Estimating Bilateral Exposures in the German Interbank Market: Is there a Danger of Contagion?

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Discussion paper 09/02
Economic Research Centre
of the Deutsche Bundesbank

February 2002

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ISBN 3–935821–06–9

Abstract

Credit risk associated with interbank lending may lead to domino effects, where the failure of one bank results in the failure of other banks not directly affected by the initial shock. Recent work in economic theory shows that this risk of contagion depends on the precise pattern of interbank linkages. We use balance sheet information to estimate the matrix of bilateral credit relationships for the German banking system and test whether the breakdown of a single bank can lead to contagion. We find that the financial safety net (institutional guarantees for saving banks and cooperative banks) considerably reduces – but does not eliminate – the danger of contagion. Even so, the failure of a single bank could lead to the breakdown of up to 15 % of the banking system in terms of assets.

JEL classifications: G21, G28

keywords: contagion, interbank market, regulation of banks

Zusammenfassung

Kreditrisiken aus Interbankbeziehungen können zu Dominoeffekten führen indem der Zusammenbruch einer Bank den Zusammenbruch anderer Banken bewirkt, die nicht direkt vom ursprünglichen Schock betroffen waren. Neuere theoretische Arbeiten zeigen, dass dieses Ansteckungsrisiko von der genauen Struktur der Interbankbeziehungen abhängt. Wir schätzen die Matrix bilateraler Kreditbeziehungen für das deutsche Bankensystem auf Basis von Bankbilanzdaten und testen anschliessend, ob der Zusammenbruch einer einzelnen Bank zu Ansteckungseffekten führen kann. Wir kommen zu dem Ergebnis, dass die Sicherungssysteme (institutionelle Garantien für Sparkassen und Kreditgenossenschaften) die Ansteckungsgefahr zwar beträchtlich verringern aber nicht vollständig eliminieren können. Die Zusammenbruch einer einzelnen Bank kann trotzdem zu einem Verlust von 15 % der Aktiva des gesamten Bankensystems führen.

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Estimating Bilateral Exposures in the German Interbank Market: Is there a Danger of Contagion?*

1 Introduction

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. Recent work in economic theory shows that this risk of contagion depends on the precise pattern of interbank linkages. For example, in the model of Allen and Gale (2000) banks hold deposits with banks of other regions in order to insure against liquidity shocks in their own region. Here a ´region´ should not necessarily be interpreted in geographical terms but could in principle refer to any grouping of banks. If a bank is hit by a shock, it tries to meet its liquidity need by drawing on its deposits at other banks before liquidating long-term assets. This pecking order follows from the assumption that the pre-mature liquidation of long-dated assets is costly, e.g. because otherwise profitable real investment projects would have to be abandoned or long-term lending relationships interrupted.

On the aggregate, the interbank market can only redistribute liquidity but does not create liquidity of its own. While this is not a problem if the aggregate liquidity need is lower than the aggregate holdings of liquid assets, it may give rise to contagion if the opposite is true. Instead of liquidating their long-term assets, banks withdraw their deposits at other banks, thus spreading their liquidity problems throughout the financial system. The possibility of contagion depends strongly on the precise structure of interbank claims. Contagion is less likely to occur in what Allen and Gale term a 'complete' structure of claims, in which every bank has symmetric linkages with all other banks in the economy (see figure 1). Incomplete structures, where banks have links only to a few neighbouring institutions (see figure 2 for an extreme example), are shown to be much more fragile.

* We are grateful to Hans Bauer, Ben Craig, Barry Eichengreen, Craig Furfine, Charles Goodhart, Ralf Körner, Hyun Shin, Karl-Heinz Tödter and Benno Wink for their invaluable comments and help. We benefited from discussions and comments at the 37th Conference on Bank Structure and Competition at the Federal Reserve Bank of Chicago, the BIS Autumn 2000 Central Bank Economists´ Meeting, the seminar on "Open Issues in Monetary Policy and Monetary Order" held at the European University Institute in Florence, the ECB/CFS/Bundesbank Joint Lunchtime Seminar and several presentations at the Bundesbank.

Figure 1: 'Complete market structure' according to Allen and Gale (2000)

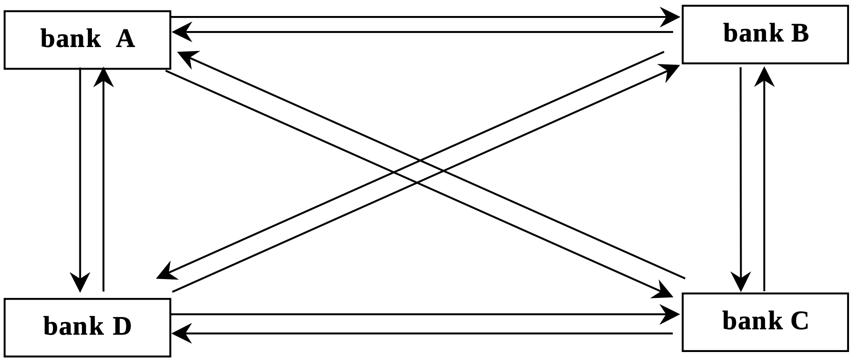
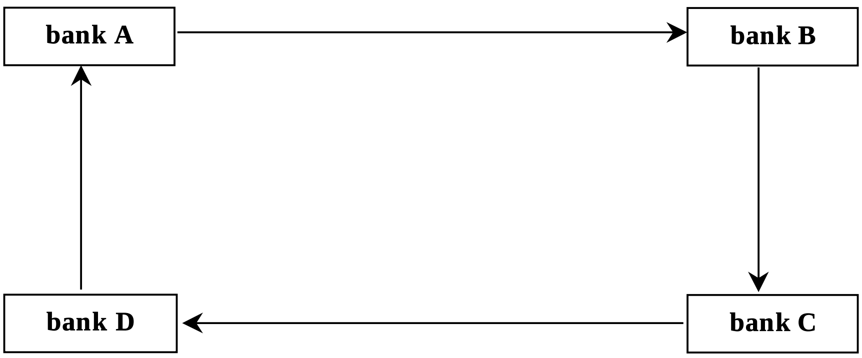


Figure 2: 'Incomplete market structure' according to Allen and Gale (2000)

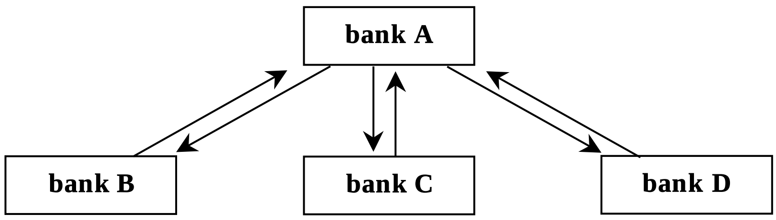


In a related paper by Freixas, Parigi and Rochet (2000), interbank lending arises not from consumers' uncertainty about *when* to consume (as in Allen and Gale) but *where* to consume. Their model can be interpreted as a payment system, where interbank credit lines are used to reduce the overall amount of liquid (but costly) reserves. In their setting, contagion can occur even if all banks are solvent. If the depositors in a sufficiently large number of banks believe that they will not obtain payment at the bank of their destination, it is optimal for them to withdraw their deposits. Since this forces banks to liquidate their investments, it triggers a run where all other depositors withdraw their deposits and the banking system reaches a gridlock.[1] Besides contagion driven by non-banks´ behaviour, the authors also consider the impact an insolvent bank has on the banking system. They find that interbank connections generally enhance the resiliency (i.e. the ability to withstand shocks) of the financial system. Interbank credit lines provide an implicit subsidy to the

[1] This can be prevented by central bank guarantees for interbank credit lines. These lines are never used in equilibrium, since by assumption all banks are solvent.

insolvent bank, which is able to spread part of its losses to other banks. Interbank lending thus contributes to loosening market discipline.[2] As in Allen and Gale, a complete structure of claims reduces the risk of contagion, while incomplete structures, or credit chains (like the one in figure 2) increase the fragility of the system. A third case considered by Freixas, Parigi and Rochet is that of a money centre bank, where the institutions on the periphery are linked to the bank at the centre but not to each other (figure 3). They find that for some parameter values the failure of a bank on the periphery will not trigger the breakdown of other institutions while the failure of the money centre bank would. They do not provide any general results, though.[3]

Figure 3: Money centre bank according to Freixas, Parigi and Rochet (2000)



Unfortunately, very little is known about the actual structure of *bilateral* exposures in the interbank market as banks do not have to disclose their counterparts. As a consequence, empirical studies concentrate mainly on the payment system, for which such data is available.[4] An exception is Furfine (1999), who uses settlement data to compute bilateral exposures in the U.S. interbank federal funds market. He finds that even in his worst case scenario (failure of the most significant bank and a 40% loss rate[5]) only 2 to 6 other banks fail, accounting for less than 0.8% of total bank assets. No contagion occurs at all if the loss rate is 5% - such as the one estimated by Kaufman (1994) for Continental Illinois. The results have to be interpreted with care, however, since the federal funds market accounts for only 10 to 20% of total interbank exposures in the United States, although its share is likely to be higher if only uncollateralized positions are considered.

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2 This provides a second rationale for central bank involvement in financial supervision, namely to organize the orderly closure of insolvent banks.

3 Rochet and Tirole (1996) and Aghion, Bolton and Dewatripont (2000) consider the incentives to bail out failing banks by providing interbank loans. The absence of a bailout could be due to a weak financial position of the banking system and thus serves as a signal triggering a bank run. They do not say much about how the precise direction of interbank linkages affects the possibility of contagion.

4 E.g. Humphrey (1986) and Angelini, Maresca and Russo (1996).

5 The 40% loss rate corresponds to the typical loss on assets of a failing bank estimated by James (1991).

An alternative approach followed by the present paper is to estimate the matrix of bilateral credit relationships from bank balance sheet data. In contrast to studies based on settlement data, this permits us to cover all interbank lending rather than only lending at short maturities. This is particularly relevant for Germany, where about half of all lending between banks is long-term.[6] This advantage comes at a cost, however. Due to the fact that we do not have complete information on the individual counterparties in the interbank business, we need to make assumptions on the distribution of bank i's interbank loans and deposits over the other banks. In order to bias our estimates against the hypothesis of contagion, we assume that interbank lending is as dispersed as possible, given the observed distribution of loans and deposits.

Our paper is closely related to Sheldon and Maurer (1998), who estimate a matrix of interbank loans for Switzerland.[7] They come to the conclusion that the interbank loan structure that existed among Swiss banks posed little threat to the stability of the Swiss banking system in the period under consideration. Our work differs from Sheldon and Maurer's in several respects. For computational reasons, they aggregate the individual banks into 12 categories. Our approach is much more disaggregated, so that we can make use of virtually all information on the interbank market that is available to us. Firstly, we consider all German banks individually. Secondly, our data permits us to estimate separate matrices for (i) loans of savings banks to their regional giro institutions, (ii) loans of giro institutions to affiliated savings banks, (iii) loans of cooperative banks to cooperative central banks, (iv) loans of cooperative central banks to cooperative retail banks, and (v) interbank loans and deposits of the remaining banks. The interbank assets and liabilities in each of these five cases are divided into five maturity categories, giving a total of 25 separate matrices for a given month, which we add up to a system-wide matrix of interbank relationships. Since banks tend to be active only in a few maturity segments at any point in time, this considerably reduces the number of possible counterparties for each institution. Our estimate should therefore be much more accurate than a matrix estimated with figures for total lending and deposits alone.

We find that interbank lending is relatively concentrated. As has already been pointed out, the theoretical literature suggests that this could make contagion a real possibility. We assess this danger by letting every bank go bankrupt one at the time and compute the effect of this failure on the other banks. We find that credit exposures in the interbank market can lead to domino effects. At worst, the failure of a single bank triggers a chain that ends with

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6 We focus only on direct lending relationships and do not capture exposures arising in the payment or security settlement systems or exposures due to the cross holding of securities.

7 They also estimate the probability of failure, and thus the likelihood of contagion, which we ignore.

the bankruptcy of almost 15% of the banking system in terms of assets. If we ignore safety mechanisms such as the institutional guarantees in the savings and cooperative bank sector, the results are even more pronounced. Our analysis takes the initial shocks leading to contagion as given. We are therefore not able to attach a probability to our scenarios.

It is important to stress that our analysis concentrates exclusively on contagion due to credit exposures in the interbank market. We rule out other channels of contagion like bank runs, which have commanded the attention of much of the theoretical literature and have dominated the discussion on banking regulation. We believe that this omission is justified not only for methodological reasons in that it permits us to isolate one specific channel of contagion. Contagion due to bank runs by non-bank depositors in the wake of the breakdown of a single institution are highly unlikely in Germany, where virtually all deposits by non-financial institutions are insured. The type of contagion we analyse is dependent less on the *behavioural* interdependence of the respective parties and more on the interdepence due to interbank linkages. In this sense, it can be described as being mechanical.

The paper is structured as follows. After a description of the dataset we present the estimation methodology. This is followed by a section on the structure of the German banking system in general and the interbank market in particular. In section 5, we estimate the danger of contagion in the German interbank market, leaving aside for a moment banking supervision and the existence of a safety net. We find that in this case, contagion may lead to the breakdown of a large part of the German banking system. We also confirm the proposition given by the theoretical literature that more symmetric (in the extreme: ´complete´) structures are less vulnerable to contagion than asymmetric (´incomplete´) structures. Having done this, we measure the importance of the safety net in place in Germany in order to prevent such scenarios. Our results suggest that these institutions and regulations dramatically reduce, but do not eliminate, the danger of contagion. A final section concludes.

2 Description of the data

The analysis is based on balance sheets, which all German banks have to submit to the Bundesbank every month. At this stage, we only consider the balance sheets from end December 1998, but we plan to make use of the time series dimension of the data in future work. In their submissions, banks have to state whether their counterpart in the interbank market is a domestic or a foreign bank, a building society (Bausparkasse), or the Bundesbank. Savings banks and cooperative banks also have to identify lending to giro institutions (Landesbanken) and cooperative central banks, respectively (and vice versa). In addition, all banks have to break down their interbank business into five maturity categories (listed in table 1)[8]. Since our data only covers domestic banks and the German branches of foreign banks, we exclude loans to and deposits from building societies, the Bundesbank and foreign banks. This leaves us with a closed system for each maturity category, where all interbank loans and deposits add up to zero in principle. [9]

Table 1 shows the maturity structure of the interbank assets and liabilities of all German banks, both vis-à-vis all other banks including foreign banks, building societies and the Bundesbank and vis-à-vis the banks contained in our sample only. More than one half of the interbank assets and liabilities have a maturity of at least 4 years. However, this share varies widely across bank type: whereas long-run interbank liabilities are very important for savings banks (91.5%) and for cooperative banks (91.7%), they are less important for commercial banks (36.2%), Landesbanken (45.5%) and cooperative central banks (27.8%). The picture differs considerably when it comes to interbank assets: here, only 8.8% (savings banks) and 11.5% (cooperative banks) of interbank loans have a maturity of at least 4 years. For the Landesbanken and the cooperative central banks the corresponding figures are 60.5% and 67.7%, respectively. On the whole, table 1 shows that the interbank market consists of far more than just the exchange of liquidity on a day-to-day basis. For the assessment of the danger of contagion, it is therefore not sufficient to consider just these short-run relationships, but it is necessary to take into account also, and especially the longer-term assets and liabilities.

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8 Deposits from banks are actually broken down into six categories, which we consolidate into five in order to make them comparable to the lending side.

9 In practice, discrepancies between assets and liabilities do arise. They are particularly accute for overnight loans and deposits, where the latter consistently exceed the former in the order of 10 to 15%. One possible reason could be the existence of floating transactions. Since the German payment system is mainly transfer-based, the interbank liabilities of the payer’s bank tend to increase before the corresponding asset position of the payee’s bank. For this reason, the individual asset positions were scaled such that their sum matches that of the liability positions within the same maturity category. Another possible source of the discrepancies between assets and liabilities are errors in the data. The database has been checked for consistency (eg all positions on the balance sheet have to satisfy an adding up constraint), but entries in the wrong category remain a possibility.

Table 1:
Interbank assets and liabilities by maturity and broad bank categories
(end December 1998)

(1): excl. interbank assets and liabilities vis-à-vis foreign banks, building societies and Bundesbank
(2): all interbank assets and liabilities

				daily	> 1 day & < 3 mths	maturity ≥ 3 mths & ≤ 1 yr	> 1 yr & < 4 yrs	≥ 4 yrs
all banks		**liabilities**	**(1)**	**11.7**	**13.2**	**14.5**	**5.6**	**55.0**
			(2)	*12.6*	*24.3*	*17.4*	*4.5*	*41.1*
		assets	**(1)**	**10.6**	**14.1**	**17.2**	**5.6**	**52.5**
			(2)	*11.2*	*18.8*	*18.0*	*6.0*	*46.0*
commercial banks		**liabilities**	**(1)**	**21.1**	**18.0**	**21.3**	**3.4**	**36.2**
			(2)	*18.6*	*32.6*	*23.7*	*3.2*	*21.9*
		assets	**(1)**	**22.3**	**30.3**	**27.1**	**5.3**	**14.9**
			(2)	*20.4*	*35.5*	*26.7*	*5.8*	*11.6*
savings banks´ sector	**Landes-banken**	**liabilities**	**(1)**	**9.6**	**19.0**	**17.3**	**8.6**	**45.5**
			(2)	*9.9*	*26.7*	*18.8*	*6.7*	*37.9*
		assets	**(1)**	**4.6**	**7.7**	**15.7**	**4.3**	**67.7**
			(2)	*4.8*	*12.2*	*18.0*	*5.2*	*59.8*
	savings banks	**liabilities**	**(1)**	**2.7**	**2.2**	**2.0**	**1.5**	**91.5**
			(2)	*2.5*	*15.3*	*2.9*	*1.4*	*77.9*
		assets	**(1)**	**20.7**	**38.5**	**28.7**	**3.2**	**8.8**
			(2)	*20.5*	*39.2*	*27.3*	*3.7*	*9.3*
coopera-tive sector	**central banks**	**liabilities**	**(1)**	**26.5**	**20.5**	**14.3**	**10.8**	**27.8**
			(2)	*26.3*	*25.9*	*17.1*	*8.2*	*22.5*
		assets	**(1)**	**9.7**	**5.7**	**18.5**	**5.6**	**60.5**
			(2)	*9.8*	*10.5*	*22.7*	*5.3*	*51.7*
	coopera-tive banks	**liabilities**	**(1)**	**3.5**	**1.7**	**1.8**	**1.2**	**91.7**
			(2)	*3.7*	*7.7*	*1.8*	*1.1*	*85.8*
		assets	**(1)**	**28.9**	**27.4**	**20.4**	**11.8**	**11.5**
			(2)	*30.5*	*28.5*	*18.4*	*12.5*	*10.0*
other banks		**liabilities**	**(1)**	**7.0**	**9.3**	**18.9**	**5.9**	**58.9**
			(2)	*6.5*	*12.8*	*18.0*	*5.2*	*57.5*
		assets	**(1)**	**2.9**	**4.5**	**5.1**	**7.4**	**80.0**
			(2)	*2.9*	*4.0*	*5.4*	*6.6*	*81.1*

3 Estimation methodology

The lending relationships in the interbank market can be represented by the following $N \times N$ matrix:

$$
\boldsymbol{X} = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{iN} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} \end{bmatrix} \begin{matrix} \Sigma_j \\ a_1 \\ \vdots \\ a_i \\ \vdots \\ a_N \end{matrix} \qquad (1)
$$

$$
\Sigma_i \quad l_1 \quad \cdots \quad l_j \quad \cdots \quad l_N
$$

where x_{ij} is the credit exposure of bank j vis-á-vis bank i and N is the number of banks. We cannot observe the bilateral exposures x_{ij}, but we do know the sum of each bank's interbank loans and deposits,

$$
a_i = \sum_j x_{ij} \quad \text{and} \quad l_j = \sum_i x_{ij} , \qquad (2)
$$

respectively. This information does not suffice to identify the elements of $\boldsymbol{X}$, so we are left with $N^2 - 2N$ unknowns. If we want to estimate the bilateral exposures, we have to make assumptions on how banks spread their interbank lending.

With the appropriate standardisation, we can interpret the a's and l's as realizations of the marginal distributions $f(a)$ and $f(l)$, and the x's as their joint distribution, $f(a,l)$. If $f(a)$ and $f(l)$ are independent, then $x_{ij} = a_i l_j$. In the terminology of information theory, this amounts to maximising the entropy of the matrix $\boldsymbol{X}$. The assumption of indepence implies that interbank loans and deposits are as equally spread over banks as is consistent with the observed marginal distributions. It can thus be interpreted as an analogue to Allen and Gale's (2000) complete structure of claims, where banks symmetrically hold claims on all other banks in the economy, conditioned on the size-structure of the banks (see figure 1).

There are many reasons to believe that independence is a rather poor description of reality. For example, we are ruling out relationship lending, which may be an important feature of the interbank market. Nevertheless, since we have to make identification assumptions, our aim should be to deviate as little as possible from the information in our data. Furthermore, by assuming independence we bias our test against the hypothesis of contagion.

The independence matrix $\boldsymbol{X}$ in (1) has the unappealing feature that the maximisation of entropy creates elements on the main diagonal that are non-zero if a bank is both lender and borrower. In this case, using $\boldsymbol{X}$ to compute bilateral exposures would amount to assuming that banks lend to themselves. This problem does not necessarily disappear as the number of banks increases, if interbank lending or borrowing is relatively concentrated. We therefore need to modify the independence assumption by setting $x_{ij} = 0$ for $i = j$.[10]

$$\boldsymbol{X^*} = \begin{bmatrix} 0 & \cdots & x^*_{1j} & \cdots & x^*_{1N} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x^*_{i1} & \cdots & 0 & \cdots & x^*_{iN} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x^*_{N1} & \cdots & x^*_{Nj} & \cdots & 0 \end{bmatrix} \begin{matrix} \Sigma_j \\ a_1 \\ \vdots \\ a_i \\ \vdots \\ a_N \end{matrix} \qquad (1^*)$$

$$\Sigma_i \quad l_1 \quad \cdots \quad l_j \quad \cdots \quad l_N$$

This should be done by departing from the assumption of independence as little as possible. More formally, this means that we have to minimise the relative entropy of $\boldsymbol{X^*}$ with respect to a matrix with elements $x_{ij} = a_i l_j$ for $i \neq j$ and zero for $i = j$:

$$\min_{\mathbf{x}^*} \mathbf{x}^{*\prime} \ln \frac{\mathbf{x}^*}{\mathbf{x}}$$

$$\text{s.t. } \boldsymbol{x} \geq 0 \quad \text{and} \quad \boldsymbol{Ax} = [a', l]', \qquad (3)$$

where $\boldsymbol{x^*}$ and $\boldsymbol{x}$ are $(N^2 - N)\times 1$ vectors containing the off-diagonal elements of $\boldsymbol{X^*}$ and $\boldsymbol{X}$, respectively, a and l are the marginals, and $\boldsymbol{A}$ is a matrix containing the adding up restrictions (2). Since the objective function is strictly concave, programme (3) yields a unique solution for the structure of interbank lending $\boldsymbol{X}$*. Programme (3) is solved numerically with the RAS-Algorithm that is commonly used in computing input-output-tables.[11]

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10 Setting the elements on the diagonal equal to zero also reduces the number of coefficients to be estimated to $N^2 - 3N$ by imposing more structure on X.

11 See Blien and Graef (1991). In a previous version of the paper we used a different algorithm which yielded the same results.

4 The structure of the German interbank market

As was mentioned above, our data contain information on interbank lending and borrowing in each of five maturity categories for

(1) deposits and loans from savings banks to regional giro institutions (Landesbanken),

(2) deposits and loans from regional giro institutions (Landesbanken) to savings banks,

(3) deposits and loans from cooperative banks to cooperative central banks,

(4) deposits and loans from cooperative central banks to cooperative banks, and,

(5) all interbank loans and deposits that do not belong to (1) to (4).

This permits us to compute a total of 25 matrices of bilateral exposures, which add up to give the total amount of interbank exposures. We use this added-up, full information, matrix to test for the possibility of contagion. For (1) to (4), we can compute interbank exposures using the independence matrix X (equation (1)) because no bank appears both as lender and depositor. Where banks do appear on both sides, in (5), we use the RAS algorithm. For comparison, we also compute a matrix of bilateral exposures using interbank borrowing and lending aggregated over cases (1) to (5) and over all maturities. This latter matrix (baseline matrix) serves as a benchmark that proxies the complete structure of claims, against which we measure deviations.

Since most banks borrow and lend only at specific maturities (which are usually different from each other), most of the elements of a (the sums of the rows in (1)) and l (the column sums) for the different maturity categories are zero. These zero restrictions considerably reduce the number of possible counterparts for each bank, and consequently yield much more precise estimates of the true structure of interbank lending than could be obtained from using aggregate exposures alone. In addition, the full information matrix differs from the baseline matrix in that it uses the available information on the intra-lending patterns of the two giro systems. Tables 2a and 2b show that the structure of interbank borrowing and lending in Germany differs considerably from the benchmark of a complete structure of claims (the numbers in each row sum up to 100). The figures refer to the exposures of the average bank within a given category (they are therefore not comparable to the figures from the consolidated balance sheet of each group presented in Deutsche Bundesbank (2000a)).

In the baseline, all banks hold virtually the same portfolio of interbank loans and deposits. The only difference is due to the restriction that banks do not lend to themselves. As a consequence, the share of banks within the same category is somewhat lower than average.

By contrast, the full information matrix implies that interbank exposures vary considerably between banks and bank categories. We find that both commercial banks and other banks transact much more with institutions of the same category than would be predicted by the baseline matrix. What is particularly striking, however, is the large share of the head institutions of the two giro systems in the interbank loans and deposits of the institutions at the base level. 75% of the interbank deposits at savings banks are held by Landesbanken, who also receive 81% of their loans. Cooperative central banks account for 82% of the deposits at and 94% of the loans of cooperative banks.

It is also striking to see that there are almost no deposits held between banks on the base level of the same giro system (savings banks: 0.5%, cooperative banks: 0.2%) and across the two giro systems (savings banks at cooperatives: 0.3%, cooperatives at savings banks: 0.3%). The full information estimate therefore shows that the interbank deposit market is organized in two-tiers: The first tier consists of most savings banks and virtually all cooperative banks, who transact mainly with the Landesbanken and cooperative central banks. The second tier consists of the head institutions of the two giro systems, the commercial banks and the other banks.

Tables 2a and 2b point to the existence of two relatively closed systems, with very few direct linkages to banks of other categories except those with the respective head institutions and deposits from other banks, which comprise mainly mortgage and development banks. We estimate that about half of these deposits represent credit lines that serve to refinance development loans. The upper tier consists of the commercial banks, a small number of savings banks (around 10), the Landesbanken and cooperative central banks plus a variety of other banks. Instead of focused relationships with a small number of head institutions, banks belonging to the upper tier entertain lending relationships with a variety of other banks belonging to the same tier, including those of other categories. As a consequence, in the upper tier the pattern of interbank exposures is much closer to a complete structure of claims than that in the lower tier.

The link between the two-tiers is provided by the Landesbanken (for the savings banks) and the cooperative central banks (for the cooperative sector). On the one hand, they provide long-term loans to and take short-term deposits from their affiliated institutions. This part accounts 36% (Landesbanken) and 50% (cooperative central banks) of their interbank loans, and 19% and 59% of their interbank deposits, respectively. On the other hand, they operate in the upper-tier interbank market as any commercial bank does. We can interpret the giro systems as some sort of internal interbank market whereas the outside interbank market consists only of the commercial banks, the head institutions of the giro systems and the other banks.

Table 2a:

Exposures in the German Interbank Market: Interbank liabilities (interbank deposits)

(average % share of banks by categories, end December 1998)

Interbank deposits at ↓ held by →		inter-bank-matrix	commer-cial banks	savings banks´ sector: Landes-banken	savings banks´ sector: savings banks	cooperative sector: central banks	cooperative sector: coopera-tives	other banks
all banks		full info	5.1	20.3	0.9	58.2	0.5	15.0
		baseline	*15.9*	*30.3*	*7.5*	*8.0*	*6.9*	*31.4*
commercial banks		full info	31.7	24.6	5.3	6.2	2.2	30.0
		baseline	*15.9*	*30.3*	*7.5*	*8.0*	*6.9*	*31.4*
savings banks´ sector	Landes-banken	full info	18.6	21.5	**19.2**	4.1	1.6	35.0
		baseline	*16.3*	*28.6*	*7.7*	*8.1*	*7.1*	*32.1*
	savings banks	full info	2.8	**75.2**	**0.5**	0.5	**0.3**	20.7
		baseline	*15.9*	*30.3*	*7.5*	*8.0*	*6.9*	*31.4*
coopera-tive sector	central banks	full info	10.0	10.7	1.8	1.4	**59.0**	17.0
		baseline	*16.2*	*30.8*	*7.7*	*6.5*	*7.0*	*31.9*
	coopera-tives	full info	1.9	5.1	**0.3**	**81.7**	**0.2**	10.8
		baseline	*15.9*	*30.3*	*7.5*	*8.0*	*6.9*	*31.4*
other banks		full info	18.6	27.6	4.0	4.1	1.6	44.2
		baseline	*16.0*	*30.5*	*7.6*	*8.0*	*6.9*	*30.9*

Linkages *within* a giro system are shaded in grey.

Table 2b:

Exposures in the German Interbank Market: Interbank assets (interbank loans)

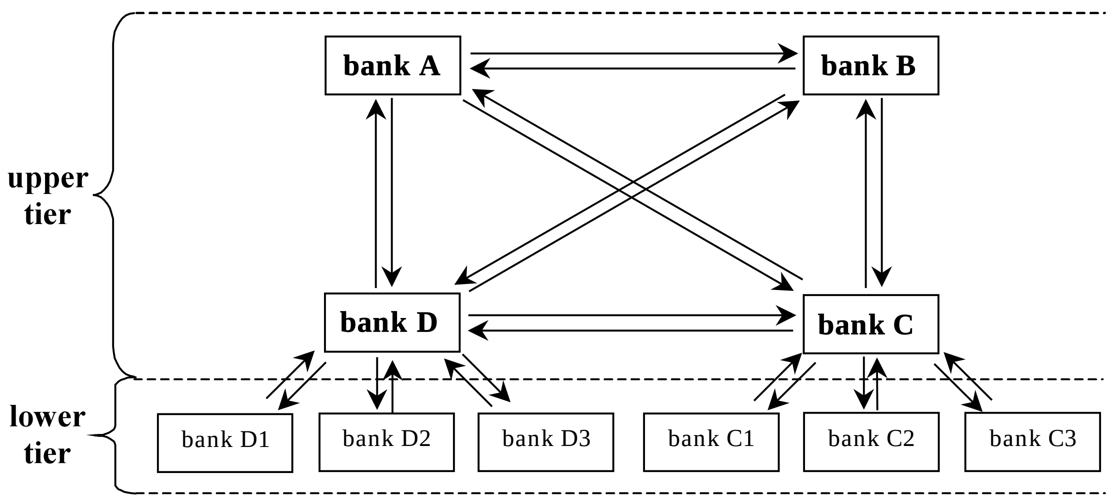
(average % share of banks by categories, end December 1998)

Interbank loans to → granted by ↓		inter-bank-matrix	commer-cial banks	savings banks´ sector: Landes-banken	savings banks´ sector: savings banks	cooperative sector: central banks	cooperative sector: coopera-tives	other banks
all banks		full info	7.6	19.0	1.3	67.1	0.4	4.7
		baseline	*19.5*	*26.8*	*16.6*	*11.4*	*6.2*	*19.5*
commercial banks		full info	43.1	23.0	2.9	10.3	1.3	19.5
		baseline	*19.4*	*26.8*	*16.6*	*11.4*	*6.2*	*19.5*
savings banks´ sector	Landes-banken	full info	18.4	19.7	**35.6**	5.0	1.7	19.7
		baseline	*19.9*	*25.3*	*16.9*	*11.6*	*6.4*	*19.9*
	savings banks	full info	8.3	**81.0**	**1.8**	1.9	**0.4**	6.5
		baseline	*19.5*	*26.8*	*16.5*	*11.4*	*6.2*	*19.5*
coopera-tive sector	central banks	full info	17.5	15.6	1.8	3.2	**49.8**	12.0
		baseline	*19.9*	*27.5*	*17.0*	*9.3*	*6.4*	*20.0*
	coopera-tives	full info	1.8	1.8	**0.5**	**94.2**	**0.1**	1.5
		baseline	*19.5*	*26.8*	*16.6*	*11.4*	*6.2*	*19.5*
other banks		full info	25.9	27.6	10.4	8.5	2.7	24.9
		baseline	*19.6*	*26.9*	*16.6*	*11.4*	*6.3*	*19.2*

Linkages *within* a giro system are shaded in grey.

The two-tier structure of the interbank market in Germany depicted in figure 4 differs considerably from the complete (see figure 1) and incomplete structures considered in the theoretical literature, although it shows some similarities to the money centre structure studied in Freixas, Parigi and Rochet (see figure 3). It is not clear a priori whether such a structure leads to a significantly higher danger of contagion compared to the complete structure as indicated by the baseline matrix. The subsequent estimations will deal with this question.

Figure 4: Two-tier structure of the German interbank market



5 Estimating the danger of contagion in the absence of the safety net

We estimate the scope for contagion by letting banks go bankrupt one at a time and measuring the number of banks that fail due to their exposure to the failing bank. We focus on gross exposures only. The reason for this is that offsetting claims enter the asset pool from which all claims are satisfied in accord to their seniority. Moreover, the resolution of a bankruptcy usually takes several years. Therefore, bilateral netting is usually not feasible.

In our simulations, the failure of bank j triggers the failure of bank i if $\theta x_{ij} > c_i$, where θ is the loss rate, and c_i is bank i's book capital.[12] Contagion need not be confined to such first-

[12] This corresponds to a rather legalistic view of bankruptcy. In practice, regulators try to take action and close a bank *before* its capital has been eaten up by losses on its loan portfolio. However, given the scenario we consider here, contagion may occur over short time spans, thus precluding regulatory action.

round effects, however. Instead, the failure of a single bank can potentially trigger a whole chain of subsequent failures (the domino effect) even if the initial impact is relatively weak. For example, suppose that bank *i* fails due to its exposure to bank *j*. This will cause the breakdown of bank *k* if its exposure to banks *i* and *j* multiplied by the loss rate exceeds its capital, i.e. if $\theta\left(x_{ki} + x_{kj}\right) > c_k$. This line of argument also applies to higher orders.

A necessary condition for contagion to occur is that the volume of a bank´s interbank loans exceeds its capital. As can be seen from table 3, this is generally the case. Of the 3,246 banks that existed in Germany at the end of 1998, 2,758 (85%) had interbank loans in excess of their capital. The average ratio of interbank loans to capital was just below 3, although this is driven by the large number of small cooperative banks in our sample which tend to hold relatively few interbank assets. The corresponding figures for the Landesbanken, cooperative central banks and other banks are well above 10. This suggests that there may be scope for domino effects.

Table 3:
Interbank lending and capital, by broad banking category
(end December 1998)

	all banks	commer-cial banks	savings banks´ sector		cooperative sector		other banks
			Landes-banken	savings banks	central banks	cooperative banks	
No of banks	3246	331	13	594	4	2256	48
of which with loans > cap	2758	228	13	432	4	2043	38
interbank loans/capital	2.96	4.64	13.73	1.95	14.39	2.69	12.94

The choice of θ is by no means obvious. The average loss realized in bank failures in the United States in the mid-1980s was 30% of the book value of the bank's assets. In addition, creditors had to bear administrative and legal costs of another 10% (James [1991]).[13] Other estimates are much lower. E.g. Kaufman (1994) estimates that the creditor banks of Continental Illinois – a bank with large interbank operations that failed due to its exposure to Latin America - would have suffered a loss of only 5% had it not been bailed out by the Fed. When BCCI failed in the early 1990s, creditors at first expected losses of up to 90%,

13 This cost represents the discount of the market value of the failed bank's assets relative to their book value.

but ended up recovering more than half of their deposits – albeit many years after the failure.[14] Creditor banks of Herstatt have so far received 72% on their assets, with the liquidation of the bank continuing to drag on even a quarter of a century after the closure in 1974.[15] These examples show that it may not be the actual losses borne by the creditor banks that matter, but the expected losses at the moment of failure which determine to which extent the exposure to the failing bank has to be written down and hence whether the creditor bank becomes technically insolvent or not.[16]

The loss rate also depends on the availability of collateral, for example in repos. Unfortunately, our data does not provide information on the share of collateralised positions. Only starting in 1999, that is after the end of our sample period and after the major structural change of European Monetary Union, was the monthly balance sheet statistic amended to include interbank repos. In the summer of 2000, such collateralized positions accounted for 6.2% of all interbank lending, although anecdotal evidence suggests that these are mostly with foreign banks. We therefore assume that the possible dampening effect of collateral on the danger of contagion in Germany is negligible.

Given the difficulties in determining the appropriate loss rate, we follow Furfine (1999) and test for the possibility of contagion using a variety of values for θ, which we assume to be constant across banks. The latter assumption is made for convenience. Although we can compute the losses on the loan portfolio that lead to bank failures, endogenizing θ for second and higher rounds of failures would require a set of assumptions on how these losses are spread between the individual creditors. In addition, we would have to add the administrative and legal expenses[17] associated with bankruptcy, not to mention taxes and salaries, all of which are senior to interbank loans. All these assumptions would, taken together, be more arbitrary as assuming a fixed loss ratio in the first place.

We run the simulations for both the baseline matrix that uses only aggregate information and for the full information matrix. The difference in the results is due to the additional information that is included in the full information matrix compared to the baseline matrix. This additional information refers to the relationships within the two giro systems and the breakdown into maturity categories. At this stage, we do not explicitely take into account

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[14] Financial Times, 8 July, 1998.

[15] Frankfurter Allgemeine Zeitung, 26 June 1999.

[16] There are several cases where regulators have been lenient in forcing banks to write down assets even though hardly anybody seriously expected their value to recover. Examples are US banks in the wake of the Mexican debt moratorium in 1982 and Japanese banks in the 1990s.

[17] In the sample of James (1991), administrative and legal expenses accounted for 10 % of total assets.

any institutional safeguards present in the German system, which may affect the possibility of contagion, although they may in part be reflected in the bilateral lending matrix ***X***. The results are reproduced in table 4.

Table 4:
Incidence of contagion in the absence of any safety net
(based on end December 1998 matrix)

		loss ratio θ =					
		0.75	0.50	0.40	0.25	0.10	0.05
average number of banks affected	full info	**30.3**	**22.2**	**20.0**	**18.0**	**17.0**	**17.0**
	baseline	*22.8*	*17.3*	*17.2*	*17.0*	*17.0*	*17.0*
% of total assets of banking system affected on average	full info	**0.85**	**0.66**	**0.58**	**0.30**	**0.26**	**0.25**
	baseline	*0.45*	*0.27*	*0.27*	*0.26*	*0.25*	*0.25*
maximum number of banks affected	full info	**2444**	**1740**	**115**	**31**	**19**	**18**
	baseline	*2159*	*1047*	*520*	*19*	*17*	*17*
maximum share of total assets affected	full info	**76.3**	**61.6**	**5.0**	**0.75**	**0.57**	**0.30**
	baseline	*70.9*	*55.8*	*48.9*	*0.57*	*0.25*	*0.25*

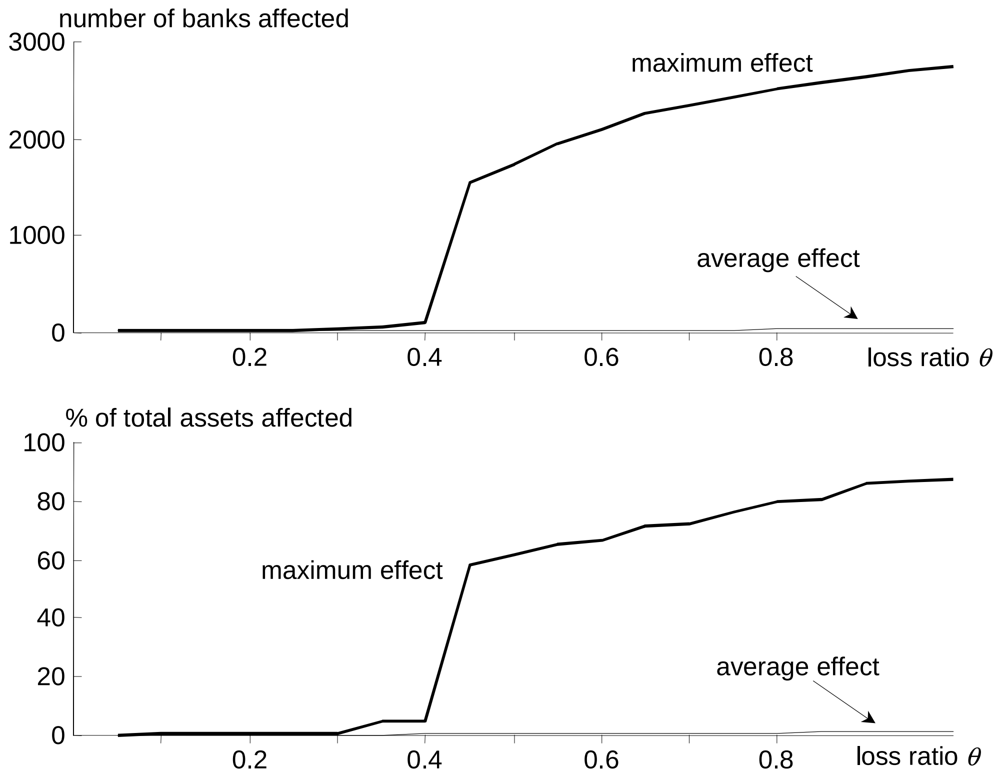
The results of this exercise are rather surprising at the first sight. Contagion always occurs *no matter which loss rate we choose*, although the choice of θ determines how many banks are affected on average. There are 17 commercial banks which fail, irrespective of which bank is the first to break down. However, we should not overvalue this result. Firstly, the banks in question are relatively small, accounting for only a quarter of a percentage point of the total assets of the banking system. Secondly, the fact that 10 of them always break down in the first round, that is due to the immediate impact, suggests that this is more a reflection of our assumption that interbank exposures are as equally spread as is consistent with the data, rather than a description of reality. We would expect that small banks are much more likely to concentrate their lending on a small number of counterparties, which would preclude that the same bank always breaks down in the first round.

While the finding that contagion always occurs may be an artifact of our methodology and should not be taken too seriously, the other results are more interesting. Assuming an (admittedly high) loss ratio of 75%, the maximum number of bank failures caused by domino effects is 2,444. This means that 88% of the institutions where contagion is a possibility because interbank loans exceed capital are affected. As is to be expected, the number of breakdowns increases with the loss rate. This increase is not linear, however.

Figure 4 shows that there is a jump in the severeness of contagion if the loss ratio exceeds 40%. This points to the existence of some critical θ: if θ is smaller than 0.40 even in the worst case the effects on contagion are rather small. With a loss ratio larger than 0.45, the increase in the damage caused by contagion again seems to be rather moderate. But, if θ lies between 0.40 and 0.45, the loss of assets due to contagion is very sensitive to changes in θ.

Figure 5: Loss ratio and the severity of contagion in the absence of the safety net

(full information matrix)



The kink in the relationship between θ and the maximum number of failures is more to the right if one considers the baseline compared to the outcome with the full information matrix. Otherwise, our findings largely confirm the theoretical results of Allen and Gale (2000) that contagion is less likely in a banking system characterized by a complete structure of claims relative to a more concentrated system.

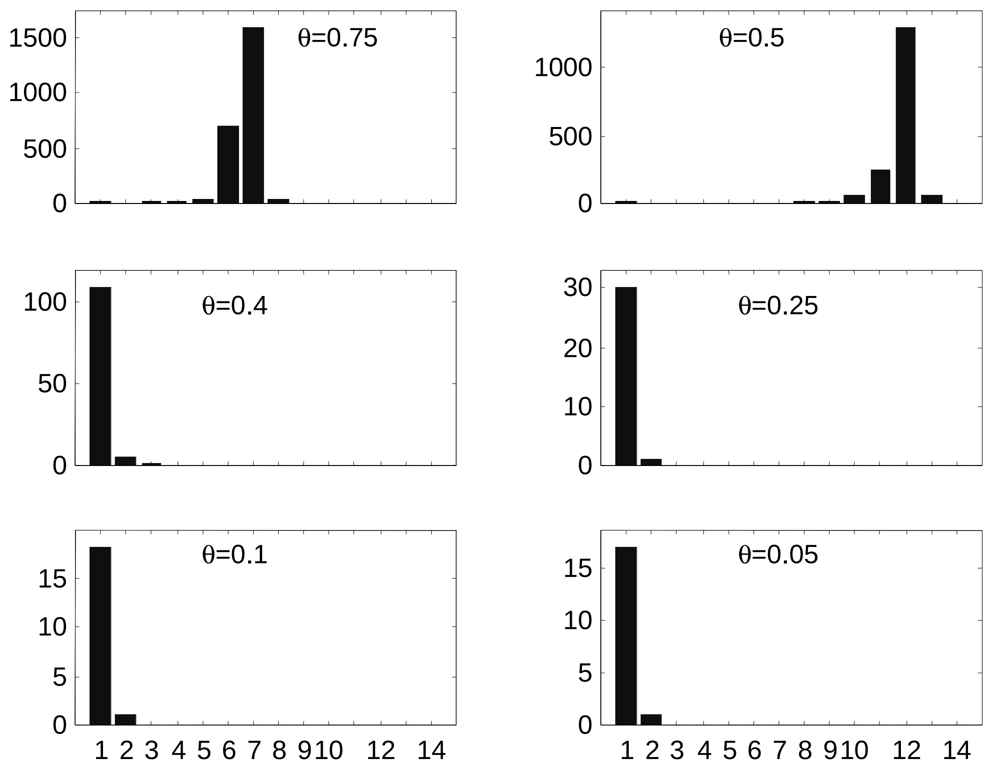
Figure 6 plots the spreading of contagion over time.[18] The number of banks that fail in the worst case are plotted on the vertical axis (note the different scales), and the round of

[18] Here we equate ‚time‘ and ‚rounds‘.

failure on the horizontal axis. For small θ's, that is when the severity of contagion is limited even in the worst possible case, the bulk of banks fail in the first-round, with some minor second- and, possibly, third-round effects. For $\theta > 40\%$, the path of contagion is very different. Although the first-round effects are only slightly larger than before, they do not peter out but at some point reach a critical mass that leads to the collapse of much of the banking system. However, such widespread contagion is rare even for high θ's. In most cases, the initial shock leads to the breakdown of a number of banks, which in turn causes a smaller number of further failures. Then the process stops. This, together with the high values of θ necessary to cause prolonged chains of failures, may explain why Furfine (1999) does not obtain higher than second-round effects.

Figure 6: Number of banks affected in round r = ...

(worst case in the absence of the safety net, full information matrix)



The reason why we find such a striking difference between the contagion patterns of low and high loss ratios – with the critical value of θ somewhere around 0.40 – can intuitively be explained by looking at what the failure of a single bank means for the continuation of the contagion process. Such an event has generally two implications: on the one handside, it reduces the pressure that drives the contagion process; on the other, the failure of the bank at hand also contributes to the continuation of this process because it can affect other banks as well. These two opposing effects jointly determine the probability with which the failure of a single bank adds to the dynamics of the contagion process or dampens them.

Their relative importance is determined mainly (1) by the interbank asset structure of the bank (which indicates how much the bank is affected by the preceding failures of other banks), (2) by the interbank liability structure of the bank (which is central for how the shock is transferred to other banks) and (3) by the loss ratio θ (which determines the strength of the transmission of the shock).

Table 5:
Incidence of contagion in the absence of the safety net, by bank categories
(based on end December 1998 full information matrix)

		loss rate θ =	**max. no of failures (worst case)** in brackets: % of total assets **in r = 1**	**sum r > 1**	**mean no. of failures (normal case)** in brackets: % of total assets **in r = 1**	**sum r > 1**	**average%-share in total inter-bank loans**
commercial banks		0.50	**22** (0.61)	**18** (0.58)	**13.9** (0.22)	**6.2** (0.36)	**16.0**
		0.10	**17** (0.25)	**15** (0.25)	**13.9** (0.22)	**3.1** (0.04)	
savings banks´ sector	**Landes-banken**	0.50	**20** (0.75)	**1720** (60.17)	**17.9** (0.37)	**268.4** (9.51)	**30.0**
		0.10	**17** (0.25)	**0** (0.00)	**17.0** (0.25)	**0.0** (0.00)	
	savings banks	0.50	**17** (0.25)	**18** (0.58)	**11.8** (0.21)	**8.2** (0.37)	**7.7**
		0.10	**17** (0.25)	**15** (0.25)	**11.8** (0.21)	**5.2** (0.05)	
coope-rative sector	**central banks**	0.50	**195** (1.56)	**1545** (60.06)	**57.6** (0.54)	**312.2** (12.28)	**7.8**
		0.10	**18** (0.30)	**1** (0.27)	**17.2** (0.26)	**0.2** (0.05)	
	coopera-tives	0.50	**17** (0.25)	**18** (0.58)	**9.3** (0.17)	**10.7** (0.41)	**7.0**
		0.10	**17** (0.25)	**15** (0.25)	**9.3** (0.17)	**7.7** (0.08)	
other banks		0.50	**25** (3.6)	**1715** (56.95)	**15.8** (0.32)	**40.6** (1.52)	**31.5**
		0.10	**17** (0.25)	**15** (0.25)	**15.5** (0.24)	**1.5** (0.02)	

This switching in the time pattern of contagion has important implications for the regulation of banks and the design of institutional safeguards. It shows that it may be possible to stop the most severe scenarios with relatively low costs at an early stage, i.e. before the dramatic wave of bank failures sets in. It must nevertheless be kept in mind that the rounds on the horizontal axis of figure 5 are not necessarily comparable to discrete time periods in the usual sense. Even very late rounds can actually occur already a very short (calender) time period after the initial shock, so that there may be virtually no possibility for a regulator to react to a process once it has started.

Table 5 shows the contagion effects by bank category of the initial shock for the loss rates of 0.50 and 0.10, respectively. As one would expect, failures of savings banks or cooperative banks have very little impact on other banks. Even in the case of a loss rate of 0.50 would the damage remain below 1% of total assets. The largest contagion effects occur if a head institution of one of the giro systems fails. With $\theta = 50\%$, the failure of a Landesbank could trigger the failure of up to 1,740 banks and more than 60% of total assets. On average, 286 banks are affected, corresponding to 10% of total assets. The effects of the failure of a cooperative central banks are similar. Again 1,740 banks – or more than 60% of the banking system in terms of assets - would fail in the worst case, and 370 banks (13% of total assets) on average. These results are compatible with the implications derived theoretically by Freixas, Parigi and Rochet (2000) on the basis of their money centre bank model.

The severity of contagion is much smaller if a loss rate of only 0.10 is assumed: In neither case would the damage be more than 0.6% of total assets. What is striking is the limited effect of a failure of a commercial bank (the category that includes the large banks). Even in the worst case, it would only cause a loss of 40 banks or 1.2% of total assets. This may in part be due to the fact that a large proportion of the interbank claims of large commercial banks are on foreign banks which are not included in our dataset. Another reason could be that due to the absence of detailled information on intra-group lending, the independence assumption is stronger for commercial than for savings or cooperative banks or their respective head institutions.

6 Banking supervision, regulation and the safety net

The preceding analysis ignored the prudential regulation of banks and the existence of a safety net, both of which may limit the probability of our scenarios. In particular, as will become clear below, the safety mechanisms that are in place in Germany are designed to prevent the failure of Landesbanken and cooperative central banks. The worst case scenarios identified in the previous section are therefore virtually impossible. In the present section we address this omission and extend our analysis to incorporate the safeguards present in the German system.

Prudential supervision limits the danger of contagion in a number of ways. Firstly, banking supervision aims at reducing the incidence of failures by forcing (or encouraging) banks to behave more prudently. In our model, this corresponds to a reduction of the probability that a shock (i.e. the initial failure of a bank) occurs in the first place. Secondly, if banks do fail, swift action by the regulator could ensure that banks are liquidated before the losses become too large. This would be reflected by a low loss ratio θ. Finally, banking regulation may limit the exposures of banks to any single debtor or group of debtors, which in turn reduces the scope for contagion. For example, in Germany bank loans to a single debtor should in principle not exceed 25% of the capital of the creditor, although interbank loans are partly exempted. For the purpose of our paper, such regulations are reflected in the pattern of interbank exposures.

While prudential supervision does play an important role in reducing the risk of contagion *ex ante*, it cannot stop this process once it is under way. In this case, two additional mechanisms could step in. The first is the Liko-Bank, a bank owned by the banking system with participation by the Bundesbank, which exists solely to provide liquidity to illiquid but solvent banks. The second mechanism is the insurance of interbank deposits.

Deposit insurance can halt contagion through credit exposures in the interbank market – as opposed to contagion through bank runs – only if it covers deposits by banks as well as deposits by non-banks. While the statuatory deposit insurance applies to non-bank deposits only (Deutsche Bundesbank [2000b]), for savings and cooperative banks, including their respective head institutions, this is supplemented by so-called “institutional guarantees“. Both the savings banks‘ and cooperative banks‘ associations operate funds backed up by mutual guarantees which serve to recapitalize member institutions in the event they become insolvent.[19] In addition to the guarantee fund, savings banks are also explicitly guaranteed by the corresponding local or regional government.[20] There is also a (small) number of public banks guaranteed by the federal government.[21]

We incorporate these safeguards into our analysis by assuming that

- savings banks never fail,
- public banks guaranteed by the federal government never fail, and

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[19] In order to alleviate moral hazard problems, failed cooperative banks usually loose their independence and are merged with stronger banks, which obtain support from the guarantee fund. A detailled description of the guarantee schemes is contained in Deutsche Bundesbank (1992) and (2000b).

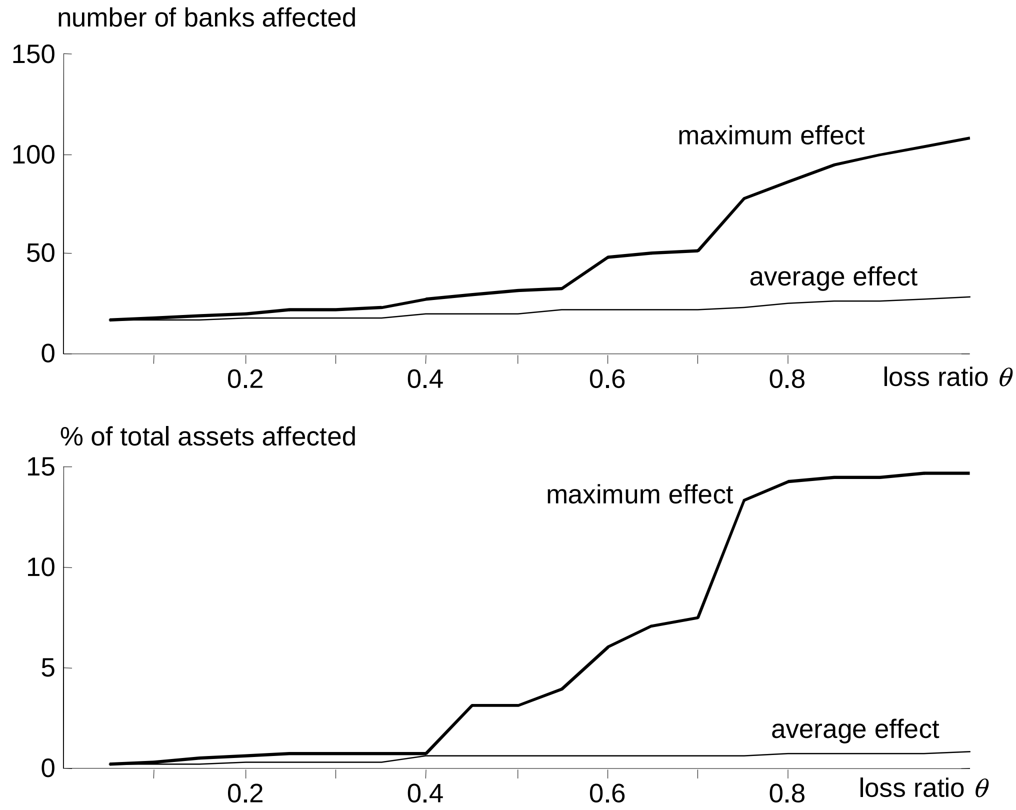
[20] These state guarantess are being phased out over the next years.

[21] E.g. the Kreditanstalt für Wiederaufbau (KfW).

- cooperative banks never fail in the first-round and hence never trigger contagion. In further rounds, they only fail if the exposure of the aggregate cooperative sector to the banks failed in previous rounds exceeds its aggregate capital. This is equivalent to assuming unlimited cross-guarantees and may thus overstate the solidarity between the individual banks of this group. As a consequence, either no cooperative bank fails or the complete cooperative sector as a whole, including the cooperative central banks, breaks down.[22]

Figure 7: Loss ratio and the severity of contagion in the case of a perfect safety net

(full information matrix)



Since in the previous section we found that the largest effects were caused by a breakdown of a head institution of the savings or the cooperative sector, we should expect much lower contagion once we incorporate the existing safeguard mechanisms. The fact that during the past half century the stability of the German banking *system* has never been called into question despite a number of bank failures can be seen as an indication that the existing

22 The charter of the safety fund for cooperative banks stipulates that each bank has to provide guarantees amounting to 60% of its statutory credit provisions. This is in addition to the contributions to the deposit guarantee fund, which covers non-bank deposits.

banking supervision and safety mechanisms have worked well in the past. This effectiveness is well confirmed by our results presented in figure 7.

We find that contagion is much more limited in scope but remains a possibility even if we incorporate safety mechanisms into our analysis. As before, we find that the maximum percentage of assets affected remains relatively flat for loss ratios below 40% but increases for higher values. For θ's in excess of 75%, about 100 banks may be affected in the worst case of contagion. This corresponds to 15% of the banking system in terms of assets, which is considerably below the corresponding values of up to 80% if one ignores the safety mechanisms. In particular, we find that the cooperative system never fails, even for the highest θ's.

When interpreting our results, it has to be borne in mind that we do not say anything about the *efficiency* of safety nets, since we we do not incorporate their direct and indirect costs.

7 Conclusions

Credit risk associated with interbank lending may lead to domino effects, where the failure of one bank results in the failure of other banks not directly affected by the initial shock. Recent work in economic theory shows that this risk of contagion depends on the precise pattern of interbank linkages. We use balance sheet information to estimate matrices of bilateral credit relationships for the German banking system. In contrast to commercial datasets, our data covers the entire banking system, so all domestic interbank loans and deposits add up to zero in principle. In their submissions to the Bundesbank, which provide the basis of our analysis, banks have to give a detailled breakdown of their interbank assets and liabilities, showing maturity categories and whether or not the counterparty is a head institution of giro system the respective bank belongs to. This permits us to estimate a matrix of bilateral credit exposures for each maturity and banking group, thus imposing much more structure on the problem than would be possible with aggregate interbank loans and deposits alone. The estimated system-wide matrix differs considerably from a matrix estimated from aggregate exposures (across all maturities and banking groups) alone.

We find that interbank lending in Germany is characterized by a two-tier structure. The first tier consists of most savings banks and virtually all cooperative banks, who transact mainly with the Landesbanken and cooperative central banks. The second tier consists of the head institutions of the two giro systems, the commercial banks and the other banks.

Our results suggest that domino effects through interbank credit exposures are possible.[23] While the danger of contagion is normally confined to a limited number of relatively small banks, bank failures that affect a sizeable part of the banking system remain a possibility even if we explicitely take into account safety mechanisms like the institutional guarantees for savings banks and cooperative banks. In the absence of such mechanisms, the effects of the breakdown of a single bank could potentially be very strong indeed. This cannot be taken as a statement on the desirability of these mechanisms or a system with publicly owned banks, though, as we do not consider the incentive effects or other important aspects they are associated with. Nevertheless, this result confirms that the existing safety nets significantly reduce the danger of contagion.

Not surprisingly, the danger of contagion crucially depends on the losses experienced by the creditor bank in the case of insolvency of the debtor bank. We find that large scale contagion can in any case only occur if the loss rate on interbank loans exceeds a value of approximately 40%.

Our findings have important implications for banking regulation. The regulator can minimize the danger of contagion in a number of ways. Firstly, it can reduce the probability of the initial shock that could trigger contagion by encouraging banks to behave more prudently. Secondly, if a bank does fail, the regulator should ensure a quick and orderly liquidation before the ratio of losses to assets becomes too large. And finally, banking regulation can limit the exposures of banks to individual debtors.

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[23] We do not consider other channels for contagion, like runs by non-banks.

References

Aghion, P., P. Bolton & M. Dewatripont (2000): Contagious Bank Failures in a Free Banking System", *European Economic Review*, 44, pp. 713-718..

Allen, F. & D. Gale (2000): "Financial Contagion", *Journal of Political Economy*, 108(1): 1-33.

Angelini, P., G. Mariesca & D. Russo (1996): "Systemic Risk in the Netting System", *Journal of Banking and Finance*, 20: 853-68.

Blien, U. & F. Graef (1991): "Entropieoptimierungsverfahren in der empirischen Wirtschaftsforschung (Entropy Optimization in Empirical Economic Research)", *Jahrbuch für Nationalökonomie und Statistik*, 208(4): 399-413.

Deutsche Bundesbank (1992): "Deposit protection schemes in the Federal Republic of Germany", *Monthly Report July 1992*: 28-36.

________ (2000a): "Longer-term trend in German credit institutions' interbank operations", *Monthly Report January 2000*: 49-68.

________ (2000b): "Deposit protection and investor compensation in Germany", *Monthly Report July 2000*: 29-45.

Freixas, X., B. Parigi & J.C. Rochet (2000): "Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank", *Journal of Money, Credit and Banking*, 32(3), Part 2: 611-38.

Furfine, C.H. (1999): "Interbank Exposures: Quantifying the Risk of Contagion", *BIS Working Paper 70.*

Humphrey, D.B. (1986): "Payments Finality and the Risk of Settlement Failure", in A Saunders & L.J. White (eds.) *Technology and the Regulation of Financial Markets: Securities, Futures and Banking*. Lexington, MA: Lexington Books.

James, C. (1991): "The Losses Realized in Bank Failures", *Journal of Finance*, 46: 1223-42.

Kaufman, G.G. (1994): "Bank Contagion: A Review of the Theory and Evidence", *Journal of Financial Services Research*, 8: 123-50.

Rochet, J.-C. & J. Tirole (1996): "Interbank Lending and Systemic Risk", *Journal of Money, Credit, and Banking*, 28: 733-62.

Sheldon, G. & M. Maurer (1998): "Interbank Lending and Systemic Risk: An Empirical Analysis for Switzerland", *Swiss Journal of Economics and Statistics*, 134(4.2): 685-704.

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