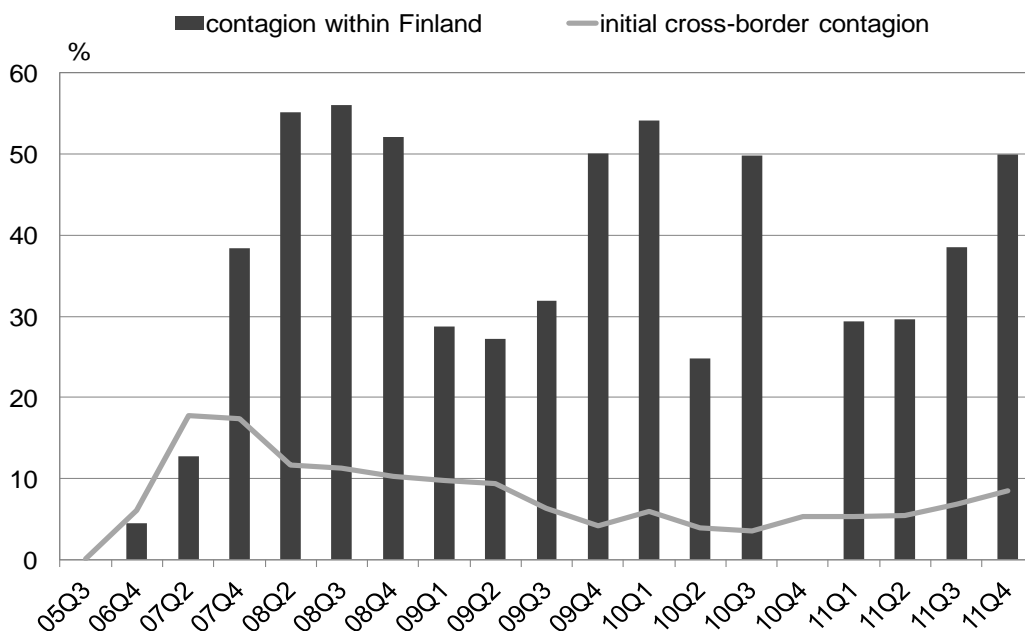


Figure 4: Contagion triggered by a foreign bank in 2005–2011

¹³A simple average over the individual banks, LGDs and quarters.

The failure of a foreign bank impacts large, medium-sized and small banks alike. In addition to French, British and American banks, the contagion is often triggered by Swedish and Danish banks. The result thus supports the findings of [27] which showed that a default of a Scandinavian bank affects the neighbouring banking systems. Nordic banks are the main international counterparties for Finnish banks and thus they form potential channels through which international contagion or market disturbances may spread to Finland.

Within the Finnish banking sector, foreign contagion follows similar patterns as domestic contagion although the high risk of domestic contagion is not reflected in the negative spillover effects of a foreign bank's default in 2009–2010. All in all, contagion caused by a failure of a foreign bank is slightly more severe than contagion triggered by a Finnish bank during the estimation period. After all contagion rounds, the contagion from a foreign bank affects 77% of the total assets of the Finnish banking sector in 2005–2011 and with a 100% LGD, while contagion from a Finnish bank impacts 66% of the total assets of the sector. Nevertheless, the impact depends on the loss-given-default, as with lower LGDs the impact from a Finnish bank is more pronounced. The findings are in line with those of [19] and [23], indicating that the more concentrated the banking system, the more vulnerable it is for foreign contagion.

5.4 The Crisis in Comparison

The operational environment of banks in the 1990s and in 2005–2011 bears several similarities. During both periods, the Finnish banking sector was highly concentrated and there were only a few large players in the market. The Finnish banks started to finance their growing lending by acquiring short-term funding from money markets at the end of 1980s. Similarly, interbank markets grew in significance in the 2000s, as liquidity was abundant in the international financial markets, which constrained the cost of financing and enabled banks to easily refinance themselves. As a consequence, some foreign banks became dependent on external (short-term) market financing and the growth of interbank assets increased the risk of contagion.

However, there are also notable differences between the periods. In 2005–2011 the interest rate level was nowhere near that of the early 1990s, the corporate sector was not as badly indebted as before and banks' capital buffers are currently larger. In addition, many borrowers and lenders are currently more aware of the dangers of over-indebtedness. In Finland, the macroeconomic shock was also somewhat milder and more transitory in the 2000s than in the 1990s. Therefore, several negative triggers and factors such as the banking system's structural weaknesses and hazardous incentive structures that were present in the 1990s were missing in the 2000s, and thus removed the initial knock-out effect. All in all, the current crisis has not eroded Finnish banks' solvency ratios, so that banks are now more resilient to domestic contagion, and bank default is a low probability event.

6 Conclusion

This paper investigates the possibility of financial contagion using data on the Finnish interbank market and the maximum entropy methodology. First, we compare the pattern and development of contagion before and during two distinctive crisis periods. These

contagion simulations shed light on the magnitude of the problems that society would face if banks fail. Secondly, as the importance of network effects is recently highlighted, the analysis provides more information on the importance of interbank linkages and transmission channels. Thirdly, the paper provides evidence on the domestic and foreign-based contagion in a concentrated banking system that is dominated by foreign banking groups and thus vulnerable to cross-border shocks.

The analysis suggests that the contagion increased both in 1988–1990 and in 2005–2011, irrespective of the original source (domestic/international) of the crisis. The method identifies five large and middle-sized Finnish banks that are able to cause contagion in 2005–2011, while suggesting that three banks were contagious during the banking crisis in the 1990s.

Before the onset of the crisis in 1990 the contagion would have affected almost half of the banking system (assuming 100% loss ratio), indicating that without the bank bailouts the implications for society would have been severe. In 2005–2011, the negative impact caused by a failure of a foreign bank (with a 100% loss-given-default) affects 77% of the total assets of the Finnish banking sector, while contagion from a Finnish bank impacts 66% of the total assets. There are also indications that the more concentrated the banking system, the more vulnerable it is to severe contagion. Moreover, strong interbank linkages with foreign banks increase the risk for domestic contagion.

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Appendix

The Method of Maximizing Entropy

The concept of entropy maximization originates in information theory, in which entropy is a measure of the average information content of a random variable. The greater the entropy of the message, the greater information content of the message.

Maximizing entropy means setting up probability distributions on the basis of partial knowledge and thus denotes the most likely outcome given the a priori knowledge about the event x_i . (For more details see [33], [34], [35].) When the probability of the outcome is maximized, the uncertainty diminishes and the estimates of parameters x_i are close to real values of x_i .

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} & | & w_{1N+1} & \cdots & w_{1M} \\ \vdots & \ddots & \vdots & \ddots & \vdots & | & \vdots & & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{iN} & | & \vdots & & \vdots \\ \vdots & \ddots & \vdots & \ddots & \vdots & | & \vdots & & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} & | & w_{NN+1} & \cdots & w_{NM} \end{bmatrix}$$

Figure A: Matrix of interbank loans and deposits

Sources: [17] and [19].

Suppose now that there are N Finnish banks that may lend to each other. In this case, the interbank lending relationships can be presented in an $N \times N$ matrix (see left-hand side of the matrix X in Figure A). [2] As there is usually no knowledge on individual interbank loans and deposits, individual x_{ij} 's are generally unknown. However, a priori data on actual individual interbank relationships and their magnitudes is gathered into an a priori matrix C that resembles matrix X . The diagonal of the matrix C is usually set at zero, since it is assumed that no bank lends to itself.

Balancing the matrix yields a unique estimate of matrix X . Matrix is defined to be balanced if it satisfies the given set of linear restrictions of the problem. These restrictions consist of the row sums (a_i), i.e. bank i 's total claims on other banks, and column sums (l_j), i.e. bank j 's liabilities in the interbank market. These sums are obtained from balance sheet data. More formally, the problem is as follows:

$$\text{Min}_{x_{ij}} \sum_{i=1}^n \sum_{j=1}^n x_{ij} \log \frac{x_{ij}}{c_{ij}} \quad (1)$$

s.t.

$$\sum_{i=1}^n x_{ij} = l_j \quad , i = 1, \dots, n \quad (2)$$

$$\sum_{j=1}^n x_{ij} = a_i \quad , j = 1, \dots, n \quad (3)$$

$$x_{ij} \geq 0 \quad (4)$$

In the case of foreign contagion, the same methodology applies, but now X becomes an $(N \times (N+M))$ matrix (Figure A). This matrix of bilateral exposures presents the interbank exposures of Finnish banks toward the other $(N-1)$ Finnish banks and the M foreign banks. The initial estimation problem and linear restrictions remain the same except for restriction (3), which becomes:

$$\sum_{j=1}^n w_{ij} = fa_i \quad , j = 1, \dots, n \quad (5)$$

in which w_{ij} represents the gross exposure of Finnish bank i to foreign bank j and fa_i stands for interbank assets of bank i. [19]