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Interbank Contagion in the Dutch Banking Sector: A Sensitivity Analysis*

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We investigate interlinkages and contagion risks in the Dutch interbank market. Based on several data sources, including survey data, we estimate the exposures in the interbank market at bank level. Next, we perform a scenario analysis to measure contagion risks. We find that the bankruptcy of one of the large banks will put a considerable burden on the other banks but will not lead to a complete collapse of the interbank market. The exposures to foreign counterparties are large and warrant further research. An important contribution of this paper is that we show, using survey data, that the entropy estimation using large exposures data as applied in many previous papers gives an adequate approximation of the actual linkages between banks. Hence, this methodology does not seem to introduce a bias.

JEL Codes: G15, G20.

1. Introduction

The interbank market is an important market in managing a bank's liquid funds. It is a market with largely unsecured exposures of

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significant size. Furthermore, the banking sector is consolidating more and more in many countries, leading to an evermore interlinked market. Such a closely linked market might be prone to contagion. These developments have led researchers and policymakers alike to take an interest in this subject, resulting in a number of valuable studies. These studies, which we will discuss in more detail shortly, generally rely on proxies of actual bank-to-bank exposures. An important finding is that the fragility of the interbank market is highly dependent on the characteristics of the market: both the market structure and the magnitude of interbank linkages determine the contagion path.

The present study adds to the literature in two ways. First, we are able to shed light on the validity of the proxy for exposures used in previous studies. In addition to information on large exposures for nearly the entire market, we have direct information about bank-to-bank exposures from a selected number of banks, covering about 80 percent of the market. Comparing the results based on the large exposure proxy and the survey exposures provides evidence that the proxy used in previous studies seems to be an adequate one. Second, the process of consolidation has gone further in the Netherlands than in most countries; loans and deposits of the five largest banks, as a percentage of the total, were at 79 percent and 88 percent, respectively, in 2004. Furthermore, the Netherlands is a small open economy. The Dutch case can thus serve as a natural experiment, showing what the effects of contagion are in a closely linked market.

The structure of the paper is as follows. Section 2 discusses existing research, while section 3 explains the methodology and describes the data sources and data characteristics. Then we present an analysis of the results in section 4. We pay particular attention to the comparison between the results based on the two separate data sources. Section 5 presents our conclusions and the policy implications implied by the analysis.

2. Previous Research into the Interbank Market

Only recently a strand of literature has begun to analyze the structure of the interbank market as a source of financial sector contagion. Theory discerns both direct and indirect contagion (de Bandt and Hartmann 2000). Direct contagion results from direct (financial) linkages between banks, such as credit exposures. Indirect contagion is the result of expectations about a bank's health and about the resilience of the sector. In contrast, the exposure of banks to similar events (such as asset price fluctuations) cannot, by definition, result in direct contagion.[1] Obviously, although these two contagion channels can work separately, direct contagion and indirect contagion are not mutually exclusive and may even reinforce each other. For instance, a bank failure may lead to further bank failures through direct linkages and may induce further bankruptcies even if depositors only assume the existence of linkages between banks (regardless of whether these assumptions are true or not). In our paper, we focus on direct linkages between banks and thus on the risk of direct contagion.

In the literature, it has become clear that the structure of the interbank market is of crucial importance for contagion, as it determines the impact of a shock to an individual bank on the complete system. Allen and Gale (2000) distinguish three types of interbank market structures. First, they define a complete structure as one where banks are symmetrically linked to all other banks in the system. Second, an incomplete market structure exists when banks are only linked to neighboring banks. A special case of this structure—the money-center structure—is introduced by Freixas, Parigi, and Rochet (2000). In this structure, the money-center bank is linked symmetrically to the other banks, while the latter have no links among themselves. Third, a disconnected incomplete market structure is defined as one where two separate (but internally connected) markets exist simultaneously. A complete market structure may give the highest level of insurance against unexpected liquidity shocks hitting an individual bank because of diversification effects. However, such a structure might also spread shocks more easily through the system, as shocks will not remain isolated at one bank or at a cluster of banks. In a model based on that of Diamond and Dybvig (1983), Dasgupta (2004) investigates the effect of a signal about a bank's health on customers' expectations and shows that contagion mainly runs from debtor banks to creditor banks.

[1] However, *assumed* similarities in banks' risk structure may lead to indirect contagion.

Empirical studies that try to model the structure of the interbank market and the following contagion risks have been carried out for several countries (Elsinger, Lehar, and Summer, forthcoming; Degryse and Nguyen 2004; Upper and Worms 2004; Mistrulli 2005; Blåvarg and Nimander 2002; Sheldon and Maurer 1998; and Wells 2004). See table 1. Most of these studies use balance sheet data or large exposures data as proxies to determine the interbank market structure. Blåvarg and Nimander (2002) and Mistrulli (2005) use bilateral observed data to model contagion risk. Mistrulli concludes that in the Italian case, the estimation based on aggregate data may underestimate contagion risk. However, this conclusion is based on a comparison of the results using, on the one hand, the maximum entropy and, on the other hand, the observed bilateral exposure data. Given the emergence of a money-center-bank structure in the Italian interbank market, it is clear that the assumption of maximum entropy becomes less appropriate. Müller (2003) explores the Swiss interbank market using new data from the Swiss National Bank. Applying network analysis,[2] she discerns systemically important banks and possible contagion paths. Furfine (1999) estimates contagion risk in the U.S. interbank market but uses bilateral data from the Fedwire payment system to build the interbank market structure. The majority of these studies find that contagion effects are small, especially since high loss rates are rare. This paper is related to these studies in several ways. For one, we base our analysis on balance sheet data and large exposures data as well. Furthermore, we use different loss rates to test the strength of the system under different shocks. However, we add a second model variant in which we incorporate the answers of banks with respect to their bilateral exposures. This provides the opportunity to test the usefulness of the large exposures data for estimating the interbank market structure.

Nevertheless, all these models focus on the credit or solvency risk of a bank failure and usually do not incorporate the effects of liquidity risk, such as the drying up of credit lines or falling asset prices. Müller (2003) introduces liquidity risk in the Swiss

[2]Müller (2003) measures, for example, the number and size of interbank interlinkages, the distance from other banks, the importance of counterparties, and the position in the network.

Table 1. Overview of Existing Literature

	Data Period	Methodology	Notes	Results
Austria Elsinger, Lehar, and Summer (forthcoming)	2001	• Network model of interbank exposures combined with macroeconomic shock		• Most failures are caused by macroeconomic shock • Recovery rates, determined by model, are high
Belgium Degryse and Nguyen (2004)	1993–2002	• Cross-entropy minimization using large exposures data	• Different loss ratios • Failure if loss $>$ tier 1	• Failure of domestic bank cannot trigger Belgian bank failure; Belgian banks exposed to French, Dutch, and British banks • Change in market structure (from complete structure to multiple money centers) decreases contagion effects • "International risk of contagion deserves more attention than domestic contagion risk"
Germany Upper and Worms (2004)	1998	• Maximum entropy • Cross-entropy minimization using large exposures data	• With/without safety net • Different loss ratios • Failure if loss $>$ tier 1	• Two-tier structure in interbank market • Contagion is serious possibility • Losses increase sharply if loss rate $>$ 40 percent • Safety nets reduce contagion effects

(*continued*)

Table 1 (continued). Overview of Existing Literature

	Data Period	Methodology	Notes	Results
Italy Mistrulli (2005)	1990–2003	• Maximum entropy • Bilateral exposures	• Different loss ratios • Completeness vs. interconnectedness	• Estimation methodology underestimates contagion risk (with regard to observed Italian bilateral exposures) • Domestic risk of contagion more important than foreign contagion risk, but still small • Change in market structure (from complete structure to multiple money centers) increases contagion effects
Sweden Blåvarg and Nimander (2002)	1999	• Bilateral exposures	• Assumption: full principle credit risk (uncollateralized) • FX settlement exposures separately measured • Different loss ratios • Failure if tier $1 < 4\%$ ratio (BIS)	• In most cases contagion will not lead to a failure of the largest banks • Foreign contagion risks stem mainly from FX settlement exposures

(*continued*)

Table 1 (continued). Overview of Existing Literature

	Data Period	Methodology	Notes	Results
Switzerland Sheldon and Maurer (1998)	1987–1995		• A bank failure depends on accounting data as ROA, E(ROA), CAR, overhead • Maximum loan portfolio diversification • One shock, complete loss • Cross-border market not taken into account (though important)	• Contagion effects are small • Domestic interbank market relatively unimportant compared to cross-border market
United Kingdom Wells (2004)	2000	• Maximum entropy • Cross-entropy minimization using large exposures data	• Model 1: lending as dispersed as possible • Model 2: concentration reflected in large exposures data • Model 3: money-center structure • Different loss ratios	• Only limited contagion effects • Spillover effects may occur, but depend heavily on loss rate • In model 2, contagion is higher, but asset losses lower • Losses are highest in model 3

interbank market through the existence of credit lines but finds that such contagion effects are smaller compared with the risk of credit exposures. In a theoretical paper, Cifuentes, Ferrucci, and Shin (2005) model the impact of asset sales of distressed banks on asset prices and the liquidity and solvency position of other banks. They conclude that liquidity requirements can be as effective as capital requirements to prevent contagion effects. Allen and Gale (2004) also analyze liquidity effects and the impact on asset prices and financial fragility. Cocco, Gomes, and Martins (2003) model lending relationships in the interbank market and the behavior of market participants, suggesting that such relationships are important. Obviously, this kind of research merits further attention.

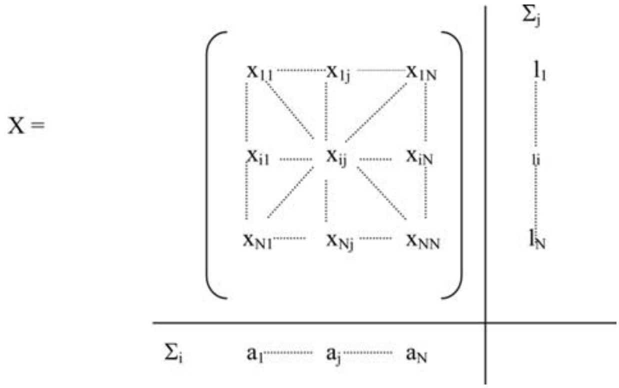
3. Methodology and Data

3.1 Interbank-Lending Matrix

To model the structure of interbank linkages between N banks, we use a matrix like X (figure 1). In this matrix, the columns represent banks' lending, while the rows represent banks' borrowing. Hence, x_{ij} gives the liabilities of bank i toward bank j. Clearly, not all banks need to be a lender and a borrower at the same time. In fact, a bank need not be active in the interbank market at all. In such a case, we would fill the corresponding cell(s) with a zero. Moreover, a bank does not lend to itself: the cells on the main diagonal from upper left to bottom right would all be zeros.

The information problem can then be identified as follows: the sum of each bank's interbank lending and borrowing, a_j and l_i, is known. These data can be obtained from the monthly balance sheet report. What is not known is the distribution of these exposures over the system, i.e., the elements of the matrix X itself. The lack of information cannot be solved easily, as the problem contains more unknowns than equations. Thus, the problem is underidentified, which implies that several solutions may lead to the same outcome (Upper and Worms 2004). There is no unique solution to this problem.

Figure 1. Interbank-Lending Matrix



Source: Upper and Worms (2004).

One solution would be to divide the aggregate exposure proportionally over all N banks. This is called *entropy maximization.*[3] A difficulty with this solution is that it assumes that all lending and borrowing is as dispersed as possible, i.e., interbank activities are completely diversified. This rules out the possibility of relationship banking.[4]

Another way of solving the problem is to *add additional information.* The large exposures data might be suitable to this end but require some additional assumptions. In using the large exposures data, we assume that the distribution obtained from these data is representative of the real distribution of exposures. This is not necessarily true, of course. However, it does improve the picture of the concentration of interbank lending and borrowing. Wells (2004) explains that, given the estimate of the interbank structure (for instance, the

[3]This problem can be compared to the outcome of rolling a pair of dice. Unless one has information that the dice are loaded in some way, the distribution that places equal weight on each outcome should be selected. But this distribution also maximizes the uncertainty, or entropy, about the outcome. Therefore, in the absence of information about concentrations in the interbank market, the maximum entropy distribution is chosen.

[4]As Cocco, Gomes, and Martins (2003) show, however, banks might want to establish relationships with banks whose liquidity shocks are less correlated with their own.

large exposures data), a minimization problem needs to be solved to find a matrix that gets as close to the estimate as possible, given the interbank lending and borrowing totals. This matrix is calculated by use of the RAS algorithm (see also the appendix).

A last approach would be to ask all banks to *report their bilateral exposures*, including the names of the counterparties and the actual amount of the exposure. Owing to the reporting cost, this is deemed impossible for the Dutch banking system as a whole, although we did obtain information from the most important banks.

In this paper we apply the first two approaches (maximum entropy and cross-entropy minimization), although we focus on the approach that adds additional information, as this seems the more relevant one. We add additional information in two different ways: first using only large exposure reporting and then adding ad hoc survey information as described in the next section. This also allows us to compare the outcomes and make an inference about the appropriateness of large exposures data for estimating the interbank market structure and contagion effects.

3.2 Data Sources

It is rather difficult to determine the precise structure of the interbank market. No information is publicly available about the size of the interlinkages in the interbank market. On a confidential basis De Nederlandsche Bank (DNB), as prudential supervisor, regularly receives balance sheet data and large exposures reports. For the analysis, three main data sources have been used, which we will discuss in turn: the monthly balance sheet report, the large exposures data report, and an ad hoc survey obtained from the largest ten banks. The *monthly report* reflects the aggregate interbank assets and liabilities of a bank and is comparable to the U.S. Call Report. Balance sheet data have been collected for December 2002 from all banks under supervision, including foreign subsidiaries and branches. These data concern consolidated data about interbank assets and liabilities, tier 1 capital, and total assets. Interbank exposures are influenced by the end-of-year effect. This implies that reported exposures at this date are lower compared with the rest of the year. However, foreign branches with a parent company within the European Union are exempted from reporting tier 1 capital, since DNB plays no role in solvency supervision of these banks.[5]

In the *large exposures data report,* banks must specify the names and amounts of bank counterparties to which they have an exposure larger than 3 percent of their actual own funds; they must also specify the names and amounts of nonbank counterparties for exposures larger than 10 percent of their actual own funds. The report is subject to many exceptions, and some banks are exempted from reporting.[6] Moreover, most banks only report risk limits and not the actual outstanding amounts, and not all exposures (such as off-balance-sheet positions) are accounted for. From the large exposures data reports, exposures on home (Dutch) and foreign (non-Dutch) bank counterparties have been selected.

To obtain complete information on the larger part of the interbank exposures, the top ten banks with respect to interbank assets were asked to fill in a *survey* on bilateral exposures. Names and amounts—based on interbank deposits, derivatives, and securities—together with an indication as to whether these amounts concern limits or outstandings, were requested for all Dutch bank counterparties for December 2002. In addition, the same data were required for the fifteen largest foreign bank counterparties. However, we only use the information about interbank deposits in this analysis, since derivatives (off balance sheet) and securities are not included in the monthly balance sheet reporting. In general, both the limits and outstandings of the interbank derivatives portfolio are larger than those for the deposit portfolio. This becomes especially clear from the outstanding interbank derivatives, which are on average about 2.5 times larger than interbank deposits, while limits on the derivatives portfolio are on average 1.6 times larger. In contrast, the reported outstanding securities as well as the limits are on average smaller than

[5]In the 1992 Law on Supervision of Credit Institutions, the aspect of "home-country control" was introduced as a consequence of the "EU license." With home-country control, branches of banks located in the EU only need a license from the country of origin and are subject to solvency supervision of this country. The host country does play a role in liquidity supervision.

[6]Not all certified banks are required to report their large exposures data. Branches with a parent company located inside the EU are exempted from reporting. Intraconcern exposures are exempted as well.

those on the interbank deposit portfolio, although this outcome may be related to the data quality.

3.3 Data Description

The Dutch interbank market, based on reporting of all Dutch banks for December 2002, covers about €93 billion of interbank assets and €364 billion of interbank liabilities. This is, respectively, 10 percent and 20 percent of the total balance sheet value of the banks and 210 percent and 397 percent of actual own funds. These exposures are largely not collateralized. The Dutch banks hence borrow on the international interbank market and have a net debit position relative to the rest of the world. This may render the Dutch banking system more likely to be the source of contagion rather than the "victim." The market is dominated by a few large banks, which cover 77 percent (€149 billion) of interbank assets and 85 percent (€309 billion) of interbank liabilities. This dominance restricts the number of possible counterparties in the market and therefore increases contagion risks.

In tables 2 and 3, we present descriptive statistics for the different types of firms active in the Dutch market. Standard deviations are shown in parentheses. Naturally, there are more observations per bank in the large exposures data report compared with the monthly report, as banks are, in most cases, exposed to several counterparties. Additionally, table 3 is divided into risk limits and risk outstandings.

These descriptives show, unsurprisingly, that the large banks are the largest party in the market. The remaining types seem to play only a limited role in the interbank market. Remarkably, for all types, interbank liabilities are larger than interbank assets. All Dutch banks, even the smaller ones, are hence net borrowers on the international interbank market. For the foreign subsidiaries and branches, this might be attributed to the link with the parent company.

Table 4 shows descriptive statistics for the survey data. The ten largest banks that were requested to report these data are of the first three types discerned in the previous tables. We use interbank outstandings from the survey data instead of interbank limits, except for one bank, which only reports risk limits. Zero-risk exposures have been excluded.

Table 2. Descriptives by Type: Monthly Report (x Million Euro), December 2002

Type	Range of Obs.	Interbank Assets	Interbank Liabilities	Tier 1	Total Assets
		Mean (St. Dev.)	**Mean (St. Dev.)**	**Mean (St. Dev.)**	**Mean (St. Dev.)**
Large Bank	4	37,220 (15, 203)	77,233 (33, 778)	14,217 (6, 823)	368,560 (210, 418)
Other Dutch	19–22	740 (1, 094)	932 (1, 281)	446 (631)	9,761 (17, 077)
Foreign Subsidiary	27–29	338 (305)	628 (923)	105 (93)	1,508 (1, 852)
Foreign Branch	9–27	682 (1, 810)	748 (1, 668)	16 (10)	1,045 (2, 161)
Investment Firm	5–6	51 (35)	131 (158)	14 (6)	268 (237)
All Banks	69–88	2,201 (8, 269)	4,444 (17, 857)	1,012 (3, 619)	20,029 (86, 397)

Note: Of the foreign branches, the tier 1 capital report is in many cases missing, as the foreign branches are generally exempted from reporting under the "home-country control" principle.

Table 3. Descriptives by Type: Large Exposures Data (x Million Euro), November/December 2002

	Limit		Outstanding	
Type	**Number of Observations**	**Mean (St. Dev.)**	**Number of Observations**	**Mean (St. Dev.)**
Large Bank	255	2,131 (2,076)	22	409 (380)
Other Dutch	188	85 (121)	153	45 (72)
Foreign Subsidiary	125	48 (62)	216	33 (48)
Foreign Branch	37	12 (24)	74	6 (5)
Investment Firm	–	– –	26	8 (7)
All Banks	605	935 (1,692)	491	48 (123)

Note: Based on bank counterparties, zero-risk exposures are excluded.

Table 4. Descriptives by Type: Survey Data (x Million Euro), December 2002

	Limit		Outstanding	
Type	**Number of Observations**	**Mean (St. Dev.)**	**Number of Observations**	**Mean (St. Dev.)**
Large Bank	33	1,206 (1,272)	56	705 (2,550)
Other Dutch	0	– –	161	60 (320)
Foreign Subsidiary	0	– –	11	32 (32)
All Banks	33	1,206 (1,272)	228	217 (1,314)

Note: Based on bank counterparties, zero-risk exposures are excluded.

An analysis of the number and relative size of the exposures on the counterparties (Dutch banks, foreign banks) in the survey data shows that a high number of exposures does not necessarily coincide with a high exposure. This holds especially for the exposures on Dutch counterparties, on which the highest number of exposures is reported, whereas the relative exposure (the exposure as a percentage of total exposure) per Dutch bank counterparty is lowest. This decreases the impact of an individual failure, because the loss is relatively small; however, it increases contagion risk, as many banks are linked.

3.4 Scenario Analysis

To measure the risk of contagion in the Dutch banking system, we perform a scenario analysis, using the obtained interbank-lending matrix. To do this, all banks are assumed to fail in turn owing to some exogenous shock. A bankruptcy does not imply that the counterparties of the failed bank lose the total amount of their exposure, as the sale of (some part of) the failed bank's assets may offer compensation.

The possibilities for compensation depend, though, on the bankruptcy legislation in a country. However, little information is available about the level of recovery (i.e., the loss rate).[7] Therefore, we use several loss rates (25 percent, 50 percent, 75 percent, and 100 percent) in this analysis to assess the resilience of the banks. Note that losses, even temporary ones, can have direct and immediate consequences for the liquidity position of a bank and hence for its solvency.[8]

We assume that a bank fails if its exposure to a failed bank (i.e., its loss) is larger than its tier 1 capital:

$$\theta * x_{ij} > c_j, \tag{1}$$

[7] James (1991) finds a mean loss rate of 30 percent of the assets of the failed bank and another 10 percent as direct bankruptcy costs. Furfine (1999) uses a loss rate of only 5 percent.

[8] An interesting theoretical paper in this respect is Cifuentes, Ferrucci, and Shin (2005), where the authors show that if the recovery rate becomes endogenous (and capital requirements or exposure limits are binding), a small shock might already have a large impact.

where θ denotes the loss rate, x_{ij} is the exposure of bank j toward bank i (alternatively, x_{ij} represents bank i's liabilities to bank j), and c_j is the tier 1 capital of bank j. If more than one bank fails, a third bank fails if its exposure to these two banks is larger than its tier 1 capital:

$$\theta * (x_{ij} + x_{kj}) > c_j. \tag{2}$$

In the analysis, we assume that the time span between a perceived increase in credit risk of a bank and the actual failure of the bank is too short for other banks to decrease their exposure to the bank in question. In addition, we do not model increased risk awareness following the initial default, and we thus assume that the loss rate is constant over time. In assessing the scenarios, we report the results prenetting because we are interested in a truly severe scenario. Obviously, having liabilities to a failed bank reduces the net exposure and thus the possible loss. Such a robustness check shows us that, compared with the results discussed in the next section, the effects in the netted case are much smaller, but the overall picture remains the same.

Completely idiosyncratic shocks are rare, and thus our assumption that at first only a single bank fails due to some exogenous shock might be a relatively strong one. It seems more likely that several banks will be simultaneously affected in the case of a shock. Moreover, a bankruptcy is often preceded by a period of distress, and thus other banks are able to take measures in time. Nevertheless, operational risk events are a different matter, as exemplified by the Barings Bank case. There, activities of a single trader led to the demise of the entire bank. In this case, the factor that triggered the failure was idiosyncratic to Barings Bank, so that other banks were not influenced by this shock. Therefore, it has to be kept in mind that although such scenarios may be rather rare events, such shocks do occur. Next to that, such a severe scenario analysis may be useful in determining the sequence and path of contagion. Still, modeling the probability of default, conditional on the state of the economy and/or crisis, would also be a possible future improvement (cf. Elsinger, Lehar, and Summer, forthcoming).

4. Results

4.1 Interbank-Lending Matrices

In this section, we first present the interbank-lending matrix based on the large exposures data and then discuss the matrix estimated with the survey data.[9]

4.1.1 Large Exposures Data

We constructed the largest possible data set of both interbank assets and liabilities and large exposures data, resulting in a data set of 88 banks.[10] The exposures on foreign banks have been divided into five geographical areas: Europe, North America, Turkey, Asia, and RoW (rest of world). Hence each bank has 92 $(88+5-1)$ possible counterparties. The interbank assets and liabilities are then divided over the matrix, following the structure of the large exposures data reports.[11] A problem with this approach is that some banks report limits, while other banks report outstandings. This would result in a bias in the estimation toward limit-reporting banks, because the limit amounts are much larger than the outstanding amounts. In our estimation we would then assign a too-high exposure to limit-reporting banks. To circumvent this problem, we express the large exposures data as a percentage of each bank's "total exposure." Here, the "total exposure" can be either total outstandings or the total of all limits. Then the percentage exposures are multiplied with the monthly report asset totals, giving exposure amounts. In the few cases where the large exposures data are missing (not all banks have to report), we use the distribution of interbank liabilities. In addition, because we do not want to allow a bank to have exposures on itself, we set the main diagonal to zero. For estimation purposes, all zeros in the matrix (i.e., a bank pair without a reported linkage) are replaced by a very small number (except for the main diagonal). This reflects

[9]We also estimated a maximum-entropy matrix without any prior information, but as these results are less informative, we do not present them here.

[10]For the foreign branches that do not report tier 1 capital, we use the mean tier 1 capital of a peer group.

[11]A formal explanation can be found in the appendix.

the many small linkages that banks may have but which fall below the reporting threshold and thus do not show up in the large exposures data. Because of this last assumption, banks have linkages with almost all other banks in the interbank-lending matrix, although the estimated exposures resulting from this assumption are small, as expected.

The percentage exposures on all foreign regions together vary between 0 percent and 100 percent of total exposures, where only a few foreign subsidiaries or branches show a 100 percent exposure. The exposure is particularly risky for such banks because the exposure is almost completely on a single foreign region (i.e., the home country, sometimes only the parent company). The average bank is exposed for about one-third (32.0 percent) of its interbank assets to foreign regions. The large banks are exposed to foreign regions by more than three-quarters (ranging between 72.6 percent and 84.6 percent) of their total exposure. The explanation for this higher average may lie in the fact that these banks do not consider the other Dutch banks as interesting counterparties. Of all regions, Europe accounts for most exposures, followed by North America.

Generally, large banks have significant relations with a smaller number of banks than do other banks.[12] The average exposure of a smaller bank to a large bank is about 28 percent of its total exposures, which we consider small in comparison with the market size of the larger banks. Strikingly, we find that foreign branches are mainly exposed to other Dutch banks (69.5 percent), while foreign subsidiaries show a higher dependency on foreign countries (table 5). From this estimated structure of interlinkages, we might deduce the existence of a two-tiered structure in the Dutch interbank market: the first tier consists of the large banks, which transact mainly with each other and with foreign (same-sized) counterparties, while the second tier consists of the remaining banks, which mainly transact with each other and to a certain extent with foreign counterparties. The two tiers are connected, but to a lesser extent than we would expect taking into account the dominance of the large banks in the interbank market.

[12]Since all banks are interlinked (because all zeros in the matrix are replaced by a small number), a threshold value is set to measure the relative number of exposures.

Table 5. Estimated Interbank-Lending Matrix: Large Exposures Data

% exposure of → *on*↓	Large Bank	Other Dutch	Foreign Subsidiary	Foreign Branch	Investment Firm	Mean
Foreign	78.8	20.5	47.2	20.3	22.1	32.0
Other Dutch	6.8	42.3	26.5	69.5	41.2	43.8
G4	14.4	37.3	26.5	10.1	36.6	24.3

Table 6. Estimated Interbank-Lending Matrix: Survey Data

% exposure of → *on*↓	Large Bank	Other Dutch	Foreign Subsidiary	Foreign Branch	Investment Firm	Mean
Foreign	90.3	19.1	45.5	15.6	18.7	29.9
Other Dutch	4.2	58.3	37.1	78.7	51.5	54.7
G4	5.5	22.7	17.4	5.6	29.8	15.4

The percentages shown in table 5 are the average exposures per type. Note that although the large banks are exposed only for 6.8 percent of their total exposures to other Dutch banks, the exposure in absolute amounts may well exceed the absolute amount of, for instance, the 42.3 percent of the exposure of "Other Dutch" to other Dutch banks.

4.1.2 Survey Data

In the second variant, the survey data obtained from the ten banks are used and substituted in the interbank-lending matrix. For the remaining banks, we continue to use the large exposures data. The percentage exposures of individual banks on the foreign regions vary between 0 percent and 100 percent of total exposures, where on average the exposure on foreign regions decreases slightly to 29.9 percent. For the large banks, however, the exposures on foreign regions have increased for all four banks (now ranging between 76.3 percent and 99.8 percent). In general, the exposures of the large banks are less dispersed over the Dutch system and are concentrated on foreign exposures (table 6). Europe remains the largest "single" exposure for Dutch banks, followed by North America. The remaining banks show a somewhat higher exposure to each other, which explains the decrease in the mean exposure on foreign regions and on the large banks. We again find a high exposure of foreign branches to other Dutch banks (78.7 percent). These figures also support our inference about the existence of a two-tiered structure in the Dutch interbank market. Moreover, the use of different data sources leads to only slightly different outcomes with respect to the characteristics of the Dutch interbank market.

4.2 Scenario Analyses

After estimating the interbank-lending matrix, we run a scenario analysis to reveal any possible contagion effects. In this analysis we let each bank (and region[13]) fail in turn and then check whether any of the other banks has an exposure on the failed bank that results in a loss larger than its tier 1 capital. A practical issue is that we do not have adequate information about the buffer capital of foreign counterparties or, in the aggregate, of regional financial systems. We assume that the foreign regions never fail as a result of the bankruptcy of other banks (or regions). This is plausible because these categories represent large regions, and it seems highly unlikely that a complete region will fail due to the failure of a (number of) Dutch bank(s). However, this assumption might underestimate the fragility of the Dutch system, as domestic defaults could trigger defaults abroad, which could in turn weaken institutions in the Netherlands. Second-round effects occur when other banks, following the failure of the first failed bank, also fail. It is assumed that if more than one bank fails in any given round, they all fail simultaneously.

Conclusions based on our scenario analyses have to be drawn with care. For example, the scenario analysis presented here does not allow for dynamic effects. The large exposures data reports are not complete and make use of risk limits, which in practice are drawn upon to a varying degree. Banks will draw more of their credit line

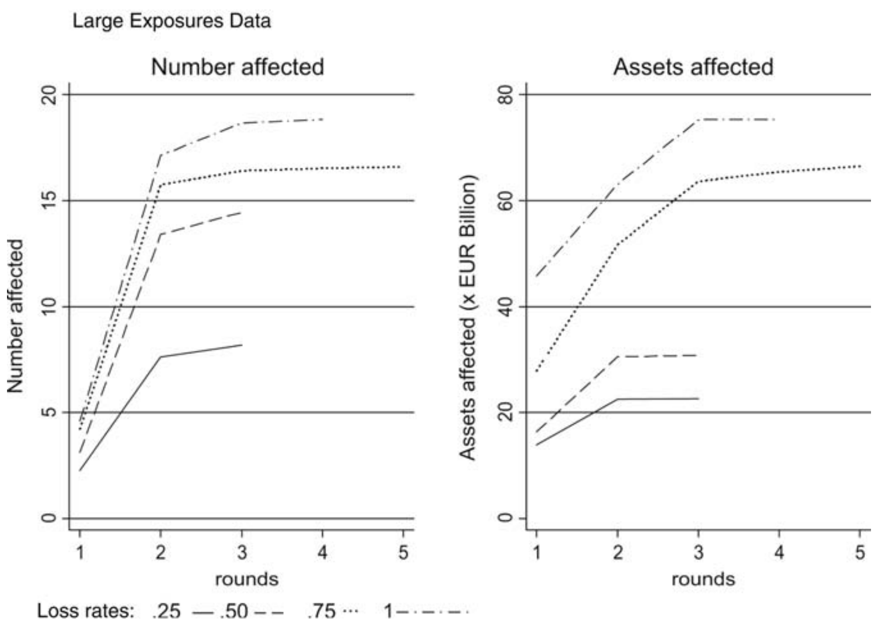
[13]This scenario can be described as an entire country running into trouble due to a domestic crisis, exchange rate crisis, excessive debts, etc.

in the interbank market if they experience problems; the risk limits thus give the upper bound to contagion risks in the interbank market. In addition, the use of outstandings might underestimate risks, since credit lines will be drawn in case of distress. The use of end-of-year data might underestimate risks as well, because interbank assets and liabilities tend to decrease in December every year. The lack of data on tier 1 capital for foreign branches forces further assumptions. Furthermore, the role of collateral has not been included in this analysis. The same remarks hold for the survey data analysis. In addition, the data reported by the ten banks in the survey data had to be standardized. Since the ten banks use different internal systems and definitions, their reports differ in their precision and may show some inconsistencies.

4.2.1 Large Exposures Data

The scenario analysis provides important insights into the contagion risks in the Dutch banking sector. Figure 2 gives an overview

Figure 2. Cumulative Effects of Simulated Failures



of the cumulative effects of a bank failure (including the failure of a region) for each loss rate by round. The left panel shows the mean of the cumulative number of failed banks per round and per loss rate, while the right panel shows the mean of the cumulative assets of these failed banks per round and per loss rate. The first, initiating bank is excluded in these measures. Note that "assets affected" is defined as the total assets of failed banks. This implies that although a bank may suffer losses following a bankruptcy, these losses are not included in the measure of assets affected if the bank does not fail consequently. However, such a small loss makes the bank in question more vulnerable for any other losses it may incur in future rounds. For both graphs it holds that the cumulative effects increase when the loss rate is increased. For a 75 percent loss rate, however, there are more rounds (i.e., five). The explanation for this result is that for the higher loss rate (100 percent), all banks that *can* be affected *are* already affected in previous rounds. Hence, no banks are left to be affected.

The steep rise in the second round in the left panel indicates that a large number of banks fail in this round. The rise in the right panel is much less pronounced. From this, the picture emerges that a small number of sometimes large banks topple in the first round, followed by a larger number of small banks.[14] Then defaults taper off.

Table 7 confirms these results. It shows the maximum number of failed banks and affected assets per loss rate. For comparison purposes, we include the results of estimation without any prior information (labeled "Maximum Entropy"). The maximum-entropy estimation shows that only with a loss rate of 100 percent are sizable losses incurred. Moreover, the maximum-entropy estimation results underestimate contagion effects, in line with Mistrulli (2005), as both the number of banks and the percentages of total assets are lower for each of the loss rates shown. The only exception is the 100 percent loss rate: it is clear that the maximum-entropy method does not function for the highly concentrated and internationalized Dutch market.

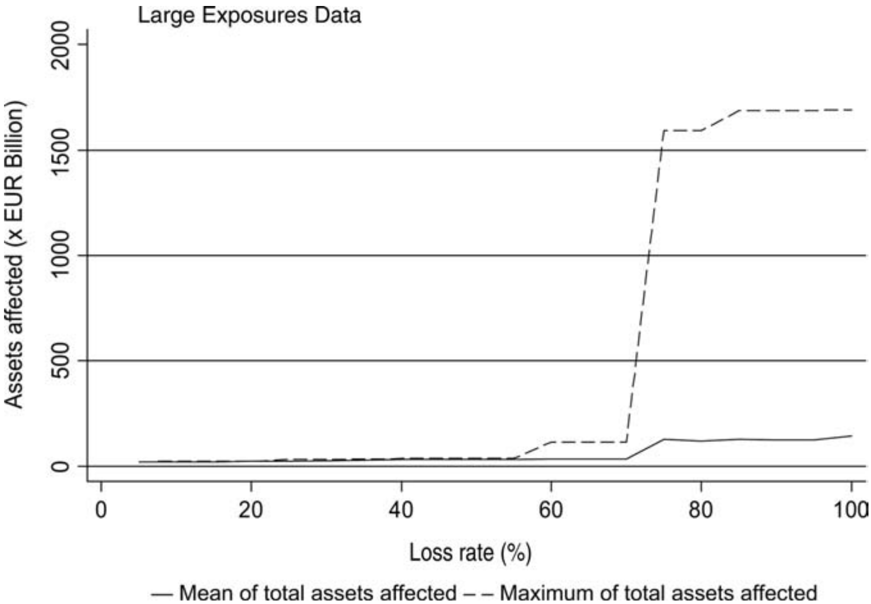
[14] Although it is tempting to think of these rounds as indicating something about time, this is not appropriate. Rather, it reflects how "close" two banks are.

Table 7. Effects of Simulated Failures: Large Exposures Data

	Maximum Entropy			Large Exposures Data					
	Max. Number of Failed Banks	Max. Amount of Affected Assets		Max. Number of Failed Banks	Max. Amount of Affected Assets		Max. Number of Failed Banks (excl. foreign regions)	Max. Amount of Affected Assets (excl. foreign regions)	
Loss Rate		billions of euro	% total assets		billions of euro	% total assets		billions of euro	% total assets
0.25	10	24	1%	11	30	2%	11	24	1%
0.50	18	33	2%	20	37	2%	17	34	2%
0.75	30	46	3%	47	1,590	90%	21	43	2%
1.00	66	1,340	76%	56	1,690	96%	24	44	3%

Note: For the maximum-entropy estimations, the results are the same whether foreign regions are included or not.

Figure 3. Effects of the Loss Rate on Total Assets Affected



Note: In this graph, the effects of and on foreign regions have been excluded.

Strikingly, for the large exposures data, the asset losses increase sharply for a 75 percent loss rate. In this case, the total assets lost as a percentage of total assets increases from 2 percent to 90 percent. However, this only holds if foreign regions are included in the analysis. The large banks do not fail if the foreign regions are excluded, meaning that the results are driven by the failure of the large banks. Consequently, we might find a turning point at which (one of) the large banks fail(s). This is shown in figure 3. In this figure we graph the mean and maximum amount of total affected assets relative to the loss rate. We clearly see a rise in the mean and a sharp increase in the maximum of total affected assets for a 75 percent loss rate. At this rate, three large banks fail for the first time. The fourth large bank already failed at a 60 percent loss rate. This is also visible in the maximum amount of affected total assets in the figure. From this figure, we might conclude that for a loss rate below 75 percent, no systemic risk emerges.

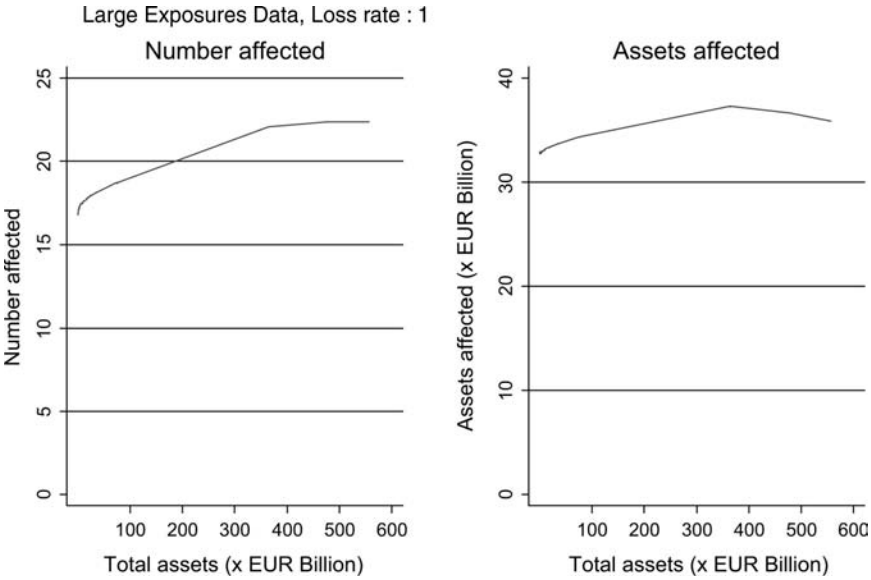
The large banks only affect a relatively small number of banks (at most, twenty-four), with low asset losses. Although the failure of a large bank may result in the bankruptcy of at least one bank of all other types, the failure of a large bank does not affect any of the other large banks. The large banks themselves only fail if either the region Europe or North America fails. In contrast to our expectations, foreign subsidiaries and branches show no explicit vulnerability to the failure of other foreign subsidiaries, branches, or foreign regions but are equally exposed to all types.[15] Investment firms are exposed to all banks.

The region Europe turns out to be the largest risk for the Dutch banking sector, resulting in the highest number of fallen banks and the highest losses in terms of assets. This is intuitive, given the interbank-lending matrix, which showed that many banks have large exposures to Europe. The failure of North America or Asia affects the sector during four rounds, while the effects of a failure of Turkey and RoW only last three rounds. Asset losses are largest for Europe (€1,690 billion) when, at most, fifty-six banks fail. All large banks fail if Europe goes bankrupt with a 75 percent and 100 percent loss rate. If the region North America fails, thirty-four banks fail, and asset losses amount to €680 billion. Fewer and smaller banks fail following the simulated failure of Turkey (twenty-four banks, €40 billion), Asia (twenty-six banks, €40 billion), or RoW (eighteen banks, €35 billion).

In figure 4, the effects of a failure on the domestic number and assets affected are graphed relative to the size of the bank that first bankrupted, for a loss rate of 100 percent. The largest amount of assets lost (€44 billion) is larger than the mean total assets of the other Dutch banks (€10 billion) but many times smaller than the mean total assets of the large banks (€370 billion). Note that the assets of the first bankrupted bank are not included in this measure. Except for the foreign regions, the failure of one of the large banks or a foreign subsidiary has the largest impact on the domestic banking system. There is, however, no substantial evidence that larger banks have higher contagion effects on the domestic system.

[15]The parent company may guarantee its foreign subsidiary or branch, for which counterparties consequently will not experience credit losses. This is not taken into account here.

Figure 4. Effects of Size on Number and Total Assets Affected



Note: In these graphs, the effects of and on foreign regions have been excluded.

Although the failure of a large bank leads to the highest *number* of bank failures if foreign regions are excluded from our analysis, the failure of a relatively small bank, a foreign subsidiary, leads to the highest domestic *asset losses*. Furthermore, the failure of a type 2 bank ("Other Dutch") also has a large effect on the number of failed banks and on the amount of assets lost. An explanation for this result might be that the large banks are especially linked to foreign regions and, to a much lesser extent, to the other banks in the Dutch banking system. Because of this, the effects of a failure of a large bank are mainly absorbed by the foreign regions and can affect the Dutch banks only to a lesser extent. However, since we have no information on foreign banks' assets or capital, the effects of a domestic failure on foreign regions are not shown in figure 4. Given the fact that the large banks are strongly connected to foreign regions, the effects of a domestic failure on foreign regions could be substantial, which, in turn, may have repercussions on the Dutch sector.

Although the results from the first scenario analysis generally confirm expectations, they do show some surprises. The large banks affect a considerable, but still limited, number of banks. Shocks resulting from the failure of a large bank are for a large (but not complete) part absorbed by the foreign regions. This is logical in light of the large foreign exposures held by the large banks, as shown by the interbank-lending matrix. Surprisingly, the bankruptcy of one of the foreign banks in the Dutch banking system results in a high(er) level of lost assets. On the other hand, all these risks are run at a loss rate of 100 percent, whereas losses are many times smaller for lower loss rates. The 100 percent loss rate seems rather high.[16] Europe as a whole does represent a systemic risk, however.

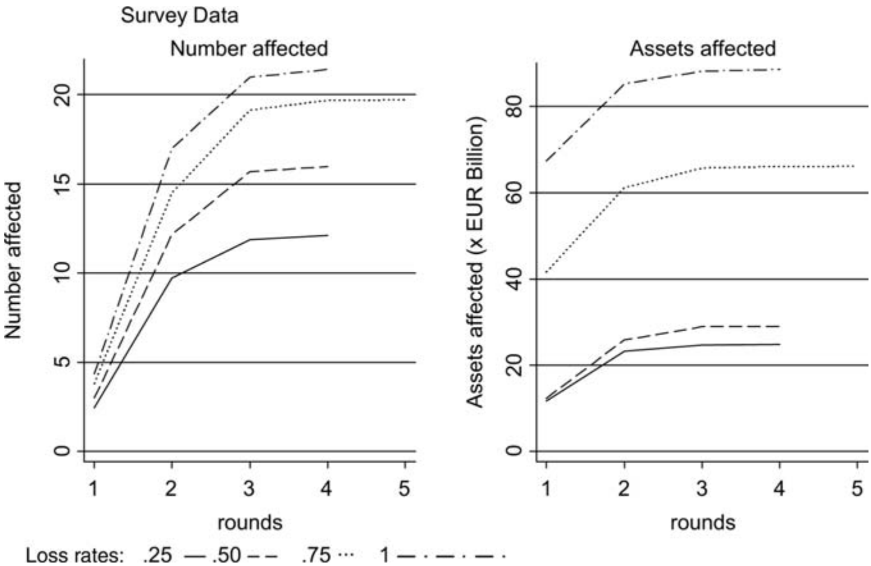
4.2.2 Survey Data

In this section we discuss the scenario using the interbank-lending matrix incorporating the survey data. Similarly to the previous analysis, this scenario analysis shows that a higher loss rate results in higher cumulative losses in terms of the number of fallen banks and assets lost (figure 5). On average, though, the effects are larger for all loss rates. In this analysis we find that a simulated failure with a 75 percent loss rate again has longer-lasting effects than for the 100 percent loss rate. First-round effects are, only with respect to the assets lost, largest for all loss rates. This does not hold for the number of failed banks, however, where the number of failed banks increases in the second round. From this we come to the same conclusion as before: a limited number of sometimes large(r) banks fail in the first round, while many smaller banks follow in later rounds.

Table 8 shows, again, that losses increase sharply for a loss rate of 75 percent. However, these losses are lower than in the previous analysis. The percentage of assets lost now amounts to 45 percent for a 75 percent loss rate and to “only” 73 percent for a complete loss. Again, this can be explained by the interbank-lending matrix used for this analysis and shown in table 6. It showed that only the large banks increased their exposure on foreign regions, while all other banks decreased their interbank positions to foreign regions.

[16] See footnote 4.

Figure 5. Cumulative Effects of Simulated Failures



Note: In these graphs, the effects of and on foreign regions have been excluded.

Therefore, the total amount of assets that can possibly be affected if one of these regions fails is lower. If the foreign regions are excluded, losses are limited but higher than before. In this scenario analysis, a turning point exists at which the large banks fail as well.

If Europe, North America, and RoW are excluded, a failure of one of the large banks affects the highest number of banks and results in the highest asset losses. Strikingly, only a few other Dutch banks (type "Other Dutch") fail following the bankruptcy of one of the large banks (at most, five per large bank). The large banks themselves only fail following the failure of Europe or North America at a 75 percent or 100 percent loss rate or following the failure of RoW at a 100 percent loss rate. The risks that many subsidiaries with Turkish parents run on their home country is reflected by the fact that only Turkish subsidiaries fail if the region Turkey goes bankrupt.

Again, Europe and North America influence the results the most. The influence of the large banks seems to be somewhat larger,

Table 8. Effects of Simulated Failures: Survey Data

Loss Rate	Maximum Number of Failed Banks	Maximum Amount of Affected Assets		Maximum Number of Failed Banks (excluding foreign regions)	Maximum Amount of Affected Assets (excluding foreign regions)	
		billions of euro	% total assets		billions of euro	% total assets
0.25	17	35	2%	17	35	2%
0.50	21	47	3%	21	47	3%
0.75	36	794	45%	24	111	6%
1.00	45	1,290	73%	29	125	7%

though, than in the previous analysis. The effects of a failure of the other types—i.e., other Dutch banks, foreign subsidiaries, branches, and investment firms—have also increased. Foreign subsidiaries have larger effects on the assets affected than do other Dutch banks.

If the effects of the different foreign regions are analyzed, it becomes clear that Europe, North America, and RoW are the main risks for the Dutch banking sector. If Europe fails, the highest number of banks fails (forty-five) and the largest amount of assets is lost (€1,290 billion). A simulated failure of the North American region results in thirty failed banks, with asset losses of €480 billion. If Asia fails, a maximum of twenty-eight banks fail, with asset losses of €41 billion. In total, thirty banks fail if RoW goes bankrupt, with asset losses of €516 billion. A failure of Turkey does not lead to large contagion risks: a maximum of six banks fail, and only first-round effects result. Furthermore, all of the failed banks in this case are foreign subsidiaries with the parent company in this particular region.

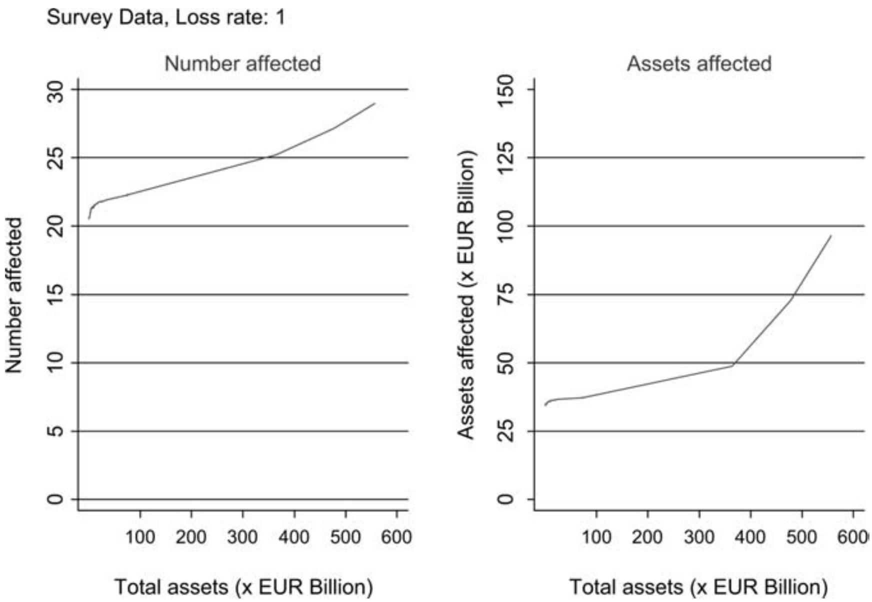
The asset size of the first failed bank still seems unrelated to the number of failed banks and the total assets lost in the domestic banking system in the scenario analysis. Although figure 6 shows an upward-sloping line, this result is triggered by a single data point. Total asset losses (€125 billion) in this scenario analysis are many times larger, though, than in the previous analysis and are a significant part of the mean total assets of the large banks. The effects of a failure on foreign banks are, again, not included in figure 6.

Similarly to the previous analysis, the main threat for the Dutch banking sector stems from abroad. The foreign regions, especially Europe, represent the riskiest counterparties in the case of failure. The large banks only affect a limited number of banks, though, resulting in higher asset losses this time. Again, there are some surprises in the form of smaller banks that affect a large number of banks with high asset losses.

4.3 Large Exposures Data versus Survey Data

In the discussion of the outcomes using either the large exposures data or survey data, it was already apparent that the results are qualitatively similar: large, systemically important banks have a sizable impact but do not infect the entire system. Looking at the

Figure 6. Effects of Size on Number and Total Assets Affected



Note: In these graphs, the effects of and on foreign regions have been excluded.

regions, we see that especially the region Europe is important as a possible source of contagion.

In addition to this qualitative assessment, we inspected the underlying estimated exposure matrices. For each individual bank the range, mean, and median are all very similar. We also looked at the distribution of percentage differences between the large exposures data and the survey data, but interpretation is difficult because (i) it is not clear which of the matrices is the true matrix, and (ii) the tails of the distributions are mainly driven by percentage changes in bank exposure pairs that are very small.

Summarizing, we find that the commonly used large exposures data seem to provide a similar picture of the interbank market characteristics and of contagion effects compared to the survey data we obtained. This can be interpreted as a validation of the approach used in previous studies.

5. Conclusions

The most important risks in the Dutch interbank market stem from exposures on foreign counterparties—in particular, European and North American counterparties. This result holds regardless of the information source used. The national interbank market only seems to carry systemic risks if a large bank fails, although even in this extreme and unlikely event, not all of the remaining banks are affected. In fact, none of the large bank failures trigger the failure of another large bank. The Dutch banking system hence cannot be pictured as one *single* line of dominoes, and the amounts outstanding per counterparty are small (losses are limited). The linkages between the large banks and the foreign regions seem to prevent large(r) negative effects from spreading further into the Dutch market.

This conclusion points to the largest risk for Dutch banks: the foreign regions. Many banks have exposures on the foreign regions. Therefore, if problems arise in one of these regions, then all types of banks will be severely hit. In particular, foreign subsidiaries and/or branches are vulnerable to shocks originating in the parent-company region. However, the indirect effects the failure of a foreign bank may have on the Dutch banking sector are not included in this analysis. Furthermore, it has to be borne in mind, on the one hand, that the foreign regions are aggregated accounts. Each foreign region is formed by summing all exposures to counterparties in that particular region. It is hard to imagine that a region (i.e., all the counterparties within it) could go bankrupt as a whole. On the other hand, examples such as the Asia crisis or the recession following September 11, 2001, point out that we cannot exclude such a scenario. Overall, interbank exposures across countries may form an important link between banks, resulting in considerable possible systemic risks. This will also hold for other small open economies.

Our analysis also shows that maximum entropy is not appropriate for estimating bilateral exposures in a concentrated market, such as the Dutch, the Belgian, or the Swiss market. In addition, for an accurate assessment of the risks in the interbank market, there is not a clear advantage in using either the large exposures data report or survey data. Both data sources give an adequate and similar overview of the risks in the interbank market. At the individual bank level, however, there are important differences. Working from the premise that the survey data are a more reliable source of information, since they have been specially requested, this implies that the large exposures data reports are not well suited for monitoring the interbank exposures of a particular bank. However, for estimates of contagion effects at the macro level, the large exposures data form an appropriate (and easier) data source.

The most important conclusion, based on the research presented, is that in order to improve the informativeness of the analyses, information about foreign exposures is necessary. Other studies in this area suffer from the same issue. In an increasingly integrated market like the interbank market, it might therefore be fruitful to merge the various analyses.

Appendix. Cross-Entropy Minimization

The minimization problem can be formally written as

$$\min \sum_{i=l}^{N} \sum_{j=l}^{N} x_{ij} \ln \left(\frac{x_{ij}}{x_{ij}^{0}} \right) \tag{3}$$

subject to

$$\sum_{j=l}^{N} x_{ij} = a_i \tag{4}$$

$$\sum_{i=l}^{N} x_{ij} = l_j \tag{5}$$

$$x_{ij} \geq 0, \tag{6}$$

with the conventions that $x_{ij} = 0$ if and only if $x_{ij}^{0} = 0$ and $\ln(0/0) = 0$. The RAS algorithm solves this type of problem (Wells 2004).[17]

Using the large exposures data, this becomes

$$x_{ij}^{0,I} = \begin{cases} 0 & \text{if } i = j \\ \frac{E_{ij}}{\sum_{J=l}^{N} E_{ij}} a_i & \text{if bank } i \text{ reports an exposure to bank } j \text{ in the large exposures data,} \end{cases} \tag{7}$$

[17] See Blien and Graef (1997) for an extended explanation of the RAS algorithm or refer to Censor and Zenios (1997) for more information.

where E_{ij} represents the exposure of bank i to bank j as reported in the large exposures data.

Using the survey data together with the large exposures data in the second part of the research, this becomes

$$x_{ij}^{0,II} = \begin{cases} 0 & \text{if } i = j \\ \frac{R_{ij}}{\sum_{J=l}^{N} R_{ij}} a_i & \text{if bank } i \text{ reports an exposure to bank } j \text{ in the survey data} \\ \frac{E_{ij}}{\sum_{J=l}^{N} E_{ij}} a_i & \text{otherwise,} \end{cases} \quad (8)$$

where R_{ij} reflects the exposure of bank i to bank j as reported in the survey data.

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