Measuring Bank Contagion Using Market Data

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Introduction

In this paper, we suggest an approach for measuring contagion across banks, and we outline preliminary results for the European banking sector. Information on contagion is crucial for authorities addressing risks to financial stability. Information on cross-border contagion, i.e., the extent to which European banking systems have become interconnected, is also critical. The introduction of the euro and the emergence of common wholesale interbank markets can be expected to increase the risk of cross-border contagion.

When we use the term "contagion," we are referring to the transmission of an idiosyncratic shock that affects one bank or possibly a group of banks, and how this shock is transmitted to other banks or banking sectors. Defined in this way, contagion is a subset of the broader concept of systemic crisis, which may result from contagion or from a common shock affecting all banks simultaneously.

The theoretical literature on banking has focused on contagion among banks via the interbank market. Allen and Gale (2000) show that in a Diamond and Dybvig (1983) liquidity framework, an "incomplete" market structure, with only unilateral exposure chains across banks, is the most vulnerable to

* The authors wish to thank Steffen Sørensen, Isabella Bosetti, and Sandrine Corvoisier for expeditious research assistance.

contagion. In contrast, a "complete" structure, with banks transacting with all other banks, poses less risk.[1] A "tiered structure" of a "money-centre" bank (or banks), where all banks deal with the centre bank, but not with one another, is also susceptible to contagion (Freixas, Parigi, and Rochet 2000). In both papers, contagion arises from unforeseen liquidity shocks, i.e., banks withdrawing interbank deposits at other banks. Alternatively, contagion could arise from credit risk in the interbank market, namely, deposits at other banks not being repaid. In the financial markets literature, most authors have stressed that contagion may also exist in the absence of explicit links. In the presence of asymmetric information on markets, difficulties in one market may be perceived as a signal of possible difficulties in others. The same consideration could apply to banks (e.g., Freixas, Parigi, and Rochet 2000), especially if one thinks that bank assets may be opaque and that balance-sheet data and other publicly available information may be uninformative.

Since bank-level data on bilateral interbank exposures are not readily available,[2] few empirical studies have examined direct exposures among banks and analyzed the effect of one bank failure on the liquidity and solvency of other banks. Using data on individual bank bilateral exposures in the Federal Funds market, Furfine (1999) finds limited evidence of contagion via direct interbank exposures. However, the Federal Funds market accounts for only 10 to 20 per cent of total interbank exposures in the United States. Sheldon and Maurer (1998) build a matrix of bilateral exposures, using interbank loans for Swiss banks. They find that the structure of the interbank market poses little threat to the stability of the Swiss banking system. In a similar fashion, Upper and Worms (2002) estimate a matrix of interbank loans for German banks and find evidence of contagion risk. The failure of a single large bank could lead to a breakdown of up to 15 per cent of the German banking system in terms of total assets. Degryse and Nguyen (2004) examine interbank exposure data from 1993 to 2002 for the Belgian banking system. They find that the patterns of linkages changed from a structure with complete links among banks to one with multiple money-centre banks. Overall, their results suggest a decrease in the risk of contagion.

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1. The intuition is that in the case of an "incomplete" market, the effects of a shock hitting one bank are concentrated, while in the case of a "complete" market, the shock is distributed among a large number of banks and, thus, can be more easily absorbed.
2. To our knowledge, the Sveriges Riksbank (Swedish central bank) is the only central bank that regularly publishes bilateral interbank exposures within the Swedish banking sector in its financial stability report.

Two other techniques were featured in the previous empirical literature on bank contagion. First, evidence of contagion was estimated with autocorrelation and survival time tests using historical data on bank failures. A number of papers have tested for autocorrelation in bank failures, controlling for macroeconomic conditions, generally in historical samples where bank failures were common in the United States.[3] Most of these studies find evidence of contagion, i.e., bank failures tend to be autocorrelated, controlling for macro variables. Similarly, using survival time tests, Calomiris and Mason (2000) find that bank-level, regional, and national fundamentals can explain a large portion of the probability of survival of banks during the Great Depression. They also find evidence of contagion, which, however, is limited to specific regions of the United States. Both approaches are inherently limited to times of widespread bank failures.

1 Identifying Contagion from Market Data

We attempt to identify contagion among banks using the distance to default, which is our preferred measure of default risk for banks.[4] With this approach, we do not take a specific view on the channel of contagion (such as the interbank market); rather, we use the innovations in this comprehensive risk measure.

Econometrically, our approach builds on recent papers by Bae, Karolyi, and Stulz (2003), who use a similar methodology to study contagion among stock market returns in emerging markets, and by Gropp and Moerman (2004), who examine the tail properties of banks' distance to default. Gropp and Moerman use the coincidence of extreme shocks in banks' distance to default to examine contagion. Both studies conclude that it may be justified to examine only the tails of the distribution (the distance to default or, in Bae, Karolyi, and Stultz (2003), equity returns) when addressing contagion.

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3. See De Bandt and Hartmann (2001) for a survey.

4. Gropp, Vesala, and Vulpes (2004) argue, specifically with respect to banks, that the distance to default may be a suitable and all-encompassing measure of default risk. In particular, its ability to measure default risk correctly is not affected by the potential incentives of the stockholders to prefer increased risk taking (unlike, e.g., the case of unadjusted equity returns) or by the presence of explicit or implicit safety nets (unlike subordinated debt spreads). Furthermore, distance to default combines information about stock returns with leverage and volatility information, thus encompassing the most important determinants of default risk (unlike unadjusted stock returns, for example). The distance to default is the basic ingredient in the Moody's KMV EDF risk metric. (KMV Corporation 1999)

We identify contagion in the negative extreme movements in bank default risk, measured through the distance to default. These events can be identified from the negative tail of the distribution of the innovations in the distance to default.

Any bank can be in the tail of the distribution if (i) it is hit by an idiosyncratic shock; (ii) there is a common shock affecting more than one bank simultaneously; or (iii) another bank (or group of banks) is hit by an idiosyncratic shock and the shock spills over to other banks.

Consequently, the empirical identification of contagion from systemic problems generated by common shocks depends crucially on the ability to control for common shocks as accurately as possible. More precisely, the probability of experiencing a large shock (e.g., 95th or 99th percentile of the distribution in the innovations in the distance to default) can be modelled as a function of variables capturing common sources of credit risk, market risks, and earnings risk, and as an indicator of other banks experiencing negative tail events at the same time. The last variables should give us an indication of the degree of contagion, in the spirit of Bae, Karolyi, and Stultz.

Since it is orthogonal to other banks being in the tail concurrently, idiosyncratic risk would be subsumed in the error term. However, the bank's degree of vulnerability may matter for the probability that a common shock affecting more than one bank will result in a large enough effect on the distance to default of the bank that it is, in fact, in the tail of the distribution. Financially strong banks would have buffers to withstand common shocks without a large effect on their default probability. The same applies to contagion: strong banks are better able to absorb credit losses from their interbank exposures, for instance. This suggests to interact the variables measuring the sources of common shocks and contagion with the degree of vulnerability of the bank.

2 Data on European Banks

To obtain our first results on contagion, we used available weekly data for the period January 1991 to January 2003 for a sample of 67 EU banks. We first calculated the distance to default for each bank in the sample and for each time period, *t*, using that period's equity market data and the same time period balance-sheet data. We then fixed extreme events arbitrarily at the 99 per cent and 95 per cent negative tails of the distribution of $(\Delta dd_{it}/|dd_{it}|)$. The 99 per cent tail is interesting to look at for identifying contagious influences from major negative shocks to banks. However, the 95 per cent tail gives us more events for a broader and statistically more reliable account of the contagious linkages across EU banks. The 95 per cent specification guarantees an adequate number of tail events for banks from all countries.

The mean of the first difference in the distance to default is approximately zero, and the largest negative change is about 4, which can be considered a sizable weekly shock (Table 1). For the relative changes we used in defining the tail events, this corresponds to the maximum weekly shock of 76 per cent.

In Table 2, we report the number of times banks are in the tails at the same time, depending on whether the banks are from the same country. This number represents the count of the coincidences of the tail events within and across countries. When the 95 per cent critical value is used, the number of domestic coincidences of negative shocks ranges from 4 (Finland) to 383 (Italy); the count for Belgium is zero, since there is only one Belgian bank in the sample. The number of cross-country coincidences ranges from 22 (Belgium) to 422 (Italy). The large number of coincidences with Italian banks can be explained by the fact that Italy has the largest number of banks in our sample. The numbers of coincidences are, of course, smaller for the 99 per cent tail events, but these coincidences still occur in our sample (note that in addition to Belgium, there are no domestic coincidences for Denmark and Finland).

The average number of domestic banks in the tail at the same time as a foreign bank is experiencing a tail event is 0.35 in case of the 95 per cent tail events. The average number of foreign banks is 2.7 (or 0.2 per country). There is significant variation by country, however. Table 3 presents the average number of other banks experiencing a tail event by countries when a single bank experiences such an event, for the negative 95 per cent tail events. The table provides the average number of banks by countries when, for example, a German bank is in the tail of the $(\Delta dd_{it}/|dd_{it}|)$ distribution. The positive averages suggest that there are events of coincidence of tail events by all country pairs. The above indications do not, however, present evidence of significant contagion, since these patterns could also be the result of common shocks.

3 Preliminary Evidence of Domestic and Cross-Border Contagion

Our preliminary evidence reveals the significance of both domestic and cross-border contagion. As noted, the reliability of these results depends on the ability to control for common shocks, which also influence the probability of banks experiencing a tail event in addition to contagion from

Table 1
Statistics on distance to default of 67 EU banks
January 1991 to January 2003

	Mean	Min.	Max.	Std. dev.	Lower 99% tail	Lower 95% tail	Upper 95% tail	Upper 99% tail
Dd	4.03	–0.29	17.11	1.88	1.383	2.106	7.702	6.687
Δdd	–0.001	–3.97	6.69	0.15	–0.347	–0.123	0.121	0.070
$\Delta dd_{it}/\lvert dd_{it}\rvert$	–0.76	2.50	0.049	–0.073	–0.029	0.029	0.073	
Number of observations	576	351	628	77.0				

Table 2
Total number of coincidences by countries
January 1991 to January 2003

	Lower 99% critical value		Lower 95% critical value	
	Number of "coincidences" with banks from the same country	Number of "coincidences" with banks from the other countries	Number of "coincidences" with banks from the same country	Number of "coincidences" with banks from the other countries
Germany	28	23	164	236
France	4	6	48	90
Netherlands	4	15	43	95
United Kingdom	17	19	169	251
Spain	17	18	118	208
Italy	58	45	363	422
Denmark	0	6	26	49
Belgium	0	4	0	22
Austria	4	7	8	36
Sweden	8	7	28	62
Ireland	3	7	25	53
Portugal	10	15	51	97
Finland	0	2	4	38
Greece	2	2	24	47

Table 3
Average number of other banks experiencing a tail event by countries when a bank is in the tail (coincidences), lower 95% critical value

	Germany	France	NL	UK	Spain	Italy	Denmark	Belgium	Austria	Sweden	Ireland	Portugal	Finland	Greece
Germany	1.84	1.55	1.72	1.14	1.21	1.29	1.34	1.83	1.56	1.45	1.89	1.47	0.75	0.65
France	0.57	0.77	0.62	0.49	0.46	0.47	0.46	0.87	0.32	0.59	0.91	0.45	0.42	0.29
Netherlands (NL)	0.66	0.65	0.59	0.54	0.40	0.54	0.44	0.87	0.39	0.61	0.81	0.64	0.29	0.27
United Kingdom (UK)	1.26	1.48	1.56	1.63	1.01	1.22	0.92	1.57	1.05	1.27	2.11	1.36	0.88	0.90
Spain	1.07	1.13	0.93	0.81	1.01	0.86	1.24	1.04	1.10	0.99	1.33	1.01	1.04	0.49
Italy	2.51	2.51	2.73	2.16	1.89	3.22	2.07	2.57	1.73	1.97	3.11	2.78	1.65	1.49
Denmark	0.31	0.29	0.26	0.19	0.32	0.24	0.44	0.22	0.32	0.41	0.44	0.22	0.21	0.06
Belgium	0.16	0.21	0.20	0.13	0.11	0.12	0.08	0.00	0.02	0.13	0.26	0.13	0.06	0.10
Austria	0.25	0.14	0.16	0.15	0.20	0.14	0.22	0.04	0.20	0.14	0.23	0.21	0.21	0.06
Sweden	0.40	0.45	0.43	0.32	0.31	0.28	0.49	0.39	0.24	0.39	0.56	0.28	0.25	0.18
Ireland	0.42	0.55	0.46	0.42	0.33	0.35	0.42	0.65	0.32	0.45	0.60	0.37	0.42	0.29
Portugal	0.62	0.52	0.71	0.52	0.48	0.60	0.42	0.61	0.56	0.42	0.70	0.81	0.40	0.41
Finland	0.14	0.21	0.14	0.15	0.22	0.16	0.17	0.13	0.24	0.17	0.35	0.17	0.08	0.10
Greece	0.13	0.16	0.14	0.16	0.11	0.15	0.05	0.22	0.07	0.13	0.26	0.19	0.10	0.47

other banks. For the results below, we used standard macro variables, such as GDP growth, interest rates, and inflation, to control for common shocks.

The main result is that domestic contagion is more prevalent and quantitatively more significant than cross-border contagion. However, cross-border contagion is also found to be significant and relevant. There is evidence of increased relevance of cross-border contagion after the introduction of the euro. This would suggest that there is an important pan-European dimension in the monitoring of systemic risk.

The risk of domestic contagion is always found to be significant in our preliminary estimation results (Table 4). We are also able to identify country pairs where contagion appears significant—U.K. and Dutch, French and Spanish, German and Austrian, and Danish and Swedish banks seem to have significant "two-way" contagion. Somewhat surprisingly, perhaps, French, German, and Dutch banks have significant contagious influences in both directions with Swedish banks. This could reflect the important central European operations of Swedish banks. Prima facie, the findings of the links between Finnish and Irish, and Finnish and Spanish banks are somewhat puzzling. We also found evidence of "one-way" contagion: the Belgian bank is found to be contagious to French banks, French and U.K. banks to Irish banks, French banks to U.K. banks, and German banks to Dutch banks.

Further analysis indicates that contagion appears to be influenced by strong interbank links, which we measured through country-level aggregated interbank data collected at the ECB. Surprisingly, German banks seemed relatively less contagious across borders than banks from major countries, even though they are apparently significant "money-centre" banks in the euro area. We found evidence that this could be due to a much higher dispersion of German bank interbank operations by countries compared with banks from other countries.

Finally, we found that the smallest banks in our sample are not able to cause cross-border contagion, while they tend to be more contagious domestically. Also, smaller banks in our sample (which are still quite large) are less likely to suffer from cross-border contagion. All banks appear equally likely to experience domestic contagion. These findings are in line with a "tiered" interbank structure at the cross-border level, such that small banks deal only with domestic counterparts, leaving foreign operations to major international banks. All in all, therefore, our contagion results could be broadly consistent with the patterns of interbank trading in Europe (i.e., with weakly dispersed or "incomplete" interbank links, and a "tiered structure" at the international level). This consistency increases our confidence in the results. And the results also appear consistent with the "money-centre" role of German banks.

Table 4
Emerging patterns of significant contagion

Contagion "to" / **Contagion "from"**	**GE**	**FR**	**NL**	**UK**	**SP**	**IT**	**DK**	**AU**	**SW**	**IR**	**PT**	**FI**	**GR**
Germany (GE)													
France (FR)													
Netherlands (NL)													
United Kingdom (UK)													
Spain (SP)													
Italy (IT)													
Denmark (DK)													
Austria (AU)													
Sweden (SW)													
Ireland (IR)													
Portugal (PT)													
Finland (FI)													
Greece (GR)													
Belgium													

References

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

Bae, K.-H., G.A. Karolyi, and R.M. Stulz. 2003. "A New Approach to Measuring Financial Contagion." *Review of Financial Studies* 16 (13): 717–63.

Calomiris, C.W. and J.R. Mason. 2000. "Causes of U.S. Bank Distress During the Depression." National Bureau of Economic Research Working Paper No. 7919.

De Bandt, O. and P. Hartmann. 2001. "Systemic Risk in Banking: A Survey." In *Financial Crisis, Contagion, and the Lender of Last Resort: A Reader*, edited by C. Goodhart and G. Illing, Part III, 249–98. London: Oxford University Press.

Degryse, H. and G. Nguyen. 2004. "Interbank Exposures: An Empirical Estimation of Systemic Risk in the Belgian Banking Sector." Central Bank of Belgium. Photocopy.

Diamond, D.W. and P.H. Dybvig. 1983. "Bank Runs, Deposit Insurance, and Liquidity." *Journal of Political Economy* 9 (3): 401–19.

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

Furfine, C.H. 1999. "Interbank Exposures: Quantifying the Risk of Contagion." Bank for International Settlements Working Paper No. 70.

Gropp, R. and G. Moerman. 2004. "Measurement of Contagion in Banks' Equity Prices." *Journal of International Money and Finance* 23 (3): 405–59.

Gropp, R., J. Vesala, and G. Vulpes. 2004. "Market Indicators, Bank Fragility, and Indirect Market Discipline." *Federal Reserve Bank of New York Policy Review.* Forthcoming.

KMV Corporation. 1999. *Modelling Risk*. San Francisco: KMV Corporation.

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

Upper, C. and A. Worms. 2002. "Estimating Bilateral Exposures in the German Interbank Market: Is There a Danger of Contagion?" Discussion Paper No. 09/02. Economic Research Centre. Deutsche Bundesbank.