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Contagion Risk in the International Banking System and Implications for London as a Global Financial Center

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Abstract

In this paper, we use the extreme value theory (EVT) framework to analyze contagion risk across the international banking system. We test for the likelihood that an extreme shock affecting a major, systemic U.K. bank would also affect another large local or foreign counterpart, and vice-versa. Our results reveal several key trends among major global banks: contagion risk among banks exhibits "home bias"; individual banks are affected differently by idiosyncratic shocks to their major counterparts; and banks are affected differently by common shocks to the real economy or financial markets. In general, bank soundness appears more susceptible to common (macro and market) shocks when the global environment is turbulent; this may have important implications for London as a major financial services and capital markets hub.

JEL Classification Numbers: C51, G21

Keywords: bank soundness, co-exceedance, contagion risk, distance-to-default, extreme value theory, LOGIT.

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I. Introduction

London is one of the world's biggest, and most open, financial centers. It dominates international financial market activity, and is also home and host to some of the biggest financial institutions in the world (Table 1). The financial sector in the United Kingdom offers a wide range of services, in areas such as asset management (hedge funds, mutual funds, and pension funds), banking (commercial, investment, and private banking), insurance and reinsurance, as well as access to key capital and commodity markets.[2] London is also a major trading center for commodities.[3]

Table 1. Market Share of Major Financial Centers
(In percent of global total)

	France	Japan	Germany	U.K.	U.S.	Others
Cross-border bank lending (March 2005)	8	8	11	20	9	44
Foreign equities turnover (January-September 2005)	..	..	3	43	31	23
Foreign exchange turnover (April 2004)	3	8	5	31	19	34
Derivatives turnover						
(i) exchange traded (volume of contracts, 2004)	4	2	12	7	31	44
(ii) over-the-counter (April 2004)	10	3	3	43	24	17
International bonds (secondary market, 2004)	..	..	..	70	..	..
Fund management (as a source of funds, 2004)	5	12	4	8	45	26
Hedge fund assets (December, 2004)	2	1	..	20	69	8
Banking assets (December 2005)[1]	9	8	6	12	17	48
Stock market capitalization (December 2005)	4	20	3	8	46	18

Sources: HM Treasury; and IMF Staff Estimates.

1/ Assets of commercial banks.

The concentration of financial services and markets in one major hub clearly offers many advantages, to both market participants and the local economy. Market participants are able to access an abundance of skilled labor, service suppliers, and infrastructure. The ability to integrate the different types of financial activities within one location leads to greater efficiency and cost savings. It provides the critical mass for ongoing innovation and growth, and fosters activities conducive to increased risk transfer among market participants. In turn,

[2] The U.K. stock market is the world's third largest by capitalization (8 percent), behind New York and Tokyo. London is second only to New York in terms of foreign listings, with 330 foreign companies listed on the London Stock Exchange as at January 2006. The U.K. insurance industry is the largest in Europe and the third largest in the world. Moreover, London is the only center where each of the 20 largest international insurance and reinsurance in the world operates.

[3] Commodities are traded on the London Metal Exchange, the International Petroleum Exchange, and the London International Financial Futures and Options Exchange, which incorporates the London Commodity Exchange.

this contributes toward improving the liquidity, breadth and depth of financial markets, and attracting an increasingly diverse group of participants. It also provides the impetus for the growth of the necessary support businesses. The concentration of financial activities and the presence of large financial institutions create strong incentives for the authorities to ensure sound supervision and governance practices, as well as promulgate effective and efficient regulation. The main aim would be to ensure stability and growth in a key sector, which provides substantial spillover benefits to the rest of the economy.

The financial sector contributes significantly to the U.K. economy.[4] It has been the second-fastest growth sector over the 1992−2004 period, expanding by an average real rate of more than 5 percent per annum, or more than double the growth rate of the overall economy. The financial sector accounts for an estimated 70 billion of national output, or almost 7 percent of GDP. It has consistently made a positive contribution to the U.K.'s balance of payments, posting a surplus of almost £20 billion in 2004, from £5 billion in 1992. From a fiscal perspective, the financial sector provides 25 percent of corporate taxes, or £8 billion, to the U.K. government.[5]

However, London's role as a center for global finance also raises the possibility that it may be a potential source of major spillovers, or "contagion," in the global financial system. Here, we define "contagion" as the transmission of idiosyncratic shocks among financial institutions. The very high volume of transactions through the different segments of the financial sector in London, combined with the increasing inter-linkages across both the local and international financial systems, mean that shocks affecting one U.K. financial institution or market could be transmitted locally and overseas. Alternatively, shocks originating elsewhere could be channeled through London and result in spillovers affecting U.K. financial institutions and markets.

In particular, the banking sector in the United Kingdom—which is considered to be of key systemic importance for financial stability—represents a potentially important channel for contagion risk. It is the third-largest in the world by total assets. Several major U.K. banks are among the top 20 largest in the world, and are of systemic importance to the local economy; some of these banks have also expanded their operations internationally across several regions. Estimates by the British Bankers' Association suggest that close to 500 international banks have representation in London, and that more than half of U.K. banking sector assets is held by foreign banks.

Key to the debate is that banks have also become increasingly inter-twined with other segments of the financial sector, both locally and across countries. For instance, banks provide insurers with liquidity facilities to pay current claims, and letters of credit as evidence of their ability to pay future claims. The formation of bancassurance groups through the merger of banks with insurers is another example of cross-sector linkages. Banks are also

[4] See Smallwood (2006) for a detailed analysis.

[5] British Bankers' Association (2006).

increasingly providing services to investors such as hedge funds, mutual funds and pension funds, in the form of devising, intermediating and making markets for financial instruments. Cross-border lending activities have also increased strongly in recent years. Given that many of these transactions and inter-relationships agglomerate in London, the U.K. banking system, in particular, represents a likely conduit for financial contagion.

In the July 2006 issue of the Bank of England's (BoE) Financial Stability Report (BoE, 2006), several banking-related developments were listed among the main vulnerabilities of the financial system.[6] The report notes that even if a crisis cannot ultimately be averted, early detection of vulnerabilities in the financial system could provide extra time to prepare contingency plans, and focus attention on likely stress points. To this end, understanding the interdependencies between individual banks with potential systemic impact and their exposure to economic and financial risks is crucial.

This paper focuses on determining the extent of contagion risk among the world's largest, systemic banks, focusing specifically on the major U.K. banks. The select foreign institutions are domiciled in France, Germany, Italy, Japan, the Netherlands, Spain, Switzerland, and the United States; they also have substantial businesses based in London. Shocks to any one of these institutions, either originating from their operations in London or in another country, could potentially impact London's vast and globally integrated financial system or be channeled through developments in London to other countries.

Our aim is to identify potential risk concentrations among the world's systemically important banks. It should be noted that the exact nature of the links between the financial institutions is not explored here. Rather, the results are intended to represent "maps" that could guide the allocation of limited surveillance and supervisory resources, so that more detailed links may then be identified as necessary. In addition to highlighting the relationships among U.K. banks, it could also focus cross-border collaboration and supervision between the U.K. authorities and their overseas counterparts.[7]

Our hypothesis consists of three related questions on the global banking system. Firstly, given the increasing internationalization of financial services, are all banks similarly affected by common shocks to the global economy or financial system? Alternatively, is "home bias" the most dominant factor, notwithstanding the effects of globalization? In other words, are banks predominantly influenced by domestic shocks, either because of their domestic focus or the local regulatory environment, despite being largely integrated into the global financial

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[6] They include: releveraging in parts of the corporate sector globally and the implications of underpriced risk; high U.K. household sector indebtedness and rising personal insolvencies; rising systemic importance of large, complex financial institution and their increasing links to U.K. banks; dependence of U.K. financial institutions on market infrastructures and utilities, and potential lack of preparedness for any disruption to these services.

[7] For example, Duggar and Mitra (2006) demonstrate that the major Irish banks are also vulnerable to shocks emanating from the Netherlands and the United States, contrary to the focus of the Irish supervisory authorities largely on the United Kingdom.

system? Or, are different banks—irrespective of domicile—impacted differently by shocks, due to their increasingly different business and geographic mixes?

We use the extreme value theory (EVT) framework to analyze contagion risk across the international banking system. The EVT approach to contagion better captures the information that large, extreme shocks are transmitted across financial systems differently than small shocks. Multivariate EVT techniques are used to quantify the joint behavior of external realizations (or "co-exceedances") of financial prices or returns across different markets.

The body of literature on EVT has grown in recent years. Recent empirical work using EVT to model contagion in financial markets, including bond, equity, and currency markets, are Bae, Karolyi, and Stulz (2003); Chan-Lau, Mathieson, and Yao (2004); Forbes and Rigobon (2001); Hartmann, Straetmans, and de Vries (2004); Longin and Solnik (2001); Poon, Rockinger, and Tawn (2004); Quintos (2001); and Starica (1999). Gropp and Moerman (2004) subsequently apply this approach to changes in the distances-to-default of 67 individual EU banks.[8] They use non-parametric tests of banks' changes in distances-to-default to test for contagion between two banks, after adjusting for bank size. Separately, Gropp, Lo Duca, and Vesala (2005) use a multinomial ordered LOGIT model to the changes in the DDs of European banks to determine cross-border contagion within the region.[9]

In this paper, we test for co-exceedances, that is, the likelihood that an extreme shock affecting a major, systemic U.K. bank would also affect another large local or foreign counterpart. We assume that contagion risk is associated with extreme negative co-movements in bank soundness, or DD. In other words, we try to determine if extreme, but plausible, negative shocks to a particular bank's stability could be associated with stresses experienced by other major banks in the international banking system. In our tests, we are able to identify the co-exceedances, or contagion, attributable to idiosyncratic shocks in the banking sector, since we factor out the impact of domestic and global shocks.

Our results reveal several key trends among major global banks, including those domiciled in the United Kingdom. Notably, "home bias" is a dominant factor in terms of contagion risk. That said, individual banks are also vulnerable to idiosyncratic shocks to major foreign banks, albeit to different degrees. Banks are also generally affected by common shocks to the real economy or financial markets, although the global banking system as a whole tends to be more exposed to these shocks during more turbulent periods, compared to the more benign periods. This suggests that London's vast and varied financial markets could potentially become a major conduit for contagion during stressful periods. Further, contagion risk across the major global banks has risen in recent years.

[8] The distance-to-default (DD) is an indicator of default risk based on Merton (1974). See Appendix II for a detailed explanation.

[9] Generally, empirical studies have shown that the distance-to-default is a good predictor of corporate defaults (Moody's KMV), and is able to predict banks' downgrades in developed and emerging market countries (Gropp, Vesala and Vulpes, 2004; and Chan-Lau, Jobert, and Kong, 2004).

Several important relationships are also highlighted at a more specific, bank-by-bank level. The inter-linkages among U.K. bank*s* are one of the important areas where risks may be concentrated, as evidenced by the existence of "home bias" in contagion risk. Specifically, shocks to Barclays appear to consistently impact the other large U.K. banks. Barclays is consistently the most exposed to shocks that affect major foreign banks, while HSBC represents the biggest contagion risk factor for foreign banks. Shocks to U.S. banks—especially to Morgan Stanley and Citigroup—appear to have become increasingly more important for foreign banks over time, while some of the major U.S. banks appear largely insulated from foreign banks' idiosyncratic shocks. Among European banks, Societé Generale (France) represents an increasing important risk for other regional counterparts. In contrast, shocks to Japan's major banks have limited impact on their counterparts, and vice-versa.

This paper is organized as follows. Section II discusses the possible international financial linkages and sources of financial sector contagion between the United Kingdom and the other major banking systems. This is followed by a description of the method and data in Section III. The empirical analysis of contagion risk across major banks is presented in Section IV. Section V concludes.

II. Bank Linkages Between the United Kingdom and Other Major Banking Centers

There are numerous potential channels for contagion from other banking systems to the United Kingdom, and vice-versa. Notably, external linkages could stem from direct and indirect equity exposures of local banks in overseas banks or, conversely, shareholdings of local banks by foreign banks; direct exposures through loan books; deposit and funding sources from overseas and/or from foreign banks operating in the United Kingdom; payments and settlement systems; holdings of credit risk transfer (CRT) instruments written on assets held by local and/or overseas institutions.

U.K.-owned banks have substantial international positions and are thus exposed to developments in other countries (Figure A.1, Appendix 1). Their asset and liability positions have increased sharply since the late-1990s, both in absolute terms, and as a proportion of the global banking total. According to BIS data, U.K.-owned banks account for 10 percent of the total international asset and liability positions of all reporting banks.

On a country-by-country basis, U.K.-owned banks' biggest exposures are to the United States.[10] According to BIS data, U.K. banks' claims on the United States easily exceed those on other major banking countries by at least 10 times. U.K. banks also have foreign equity exposure in various other markets through their expansion overseas. Specifically, some of the banks among the United Kingdom's "big five" have expanded their operations overseas to diversify their sources of earnings, and invest or lend in markets with higher growth prospects.

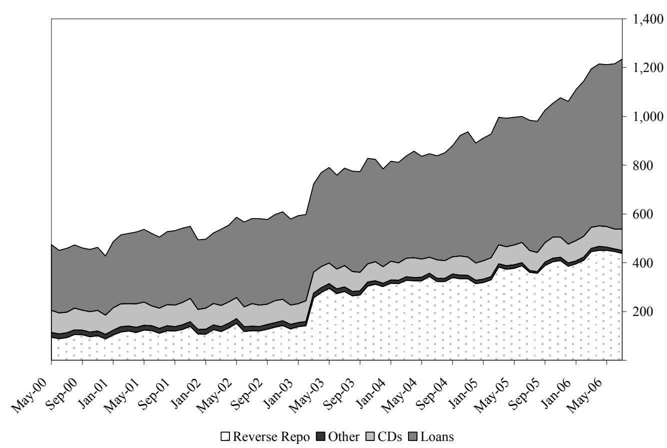
[10] See Figure A.2(i), Appendix 1.

Foreign ownership in the U.K. banking system has also increased. The purchase of Abbey National Bank—the sixth largest in the United Kingdom—by Banco Santander (Spain's largest bank) in 2004, is a major development in this area, and is reflected in the marked increase in Spanish claims against the United Kingdom in 2004.[11]

Banks resident in the United Kingdom have, by far, the biggest external positions, in both assets and liabilities, even compared to the United States (FigureA.3, Appendix 1). Again, this emphasizes the importance of the United Kingdom as a key international banking hub. In terms of market share, U.K. resident banks (which include foreign-owned ones) account for about a fifth of all external assets, and the same for external liabilities of banks globally—twice the amount of the next largest country. Thus, the U.K. financial system could be exposed to contagion not just through the activities of its local banks, but also those of its foreign resident banks. Conversely, foreign financial institutions could channel the impact of transactions effected in the United Kingdom back to their home banking systems.

The London interbank market is another potential source of contagion during periods of extreme stress. It is a key source of liquidity for banks in the system and continues to expand in size (Figure 1). Select participants in this market—which comprise major banks from around the world—set the primary benchmark or reference rate for short-term interest rates globally, in the form of the London Interbank Offered Rate (LIBOR). The increasing links between financial institutions mean that a shock to one financial institution could be quickly transmitted across the financial system, giving rise to systemic liquidity problems.[12]

Figure 1. United Kingdom: Growth in the Interbank Money Market
(In billions of pound sterling)



Source: Bank of England.

Interbank lending is the single largest form of counterparty exposure among the major U.K. banks. U.K. banks had large exposures to more than 50 different counterparties, as at end-

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[11] See Figure A.2(g), Appendix 1.

[12] See Ong and Andersson (2006).

September 2005; the stock of interbank lending was equivalent to more than 200 percent of U.K. banks' Tier 1 capital as at the end of 2005.[13] Five or more of the major U.K. banks having large exposures to a concentration of 12 financial institutions as at 2006 Q1; the major U.K. banks' large exposures to non-U.K. large, complex financial institutions amounted to £98 billion, or equivalent to 63 percent of their Tier 1 capital. Meanwhile, banks' increasing reliance on wholesale markets in the United Kingdom, which include interbank borrowing, could also exacerbate any stress that arises.

Any pressure on the interbank market could be exacerbated by the fact that banks around the world have their biggest debts in the United Kingdom, while their total claims against borrowers in that country are the second largest (Figure A.4, Appendix 1). In aggregate, these banks have around a fifth of each of their total assets plus liability positions with the United Kingdom, similar to their position with the United States. Banks from several major banking countries, such as Germany, Japan and the United States, have their biggest claims against the United Kingdom. The claims of the Dutch, French, Japanese, and Swiss banks against the United Kingdom represent their second-largest exposure, behind their claims against the United States. This means that any disruption to the liquidity flows through the U.K. system could potentially be transmitted overseas rapidly.

The CRT market represents an increasingly important source of risk between banks and other institutional investors. They usually include other banks, insurers and, increasingly, other financial institutions such as hedge funds and pension funds.[14] While the increasing ability to trade credit risk in financial markets has facilitated the dispersion of risk across the financial and other sectors, there are specific risks attached to CRT instruments which could be heightened, in a relatively "new" market, by the still-limited liquidity and lack of transparency in some segments. The situation is compounded by problems associated with, among others, the creditworthiness of transaction counterparties, and the adequacy of existing market and legal infrastructure. London is the main center of the global credit derivatives market, with more than 40 percent of the total global size, and is thus potentially exposed to shocks through this segment of the market as well.

III. Empirical Method

A. Model

We employ a binomial LOGIT model to determine the likelihood that a large shock to one major bank would cause stress to another large counterpart. Specifically, we apply the model used by Gropp, Lo Duca, and Vesala (2005) to estimate the probability that the (percentage) change in the DD of one bank falls in a pre-specified percentile in the negative tail, following large negative shocks to the DDs in the rest of the banks in the sample, and after controlling for country-specific and global factors.

[13] See BoE (2005) and BoE (2006).

[14] See Chan-Lau and Ong (2006).

DDs are used as a comprehensive measure of a bank's default/solvency risk.[15] First, we estimate an individual bank's DD as a comprehensive measure of its default/solvency risk.[16] An increase in the DD implies greater stability/soundness, or a lower risk of default. Next, we derive the changes in DD (we denote the percentage change in the DD as "ΔDD") from the generated series of DDs, and identify extreme negative values in the ΔDDs of individual banks across countries.[17] Corresponding ΔDDs between banks reflect interdependencies which incorporate all potential channels of contagion, thus precluding the need to define explicit links between banks or to specify a particular channel of contagion.[18] We define large shocks (or "extreme values") as the 10^{th} percentile left tail of the common distribution of the ΔDDs across all banks (Figure 2).[19]

Our analysis differs from existing studies in two important ways:

- We test for contagion risk among individual, systemically important banks.[20] We select the 24 biggest banking groups in the world, by total assets, on the basis that these banks could individually pose systemic risk to the domestic or foreign banking

[15] The DD measure represents the number of standard deviations away from the point where the book value of a bank's liabilities is equal to the market value of its assets. The DD is an attractive measure in that it measures the solvency risk of a bank by combining information from stock returns with information from leverage and volatility in asset values—key determinants of default risk. It does not require specification of a particular channel of contagion, that is, the channel through which the transmission of shocks occurs. It should be noted that DDs are risk-neutral, that is, they do not take into account that risk preferences may be different between volatile and benign periods.

[16] Appendix 2 describes the method for calculating the DD measure; Figure A.5 presents the time series DDs for the individual banks.

[17] We calculate weekly ΔDDs—on a daily basis—for the following reasons: (i) extreme events are more significant if they are prolonged; events that last for only a day are of little concern; (ii) the use of weekly changes reduces "noise" in the data. For instance, stock price returns exhibit day-of the-week effects (Chang, Pinegar, and Ravichandran, 1993; French, 1980; Jaffe and Westerfield, 1985; Keim and Stambaugh, 1984; and Lakonishok and Smidt, 1988), while non-synchronous trading effects related to the overnight or weekend non-trading periods impact the calculation of daily close-to-close returns (Rogalski, 1984), effects of which could be "smoothed" using weekly data.

[18] Appendix 3 provides a detailed description of the model. Figure A.6 shows the changes in individual banks' DDs used as input into the model.

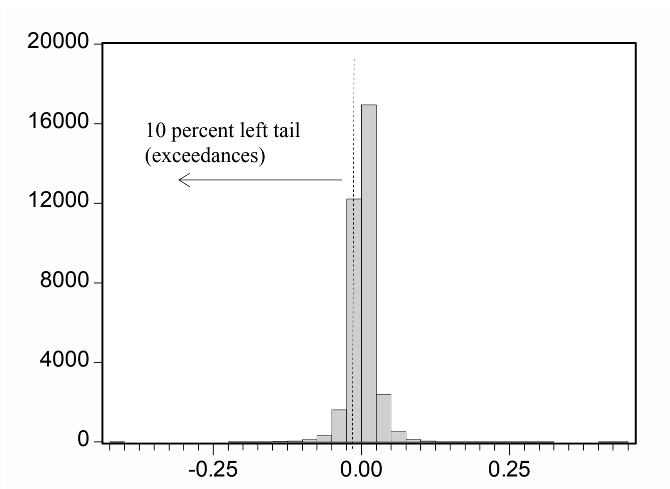
[19] Figure A.7, Appendix 3 presents the 10^{th} percentile left tail (extreme values or co-exceedances) of the common distribution of the ΔDDs for individual banks. Ideally, a first or even fifth percentile left tail would capture the very extreme events; however, either cut-off would have resulted in much too few observations for this period of data.

[20] Gropp, Lo Duca, and Vesala (2005) and Gropp and Moerman (2004) incorporate most listed banks in the EU, in their respective papers, including banks that are also nonsystemic. This could have the effect of overestimating the impact of certain banking systems on others. Indeed, Gropp and Moerman (2004) observe that "an unreasonable number of very small banks" appear to have systemic importance in their results.

systems. In particular, we include institutions from two of the biggest banking systems in the world—that is, Japan and the United States—which contribute significantly to international banking activity.[21] The influence of big banks from Japan and the United States, which represent 9 out of the 24 biggest banks, is likely to be very important, especially given sharp increase in international banking activity in recent years. The focus on major banks is very pertinent given that the financial authorities in our sample countries are looking to improve cross-border collaboration on supervision issues and are thus highly concerned about the impact of systemically important banks.

- We incorporate local and global market and real economy factors into our model. Given the global nature of our dataset, we utilize a world stock market index to include shocks that are global in nature, in addition to using individual local stock market indices and domestic interest rate yield spreads to reflect domestic developments.

Figure 2. Distribution of Changes in Distance-to-Default, 18-Bank Sample 1/



Source: Authors' calculations.

1/ Stacked data on 18 banks' changes in distance-to-default; 10th percentile left tail is −0.018.

[21] Gropp, Lo Duca, and Vesala (2005) and Gropp and Moerman (2004) only examine the inter-relationships among banks in the EU, potentially omitting important linkages with other major banking centers.

B. Data

Our dataset includes the world's top 24 largest exchange-listed banking groups by total assets, as at end-2005, according to Bankscope.[22] In addition to the major U.K. banks, these comprise institutions from other major banking systems such as France, Germany, Japan, the Netherlands, Switzerland, and the United States; a Spanish banking group, a Belgian, and an Italian banking group also make up the top-24, although banking activity in these three countries are much smaller by comparison. All these banks have a presence in London, and in other major overseas financial centers. Balance sheet data for the individual banks are obtained from Bankscope, while their financial prices are available from Bloomberg L.P.

We use three separate control variables to account for common factors affecting the local financial markets, the local real economy and global market developments. Specifically, we incorporate the price return volatility of the local stock market index returns to capture local market influences; changes in the slope of the local term structure (between one- and ten-year government bonds) to represent developments in the domestic real economy;[23] and the price return volatility in the Morgan Stanley Capital International (MSCI) All-Country World Index (ACWI) returns to account for global market factors. These variables are constructed using data obtained from Bloomberg L.P.[24]

The sample period, determined by data availability, is May 30, 2000 to August 2, 2006. However, data for six banks—Credit Agricole (France), Credit Suisse (Switzerland), HBOS (United Kingdom), Mitsubishi UFJ (Japan), Mizuho (Japan), and Sumitomo Mitsui (Japan)—are only available from later dates.[25] Thus, only 18 banks are tested for the full sample period (the "main sample"); the other banks are subsequently added to the main sample as their data become available, and we rerun the tests for each expanded sample (see below).

C. Granger-Causality

We initially perform a set of pairwise Granger-causality (GC) tests on the 18 banks to determine the broad trends in the ΔDD relationships between pairs of banks. Given the intensifying interlinkages across financial institutions, we would expect to see stronger co-movements between banks' risk measures over time. While this could be captured by calculating the rolling correlations between the ΔDDs, GC tests go beyond standard correlations; they show whether the past ΔDDs of a particular bank help to explain the

[22] We originally selected the top 35 largest banks in the world, but subsequently refined the sample to the 24 largest exchange-listed banks for which good quality and sufficient data are available. The list of banks in our dataset is presented in Table A.1, Appendix 4.

[23] See, for example, Bernard and Gerlach (1998), Estrella (2005), and Estrella and Hardouvelis (1991).

[24] See Appendix 4 for details of the control variables dataset.

[25] See Table A.2, Appendix 4.

current ΔDDs of another bank, after also taking into account the past ΔDDs of the latter. It should be emphasized that GC does not imply that the ΔDD in one bank causes the ΔDD in the other. In other words, it does not imply causality in the usual sense—GC merely measures the information content and precedence of one variable versus the other.

We run bivariate regressions with 30 lags to measure GC. Put another way, the ΔDD for a particular bank is regressed on 30 of its own lags and 30 lags of another bank, and vice versa, for all pairwise permutations, such that:[26]

$$\Delta DD_t^i = c^i + \sum_{s=1}^{30} \beta_s^i \Delta DD_{t-s}^i + \sum_{s=1}^{30} \beta_s^j \Delta DD_{t-s}^j + \varepsilon_t^i . \tag{1}$$

This test is performed on data for the full sample period of May 30, 2000 to August 2, 2006.

The GC results show substantial "causality" between European and U.S. banks. Interestingly, while U.K. banks Granger-cause ΔDDs in continental European and U.S. banks, the converse is less so (Table 2). U.S. banks largely do not Grange-cause ΔDDs in European banks, but some of the former appear to experience significant spillovers from the latter. There appears to be little Granger-causality among domestic banks, both in the United Kingdom and the United States.[27]

The results may not accurately depict the co-exceedances (common occurrence of extreme events) across banks, which are key in determining contagion risk. The results in Table 2 reflect the inter-bank relationships over the full sample period. In reality, relationships between financial institutions are likely to be very different across tranquil and turbulent periods. High correlations in bank soundness during normal times provide little information on the likelihood of contagion. Further, some of these GC effects could have also captured common factors that affect all banks, or local banks in any one country. Thus, to capture spillovers in the international banking system, we employ an EVT framework to measure the probability of co-exceedances between individual, systemically important banks, once common shocks have been taken into account.

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[26] The number of lags is arbitrary; the larger the number of lags, the better. In this instance, we choose 30 lags to incorporate daily movements over a one-month period.

[27] The number of lags is arbitrary and the larger the better. We choose 30 lags to incorporate movements in the past month.

Table 2. United Kingdom: Pairwise Granger-Causality Between the World's Largest Banking Groups (18-Bank Sample)
May 30, 2000–August 2, 2006

Country	Bank	Belgium	France		Germany	Italy	Netherlands		Spain	Switzerland	United Kingdom			United States					
		Fortis	BNP Paribas	Societe Generale	Deutsche Bank	Unicredito	ABN Amro	ING	Santander	UBS	Barclays	HSBC	RBS	Bank of America	Citigroup	Goldman Sachs	JP Morgan Chase	Merrill Lynch	Morgan Stanley
Belgium	Fortis			x	x	x										x		x	x
France	BNP Paribas			x	x							x				x	x	x	x
	Societe Generale				x											x	x	x	x
Germany	Deutsche Bank		x	x		x		x									x	x	x
Italy	Unicredito	x		x	x		x	x	x	x	x		x			x		x	x
Netherlands	ABN Amro			x	x	x										x	x	x	x
	ING			x	x	x											x	x	
Spain	Santander			x	x								x				x		x
Switzerland	UBS	x	x	x	x		x	x	x		x		x		x	x	x	x	x
U.K.	Barclays	x	x	x	x	x	x						x					x	x
	HSBC		x	x	x	x	x	x	x	x					x	x		x	x
	RBS	x	x	x	x	x	x	x	x	x					x		x		
U.S.	Bank of America											x							
	Citigroup		x	x	x		x		x	x	x		x				x		
	JP Morgan Chase			x									x					x	
	Goldman Sachs		x	x						x			x				x		
	Merrill Lynch		x	x			x			x			x		x		x		
	Morgan Stanley		x	x						x				x			x		

Source: Bankscope, Bloomberg L.P. and authors' calculations.

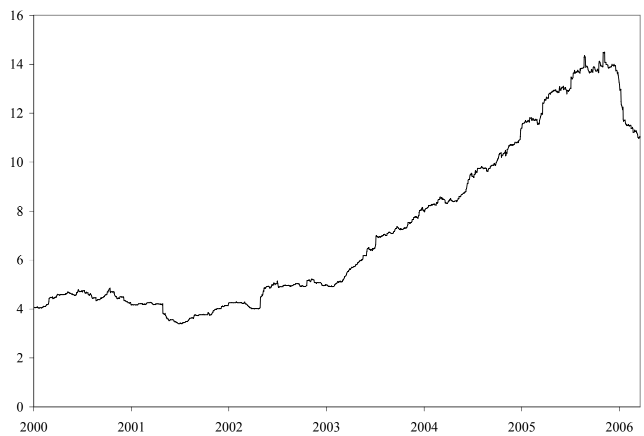
Notes: Factors in the columns are Granger-caused by factors in the rows.
The Granger-causality test used 30 lags.
The F-statistic of the joint significance of the lags of bank 2 in explaining bank 1 is noted—in the matrix an "x" is noted if the F-statistic shows significant GC at 1 percent or less.
☐ represents the grouping of major banks in any one country, where 3 or more banks are represented in the sample.

IV. Default Risk and Contagion Results

A. Analysis

Our examination of the main sample of 18 banks shows that bank soundness broadly deteriorated across countries during the mid-2000 to mid-2003 period (example in Figure 3).[28] The collective decline in DDs has coincided with the period following the bursting of the global information technology (IT) bubble; the slowdown in global economic growth; the economic and financial difficulties experienced in some Latin American countries, such as Argentina and Brazil, where some of the major banks have direct business interests. The U.K. and U.S. banks appear to have been less affected by the general turbulence, relative to banks from other countries, as their DDs remained relatively stable during this time.

Figure 3. Distance-to-Default: HSBC Holdings PLC



Sources: Bankscope; Bloomberg L.P.; and authors' calculations.

The stresses on the global banking system during the first-half of the sample period are also evidenced in the number of negative extreme values, or left-tail events, across banks (examples in Figures 4 and 5).[29] Among the U.K. banks, Barclays has been most affected, while RBS and, in particular, HSBC registered few extreme values. The occurrences are particularly frequent for some foreign banks, such as ABN Amro (Netherlands), BNP Paribas (France), Deutsche Bank (Germany), Fortis (Belgium) and Societé Generale (France).

[28] See Figure A.5, Appendix 2 for full sample.

[29] See Figures A.6 and A.7, Appendix 3 for full samples.

Figure 4. Changes in the Distance-to-Default: HSBC Holdings PLC

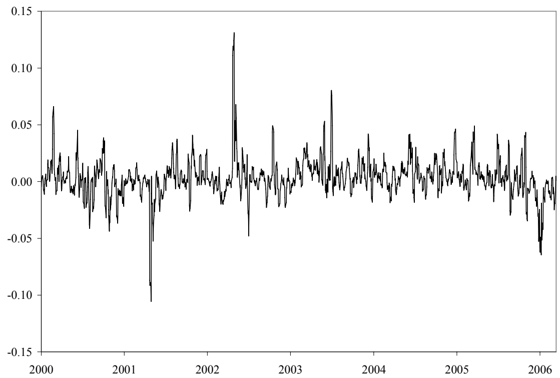
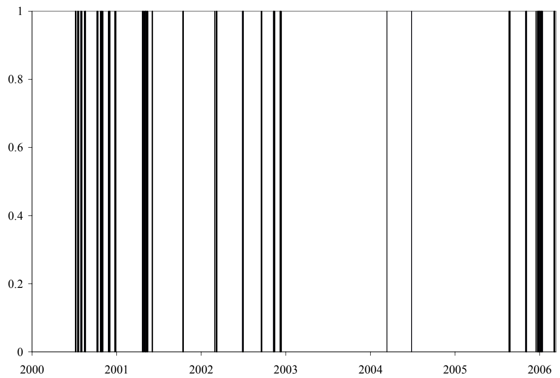


Figure 5. Binomial LOGIT Representation of the 10th Percentile Left Tail: HSBC Holdings PLC

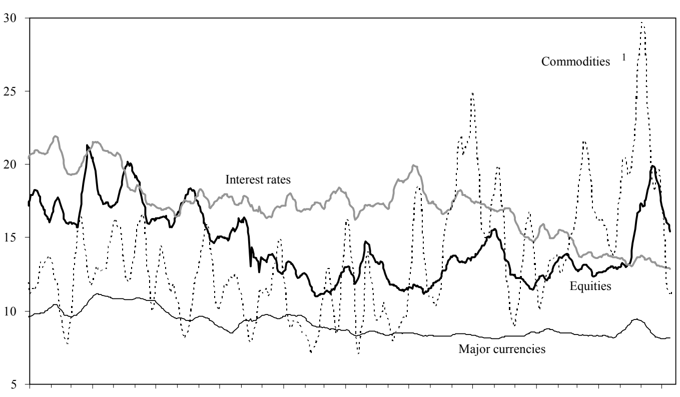


Sources: Bankscope; Bloomberg L.P.; and authors' calculations.

The health of the global banking system improved vastly over the mid-2003 to end-2005 period. The DDs of all banks in our sample rose strongly during this period; correspondingly, the overall number of left-tail events fell substantially. In the case of a few banks—namely, Citigroup (United States), HSBC (United Kingdom), Merrill Lynch (United States)—no left-tail event is recorded. Solid growth, high liquidity, supported a period of declining risk aversion (Figure 6).

However, the global banking system came under some pressure in 2006. The number of left-tail events increased across many banks in our sample during this period. While the exact causes of the observed stress are unclear, it has coincided with the oil and commodity price shocks experienced in early-2006, as well as with the sharp corrections in global asset prices observed in the second quarter of 2006.

Figure 6. Implied Volatilities in Global Markets
(In percent) 1/



Sources: Bloomberg L.P.; Commodity Research Bureau; and authors' calculations.
1/ 10-day moving average of 10-day historical volatilities of CRB index.

U.K. Banks

Contagion risk is significant among U.K. banks (Table 3). Both HSBC and RBS are exposed to contagion risk from Barclays; in turn, Barclays appears to be exposed to shocks both of these banks as well. However, HSBC and RBS are not significantly influenced by each other.

Barclays appears to be most exposed to contagion risk from foreign banks, but HSBC represents the biggest contagion risk to foreign banks.[30] Barclays is most exposed to shocks to Dutch and U.S. banks, while shocks to HSBC also appear to impact Deutsche Bank (Germany), ING (Netherlands), and JP Morgan Chase (United States). This could possibly be attributable to Barclays Capital—the only major U.K.-owned investment bank—likely having far more complex counterparty relationships with U.S. and European investment banks, compared to the other U.K. banks.

By and large, the other U.K. banks appear mostly insulated from contagion risk from foreign banks. Interestingly, these findings contrast with those of Gropp, Lo Duca, and Vesala (2005). In that paper, the authors find that the U.K. banking sector is exposed to contagion risk from Spain's banking sector, and vice-versa, over the 10-year period from 1993 to 2003. The contrasting results may be explained by the fact that our analysis focuses on individual, systemic banks, and we correct for the effects of broader common factors.

Increased risk in the domestic stock market appears to be an important factor affecting banks. Specifically, the occurrence of left-tail events for Barclays and RBS appear to vary positively with risk (as represented by an increase in the volatility of returns) in the FTSE 100 index. In contrast, HSBC appears largely unaffected, notwithstanding its biggest share in the capitalization of the index.[31] One possible explanation could be that HSBC's operations are well-diversified across businesses and countries, and are thus less likely to be significantly affected by developments in any particular market or economy.

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[30] Table A.3, Appendix 5 present the binomial LOGIT results for the U.K. banks.

[31] See Table A.4, Appendix 6 for a breakdown of each bank's capitalization in the composition of the representative stock market index.

Table 3. Contagion Risk among the World's Largest Banking Groups (18-Bank Sample), May 30, 2000–August 2, 2006
(In percent level of significance)

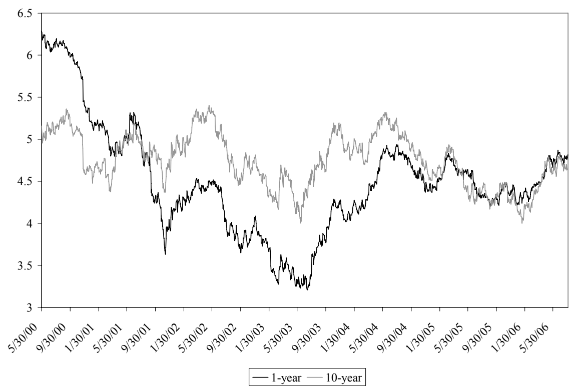
Country	Bank	Contagion to: Belgium	France		Germany	Italy	Netherlands		Spain	Switzerland	United Kingdom			United States					
		Fortis	BNP Paribas	Societe Generale	Deutsche Bank	Unicredito	ABN Amro	ING	Santander	UBS	Barclays	HSBC	RBS	Bank of America	Citigroup	Goldman Sachs	JP Morgan Chase	Merrill Lynch	Morgan Stanley
	Initial shock to:																		
Belgium	Fortis				5.0			1.0											
France	BNP Paribas			5.0															
	Societe Generale																		
Germany	Deutsche Bank							5.0											
Italy	Unicredito							1.0											
Netherlands	ABN Amro	5.0	1.0	1.0	1.0						1.0							1.0	1.0
	ING								5.0						5.0				
Spain	Santander																	5.0	
Switzerland	UBS			5.0					5.0						1.0				
United Kingdom	Barclays											1.0	1.0						
	HSBC				5.0			1.0			1.0						5.0		
	RBS										1.0			1.0					
United States	Bank of America																		
	Citigroup	1.0														5.0			
	Goldman Sachs																		5.0
	JP Morgan Chase													1.0	5.0				
	Merrill Lynch			5.0															
	Morgan Stanley						5.0				1.0			5.0	5.0	5.0			
Other factors	Constant	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Local market volatility	1.0	1.0		1.0	1.0	1.0	1.0	1.0		1.0		1.0					1.0	
	Change in term structure		1.0	1.0			1.0			1.0							5.0		
	Global market volatility							1.0								5.0		1.0	1.0
	McFadden R^2	0.45	0.47	0.45	0.45	0.57	0.49	0.50	0.47	0.49	0.48	0.54	0.50	0.55	0.59	0.57	0.46	0.47	0.59

Sources: Bankscope, Bloomberg L.P. and authors' calculations.

Notes: Columns represent dependent variables; rows represent explanatory variables.
Blank cells represent non-significance at any level below 5 percent.
represents significance at the 5 percent level or lower.
represents significance at the 1 percent level or lower.
represents significance (negative sign) at the 5 percent level or lower.
represents coefficients on own-lags, of up to 5 lags.
represents the grouping of major banks in any one country, where 3 or more banks are represented in the sample.

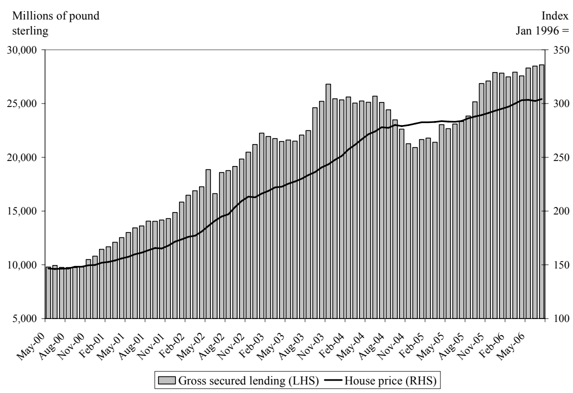
The outlook for the real economy, as represented by changes in the term structure of interest rates, has not had a significant impact on bank soundness in the United Kingdom. This is not surprising given the solid growth, benign interest rate environment in recent years and the booming housing market (Figures 7 and 8). Moreover, the traditionally high concentration in fixed-rate mortgages in the United Kingdom and the favorable loan-to-value mortgage environment means that any increase in interest rates is less likely to pose an immediate threat to the credit quality of banks' loan portfolios.[32]

Figure 7. United Kingdom: 1- and 10-Year Treasury Yields
(In percent)



Source: Bloomberg L.P.

Figure 8. United Kingdom: Nominal House Prices and Gross Bank Lending Secured on Dwellings



Sources: Bank of England; Halifax; and Nationwide.

Foreign Banks

Some U.S. banks are vulnerable to contagion risk from banks from their own country as well as from overseas. Table 3 suggests that some of these banks are susceptible to shocks affecting European banks; however, no European bank represents a common contagion factor. Goldman Sachs appears to be largely insulated from external shocks, while shocks to U.S. banks appear to have little effect on many of their foreign counterparts.

There appears to be little interaction between several U.S. banks with domestic stock market and interest rate shocks. This suggests that stresses to U.S. banks during this period have not necessarily been tied to developments in the local market or economy. Rather, bank soundness appears to be more closely related to volatilities in global markets, potentially reflecting the global nature of U.S. banking businesses.

[32] In the United Kingdom, the split of fixed/floating rate new loans to households averaged 66 percent fixed and 34 percent floating in the year to November 2006, while the stock of fixed rate loans is estimated at around 40–45 percent. Although some lenders have reportedly increased their maximum LTV ratios quite aggressively (up to 125 percent) for new mortgage loans, the average LTV ratio for the stock of mortgages remains much lower than during the early-1990s. This is largely because the LTVs for older loans may have declined with the continuing rise in associated property prices. The stock of LTVs averaged an extremely favorable 40−50 percent in 2005, and is slightly higher than 50 percent for most banks currently.

Contagion risk appears quite significant among European banks. Contagion among same-country banks is difficult to determine, given the limited number of major global banks from each country. Shocks to ABN Amro (Netherlands) appear to impact banks across several countries, including those in the United Kingdom and the United States, while Societé Generale (France), Deutsche Bank (Germany) and ING (Netherlands) are among those most vulnerable to contagion risk from other major international banks.

Interestingly, our results thus far show some consistency with those of Gropp and Moerman (2004), notwithstanding the differences in time periods, model and bank samples (see above). The authors identify ABN Amro (Netherlands) and HSBC (United Kingdom) to be among the more systemically important banks for those outside their own country. They also find close links among banks within countries.

B. Robustness Tests with Sub-Samples

Next, we split the sample period into two sub-samples, to determine the robustness of our initial findings. A natural structural break would be around mid-2003, which separates the turbulent period in global economic and market conditions from the benign period that followed. Thus, we define the first sub-sample as May 30, 2000–May 30, 2003, and the second as June 1, 2003–August 2, 2006.

Our results reveal several key trends among the major international banks. Broadly, we find that "home bias is a dominant factor in terms of contagion risk, although banks are also affected differently by idiosyncratic shocks to their major counterparts, possibly due to their different business and geographic mixes (Table 4). Broadly, individual banks are not similarly affected by common shocks to the domestic real economy or to financial markets, although the global banking system as a whole tends to be more exposed to these shocks during more turbulent periods, compared to the more benign times. Importantly, contagion risk across the major global banks has risen in recent years (Table 5).

Table 4. Significant Co-exceedances, 2000−2006
(In percent of total possible bank transmission channels)

	Contagion to:	
	U.K. banks	Other banks
Initial shock to:		
U.K. banks	67	9
Other banks	4	13

Source: Authors' calculations.

Table 5. Change in Significant Co-exceedances, 2000−03 to 2003−06
(In percentage points)

	Contagion to:	
	U.K. banks	Other banks
Initial shock to:		
U.K. banks	0	9
Other banks	2	2

Source: Authors' calculations.

Several themes emerge for U.K. banks when the two sub-samples are compared (Table 5). Over the past few years, contagion risk between U.K. and non-UK banks has increased. For the U.K. banks, Barclays is consistently the most exposed to contagion from foreign banks across both sub-periods; contagion risk from foreign banks to the U.K. banking sector in general has also increased over time.

Several key trends are also observed among the major foreign banks. The exposure of U.S. banks to each other appears to have intensified in recent years; the impact of U.S. banks on foreign banks has also increased. Meanwhile, shocks to Societé Generale (France), HSBC (United Kingdom) and Morgan Stanley (United States) have had increasingly greater impact on foreign banks. Within Europe, contagion risk from the French banks appears to have increased over time.

We subsequently add the remaining six banks to the sample of 18 banks as their data become available, and we rerun the tests for each expanded sample.[33] The banks are added in the following order: Mitsubishi UFJ (Japan), HBOS (United Kingdom), Credit Agricole (France), Credit Suisse (Switzerland), Sumitomo Mitsui (Japan), and Mizuho (Japan).[34] Our analysis of each of the six sets of results reveal several notable trends:

- Barclays (United Kingdom) is the consistent risk factor for its local counterparts, while HSBC remains the most important U.K. contagion risk factor for foreign banks.
- Among U.S. banks, Morgan Stanley, and Goldman Sachs are largely insulated. Morgan Stanley consistently represents the biggest contagion risk for other foreign banks; Citigroup has also become increasingly important in recent years.
- In continental Europe, shocks to Societé Generale has had the widest impact over time, while banks such as Fortis (Belgium) and Santander (Spain) have become more exposed to shocks from elsewhere.
- Contagion risk for major Japanese banks has been limited. Japanese banks appear to pose little contagion risk to the other major international banks, despite the size of the banking system, which is the fourth largest in the world. Similarly, these banks are largely insulated from shocks to foreign banks.

C. Caveats

Several caveats apply to our findings:

- We use data on banking groups to test for contagion through the banking sector. Some of these groups provide banking, insurance and/or other finance-related services. Although banking services tend to be the dominant business for the

[33] The 10^{th} percentile left tail for each sample, expanded by one bank at a time, remains at −0.018.

[34] See Table A.5, Appendix 7 for the 24-bank results. Detailed results for the 19−23 bank samples are available on request.

institutions in our sample, our results could potentially be capturing contagion through other segments of the financial sector.

- Some of the banking groups in our sample represent important constituents in their respective country's stock market indices, and some are also represented in the MSCI ACWI.[35] This means that some of the stock market volatility effects captured in the results could be partly driven by the volatility in the individual bank stocks. This suggests that the impact of idiosyncratic shocks on inter-bank contagion represent "conservative" estimates.[36]

- The balance sheet data on banks' long- and short-term liabilities are only available on an annual basis from Bankscope. Thus, our calculation of daily DDs require extrapolation between two data points. In this case, we assume that the liabilities change proportionally each day.

- Finally, the DD risk measure does not factor in default risk arising from off-balance sheet exposures, which could be substantial especially for major international banks engaged in proprietary trading activities. Notwithstanding this limitation, empirical studies have shown that the DD is still a good indicator of default risk in the banking sector (Gropp, Vesala, and Vulpes, 2004; and Chan-Lau, Jobert, and Kong, 2004).

V. Conclusion

London is indisputably one of the world's most important financial hubs. The dynamism of its financial sector offers significant opportunities to financial services providers. The increased inter-linkages between financial instruments and among financial institutions result in greater efficiency. The breadth and depth of London's financial sector and markets also improve its ability to absorb shocks to the system. However, the accessibility, innovation and integration that represent London's major competitive strengths also heighten participants' exposure to the risk of contagion through numerous channels when market events occur. The banking sector is a potentially key conduit for contagion risk within the local financial sector and between financial systems across countries, given that several U.K. banks are among the largest in the world and close to 500 international banks are represented in London.

This paper uses market-based indicators to highlight potential inter-relationships among the world's biggest banking groups and their exposure to contagion risk from their counterparts. Specifically, the main objective is to identify potential contagion among those banks—all of which are represented in London and could cause systemic stress to the international financial system—with the financial center in London acting as a potentially important conduit. In doing so, our results also provide some information on areas where risks may be

[35] See Table A.4, Appendix 6.

[36] We test for robustness by omitting the local stock market variable and rerunning the binomial LOGIT model. Our results show that the contagion effects remain largely the same; some of the local market effects are captured by the global market variable. However, the McFadden R^2 is slightly stronger for the existing model.

concentrated, thus highlighting relationships which may require closer supervision and surveillance and a more detailed understanding of linkages by the local authorities. Our findings could also help country authorities focus their collaborative supervisory efforts on specific areas, given their limited resources.

Using an EVT framework, our results yield several clear trends of the inter-relationships among the world's biggest banks from three regions. Overall, the risk of contagion among local banks is highest ("home bias"), while inter-linkages with foreign banks appear to have increased over time. Specifically, contagion risk is high among U.K. banks, with shocks to Barclays seeming to have a significant impact on each of the other major U.K. banks. The "home bias" findings for the U.K. banks are also consistent for banks domiciled in other countries. Our findings also suggest that bank soundness is more susceptible to market- and economy-wide factors when the environment is turbulent, but is less so during more benign periods.

In light of these findings, ensuring sound risk management continues to be a key challenge for the banking sector. The U.K. authorities appropriately emphasize that responsibility for mitigating risks to the financial system is shared between the private sector and the public authorities (BoE, 2006). Joint risk management arrangements have been initiated on the domestic front. The Cross-Market Business Continuity Group (CMBCG) is an explicit and formal arrangement between the U.K. authorities (BoE and FSA) and key financial institutions operating in the United Kingdom, irrespective of their U.K. or non-U.K. status. It has been set-up to establish contacts in advance of a crisis, and which could be called upon whether the event is an operational disruption or a financial crisis. The authorities also note that the need for better planning and testing for system-wide disruptions is greatest in the area of private sector co-ordination. Encouragingly, risk management by banks has become increasingly more professionalized, ahead of the proposed introduction of new bank capital standards under Basel II. However, the authorities have identified several areas where risk management could be improved further, notably, in managing liquidity risk, aggregate economic and financial risk, risk aggregation within and across firms, and contingency planning. The authorities are also promoting greater use of stress-testing as a key risk management tool.[37]

Greater emphasis is being placed on improving cooperation in cross-border financial crisis prevention and management. The U.K. FSA, its European regulatory counterparts and the European Commission support more efficient, risk-based cross-border collaboration among supervisors. Internationally, the existing tripartite of Switzerland, the United Kingdom, and the United States is considered one of the most fully-developed examples of home/host collaboration in supervision. In other collaborative efforts, the FSA and the New York Federal Reserve have worked closely and continuously with major participants in the credit risk transfer market to resolve the issue of backlogs in trade confirmations and assignments, and continue to emphasize the need for "borderless" solutions in the oversight of the credit

[37] See BoE (2006) for a discussion of work that is under way and new work that may be required in this area.

derivatives market.[38] The U.K. authorities also acknowledge that managing the impact from a failure of a major global financial institution would require significant cross-border co-ordination. For example, the U.K. authorities have signed the EU Memorandum of Understanding for crisis management, which includes performing crisis simulation exercises at the EU level. Nonetheless, the U.K. authorities acknowledge that there is a need for further work on cross-border co-ordination and information sharing between national authorities in promoting financial stability.[39]

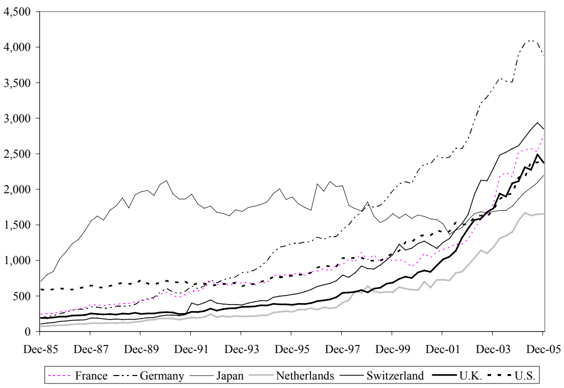
[38] See Geithner, McCarthy and Nazareth (2006).

[39] See Gieve (2006).

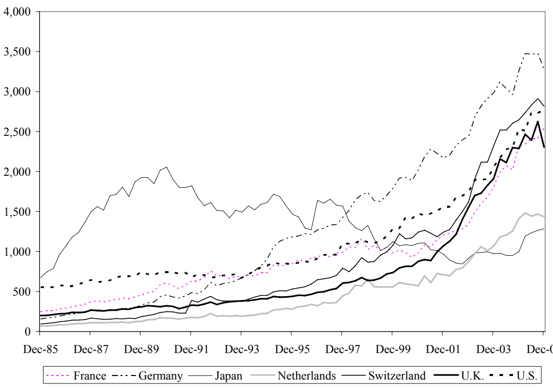
Appendix I. International Banking Activity

Figure A.1. International Positions by Nationality of Ownership of BIS Reporting Banks

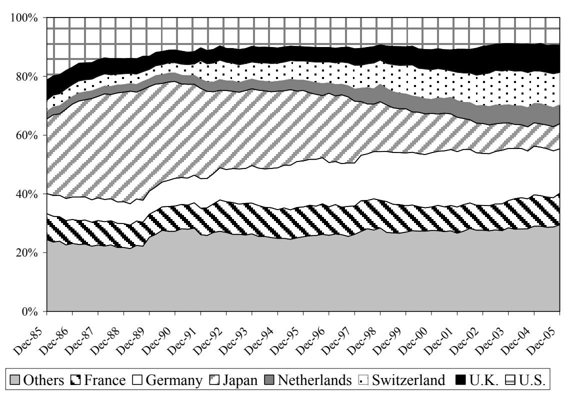
(a) Assets
(In billions of U.S. dollars)



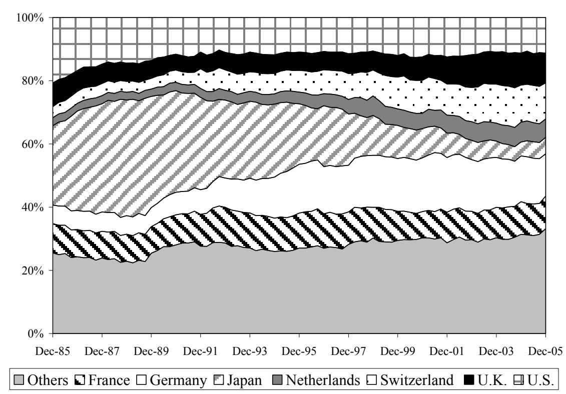
(b) Liabilities
(In billions of U.S. dollars)



(c) Assets
(In percent of global total)



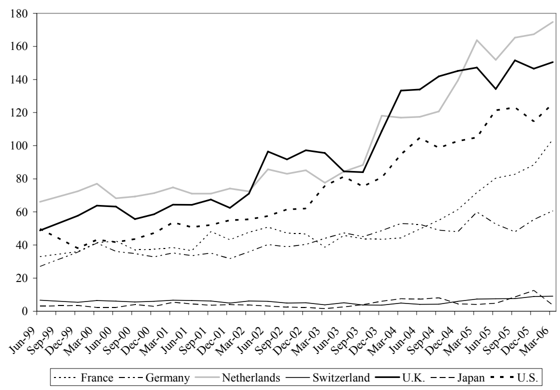
(d) Liabilities
(In percent of global total)



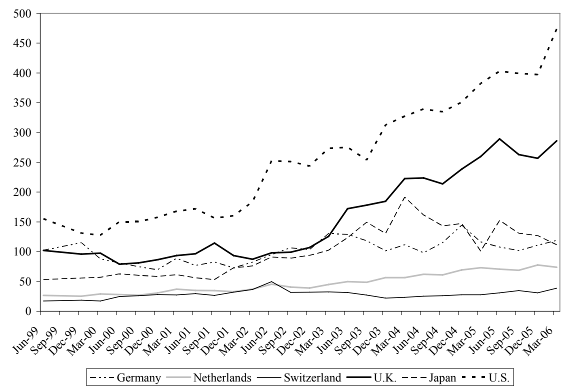
Sources: Table 8A of International Banking Statistics; and Bank for International Settlements.

Figure A.2. Consolidated Foreign Claims on Select Individual Countries, by Nationality of Reporting Banks
(In billions of U.S. dollars)

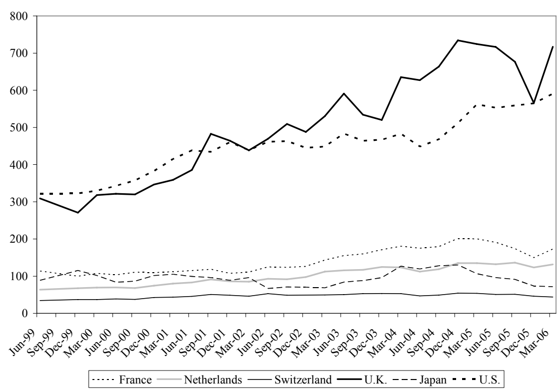
(a) Belgian



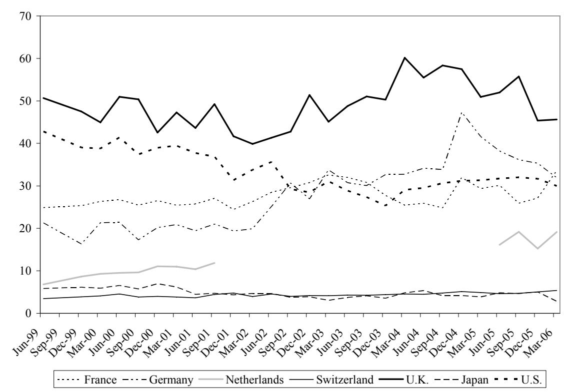
(b) French



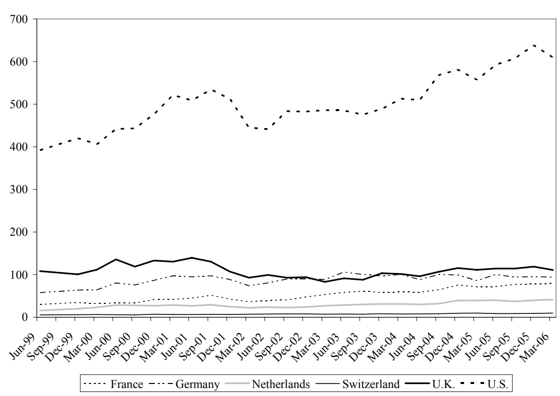
(c) German



(d) Italian



(e) Japanese



(f) Dutch

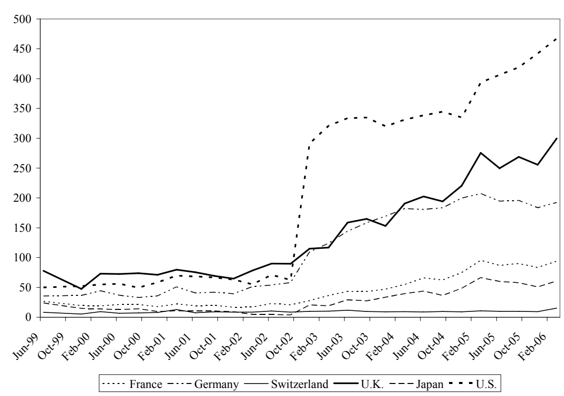
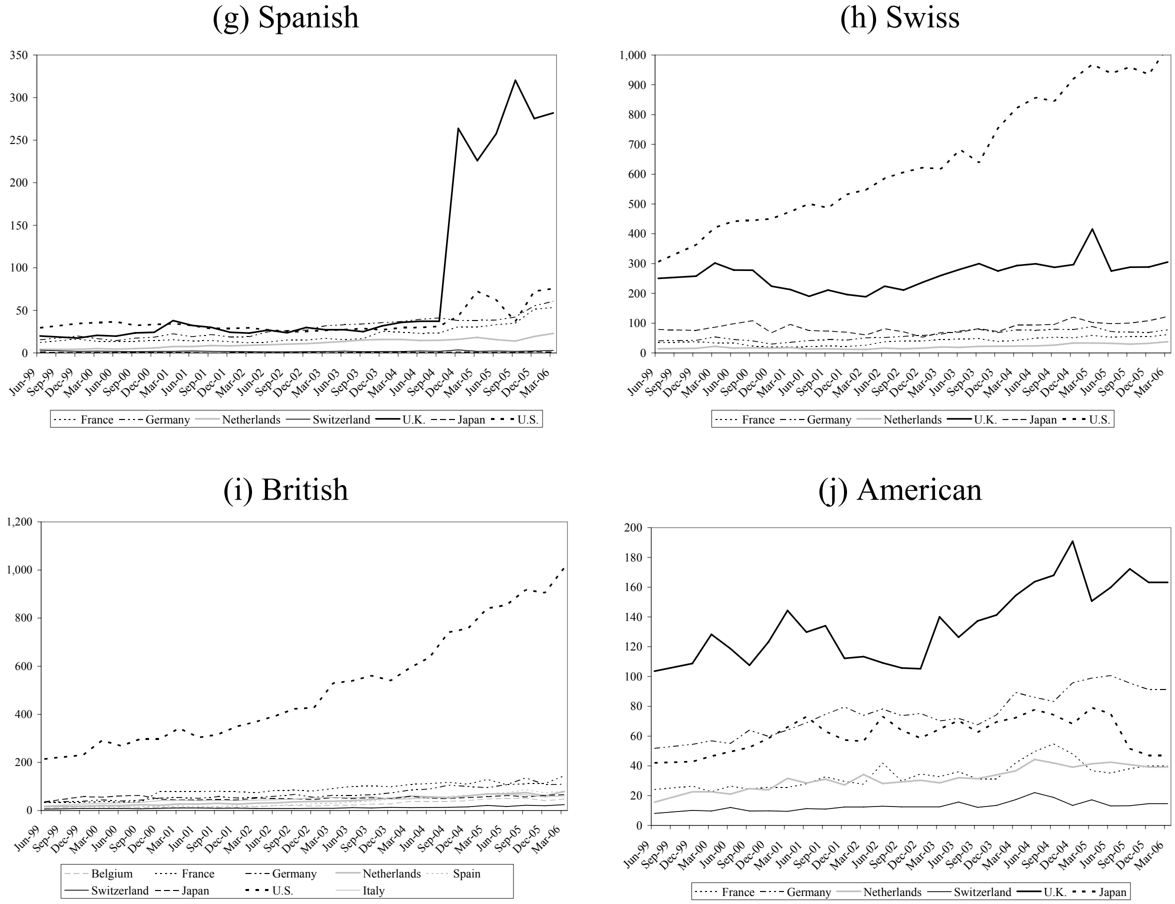


Figure A.2. Consolidated Foreign Claims on Select Individual Countries, by Nationality of Reporting Banks (cont'd)



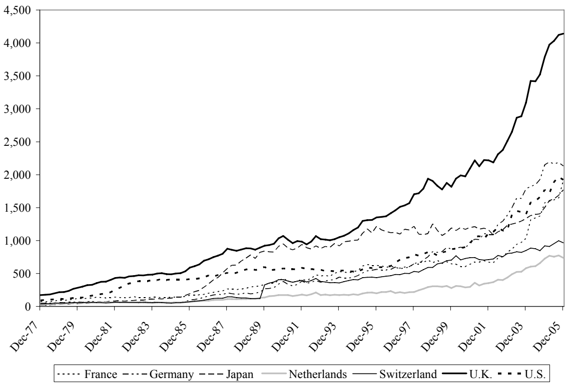
Notes: The data is reported on an "immediate borrower" basis, that is, inter-office positions are netted out and the positions are allocated to the country where the final risk lies. In other words, the country of ultimate risk is the country in which the guarantor of a financial claim resides and/or the country in which the head office of a legally dependent branch is located.

The claims of Italy and Spain against the key countries are presented here due to the presence of their banks among the 20 largest in the world, even though international banking activity in these countries are relatively small. The United Kingdom's claims against these three countries are also presented for completeness, given our interest in the international exposures of U.K. banks.

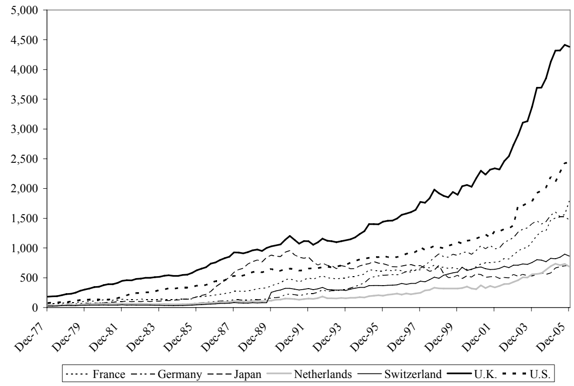
Source: Table 9B of International Banking Statistics, Bank for International Settlements.

Figure A.3. External Positions of Banks in Individual BIS Reporting Countries

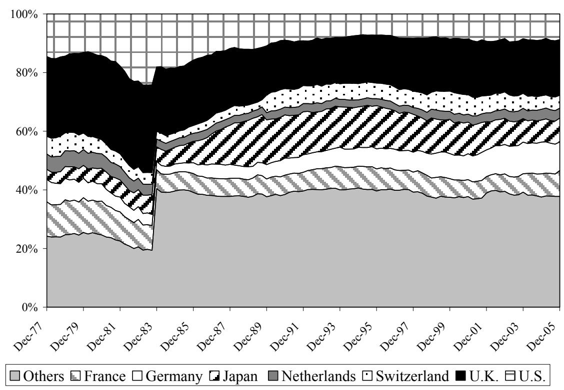
(a) Assets
(In billions of U.S. dollars)



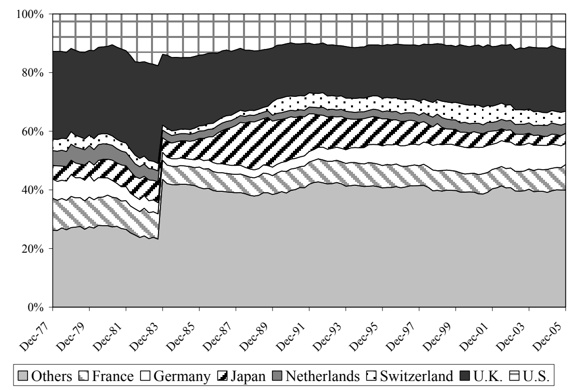
(b) Liabilities
(In billions of U.S. dollars)



(c) Assets
(In percent of global total)



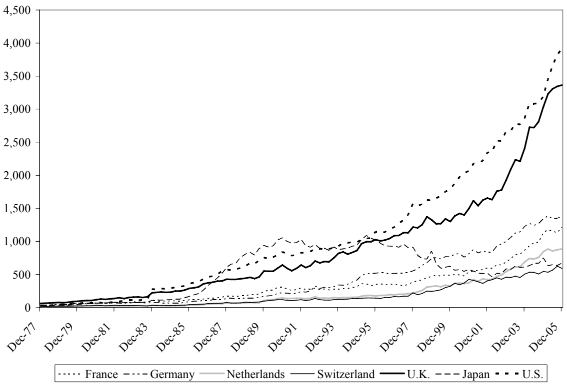
(d) Liabilities
(In percent of global total)



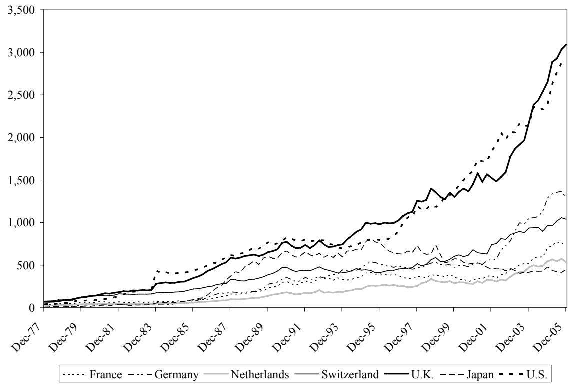
Source: Table 2A of International Banking Statistics, Bank for International Settlements.

Figure A.4. External Positions of BIS Reporting Banks vis-à-vis Individual Countries

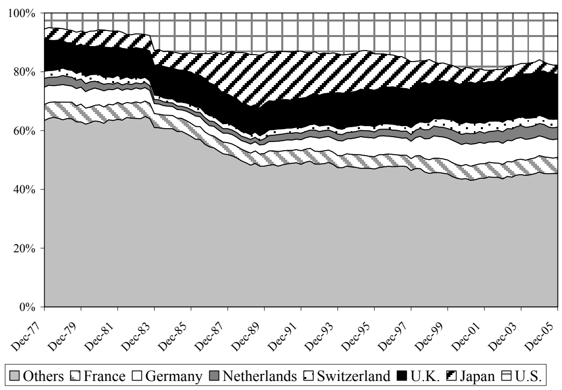
(a) Assets
(In billions of U.S. dollars)



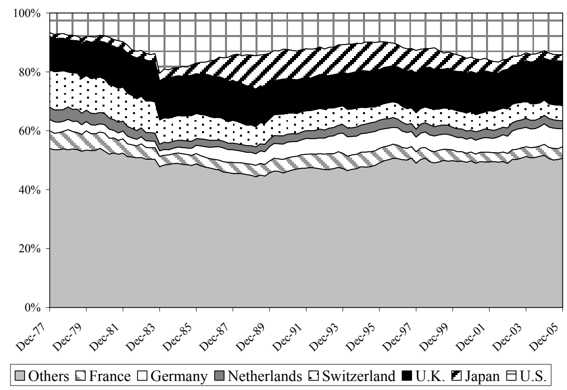
(b) Liabilities
(In billions of U.S. dollars)



(c) Assets
(In percent of global total)



(d) Liabilities
(In percent of global total)



Source: Table 6A of International Banking Statistics, Bank for International Settlements.

Appendix II. Calculating the Distance-to-Default

The distance-to-default (*DD*) measure is based on the structural valuation model of Black and Scholes (1973) and Merton (1974). The authors first drew attention to the concept that corporate securities are contingent claims on the asset value of the issuing firm.[40] This insight is clearly illustrated in the simple case of a firm issuing one unit of equity and one unit of a zero-coupon bond with face value *D* and maturity *T*. At expiration, the value of debt, B_T, and equity, E_T, are given by:

(A.1) $$B_T = \min(V_T, D) = D - \max(D - V_T, 0),$$

(A.2) $$E_T = \max(V_T - D, 0),$$

where V_T is the asset value of the firm at expiration. The interpretation of equations (A.1) and (A.2) is straightforward. Bondholders only get paid fully if the firm's assets exceed the face value of debt, otherwise the firm is liquidated and assets are used to partially compensate bondholders. Equity holders, thus, are residual claimants in the firm since they only get paid after bondholders.

Note that equations (A.1) and (A.2) correspond to the payoff of standard European options. The first equation states that the bond value is equivalent to a long position on a risk-free bond and a short position on a put option with strike price equal to the face value of debt. The second equation states that equity value is equivalent to a long position on a call option with strike price equal to the face value of debt. Given the standard assumptions underlying the derivation of the Black-Scholes option pricing formula, the default probability in period *t* for a horizon of *T* years is given by the following formula:

(A.3) $$p_t = N\left[-\frac{\ln\frac{V_t}{D} + \left(r - \frac{\sigma_A^2}{2}\right)T}{\sigma_A\sqrt{T}}\right],$$

where *N* is the cumulative normal distribution, V_t is the value of assets in period *t*, *r* is the risk-free rate, and σ_A is the asset volatility.

The numerator in equation (A.3) is referred to as *distance-to-default*. An examination of equation (A.3) indicates that estimating default probabilities requires knowing both the asset

[40] Models built on the insights of Black and Scholes (1973) and Merton (1974) are known in the literature as structural models.

value and asset volatility of the firm. The required values, however, correspond to the *economic* values rather than the accounting figures. It is thus not appropriate to use balance-sheet data for estimating these two parameters. Instead, the asset value and volatility can be estimated. It is possible to solve the following equations (A.4) and (A.5) for the asset value and volatility:

(A.4) $$E_t = V_t N(d_1) - e^{=rT} DN(d_2)\text{, and}$$

(A.5) $$\sigma_E = \frac{V_t}{E_t} N(d_1),$$

if E_t, the value of equity; σ_E, the equity price return volatility; and D, the face value of liabilities, are known; and d_1 and d_2 are given by:

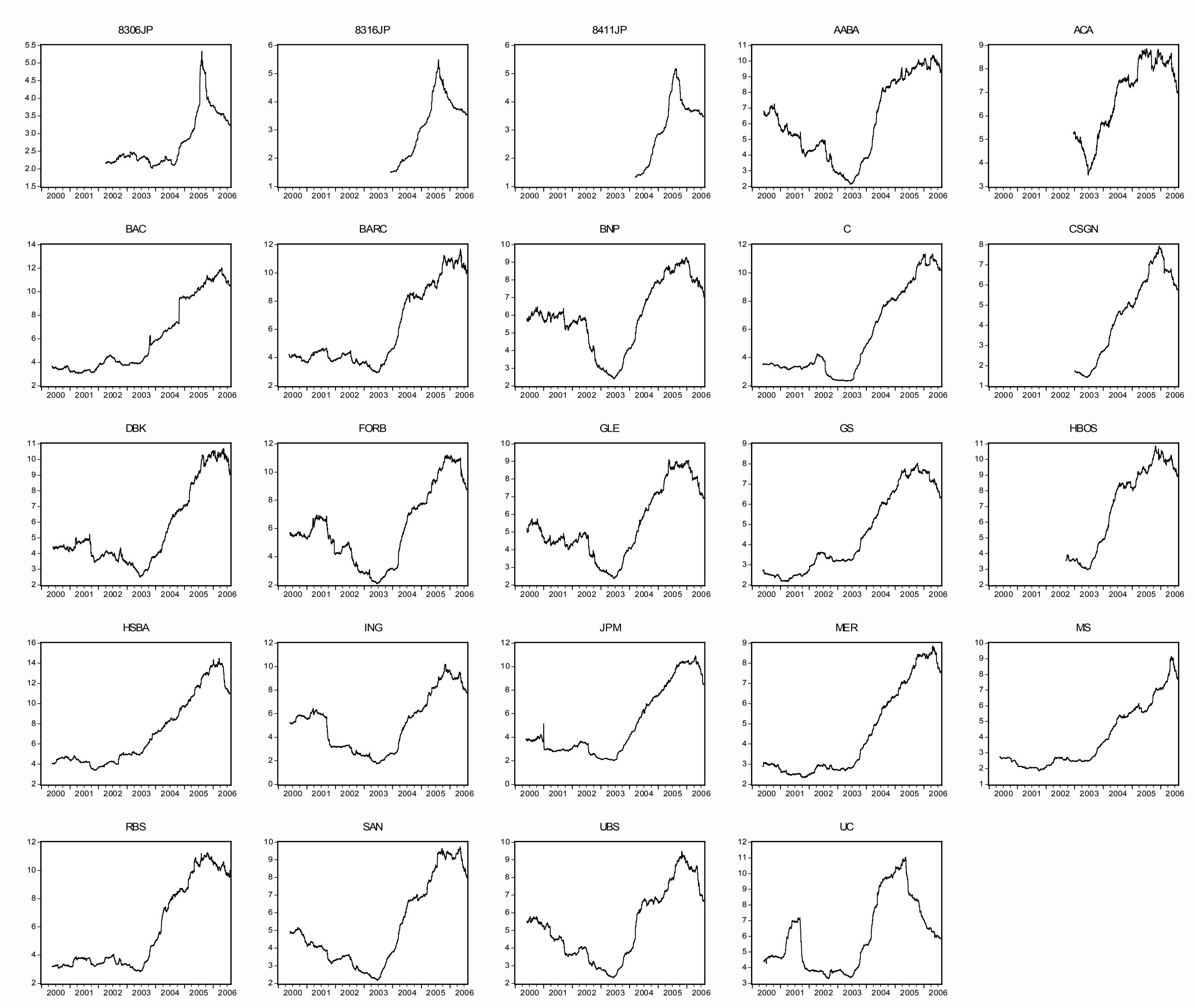
(A.6) $$d_1 = \frac{\ln \frac{V_t}{D} + \left(r - \frac{\sigma_A^2}{2} \right) T}{\sigma_A \sqrt{T}}\text{, and}$$

(A.7) $$d_2 = d_1 - \sigma_A \sqrt{T}\ .$$

The first two parameters can be calibrated from market data: the value of equity corresponds to the market value of the firm, and the equity volatility corresponds either to historical equity volatility or implied volatility from equity options. The last parameter, the face value of liabilities, D, is usually assumed equal to the face value of short-term liabilities plus half of the face value of long-term liabilities; the time horizon T is usually fixed at one year.[41] Once the asset value and volatility are estimated, the default probability of the firm could be derived from equation (A.3).

[41] This is based on work done by Moody's KMV (see Crosbie and Bohn, 2003).

Figure A.5. Distances-to-Default of Individual Banks



Sources: Bankscope; Bloomberg L.P.; and authors' calculations.

Appendix III. The Binomial LOGIT Model

Step 1: Defining the "Extreme Values"

We begin by calculating the weekly (5 trading-day) changes in the distance-to-default. The *DD*s are derived per Appendix 2, and the changes in the *DD*s (Δ*DD*s) are calculated as follows:

(A.8) $$\Delta DD_{it} = \frac{DD_{it} - DD_{it-5}}{| DD_{it-5} |}.$$

We then stack all ΔDD_{it} observations from equation (A.8) and calculate the threshold, T_{10}, for the bottom 10 percent tail.[42] For estimation purposes, we initially omit six banks—the three Japanese banks, Credit Agricole (France), Credit Swiss (Switzerland) and HBOS (United Kingdom)—due to the shorter periods for which their respective data are available.[43] From the remaining 18 banks over the sample period May 30, 2000 through August 2, 2006, the threshold for the 10th percentile left tail is calculated at −0.018. Observations that fall below this threshold, that is, in the bottom 10 percent tail, are the "extreme values".

Step 2: Applying the Econometric Model

A co-exceedance is defined as the probability that a particular bank will experience a large negative shock as a result of shock to another bank in the sample, after controlling for common shocks. The co-exceedances for each bank *i* at time *t* are defined as binary variables, y_{it}, such that:

(A.9) $$y_{it} = 1 \text{ if } \Delta DD_{it} < T_{10}, \text{ and 0 otherwise,}$$

where T_{10} is the 10th percentile threshold in the left tail of the distribution.

We estimate the conditional probability that bank *i* will be in distress at time *t* conditional on bank *j* ($j \neq i$) being in distress, after controlling for other country-specific and global factors, as:

(A.10) $$\Pr(y_{it} = 1 | x, \beta) = \frac{e^{\alpha_i F_{it} + \sum_{s=1}^{5} \rho_{si} C_{it-s} + \gamma_j \sum_{j=1}^{B} C_{jt-1}}}{1 + e^{\alpha_i F_{it} + \sum_{s=1}^{5} \rho_{si} C_{it-s} + \gamma_j \sum_{j=1}^{B} C_{jt-1}}},$$

---

[42] We initially calculate the 5 percent tail, but there are too few observations for estimation purposes.

[43] See Appendix 4 for details on the dataset.

which is based on the cumulative distribution function for the logistic distribution, x represents the explanatory variables F and C, and β the slope coefficients α, ρ, γ. The parameter α represents the sensitivity of bank i to real and financial developments in its own country and in the global market, F_{it}; ρ represents the sensitivity of bank i to extreme shocks it has experienced itself in the previous periods of up to s lags, C_{it-s};[44] and γ represents the sensitivity of bank i to extreme shocks experienced by the rest of the banks in the sample during the previous period, C_{jt-1} (where $j \neq i$), or in other words, the co-exceedance of bank i with other banks. All the C variables are lagged by one period to capture the impact on bank i from developments at the other banks, taking into account the differences in trading hours across the different time zones. The other explanatory variables are defined in the next sub-section.[45]

The goodness of fit in LOGIT (and other binary) models is given by the McFadden R^2. This statistic is the likelihood ratio index, computed as:

$$\text{(A.11)} \qquad R^2 = \frac{(1 - l(\tilde{\beta}))}{l(\tilde{\beta})},$$

where $l(\tilde{\beta})$ is the restricted log likelihood—this is the maximized log likelihood value when all slope coefficients are restricted to zero, and is equivalent to estimating the unconditional mean probability of an observation being in the tail.

Step 3: Incorporating Non-Bank Explanatory Variables

Country-Specific Market Shocks

We use the local stock market return volatility to control for country-specific market shocks. We calculate the weekly (5 trading-day) returns on each country-specific stock index by taking the weekly log-difference of the stock index in the local currency.[46] The volatility of returns is proxied by the conditional variance estimated from a GARCH(1,1) model of the weekly returns, such that,[47]

$$\text{(A.12)} \qquad X_t = c + \varepsilon_t, \text{ and}$$

[44] This operation adjusts for any serial correlation in the residuals, which may be induced by our use of overlapping weekly ΔDDs.

[45] The results are not significantly different when we apply the GOMPIT distribution, instead of the LOGIT distribution.

[46] See Table A.4, Appendix 6 for the list of stock market indices in our sample countries.

[47] This method was introduced by Ding and Engle (1994), and subsequently applied by De Santis and Gerard (1997, 1998), Ledoit, Santa-Clara and Wolf (2003) and Bae, Karolyi and Stulz (2003).

(A.13) $$\sigma_t^2 = w + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2,$$

where X_t is the weekly local currency return in the country's stock price index and σ_t^2 is the GARCH volatility, at time *t*,. The ARCH effect is captured by the lagged square residual, ε_{t-1}^2. We predict this period's variance by forming the weighted average of a long term average (the constant, *w*), the forecast variance from the previous period (σ_{t-1}^2), and information about volatility observed in the last period (ε_{t-1}^2). This model is consistent with the volatility clustering associated with financial returns data, where large changes in returns are likely to be followed by further large changes. Lagrange multiplier tests show significant ARCH(1) effects for all the stock market returns used in this paper.

Developments in the Real Economy

We use (5 trading-day) changes in term structure spreads to represent expectations of changes in the business cycle in a bank's home country. Put another way, the changes in the spreads reflect the broader real economy developments in that country. The term structure spread is calculated as the difference between a long-term interest rate (the 10-year government bond yield) and a short term rate (the 1-year government bond yield) in any one country.[48] Thus, the *change* in yield curve slope—our explanatory variable—is defined as follows:

(A.14) $$\Delta yc_t = \frac{yc_t - yc_{t-5}}{|\, yc_{t-5} \,|},$$

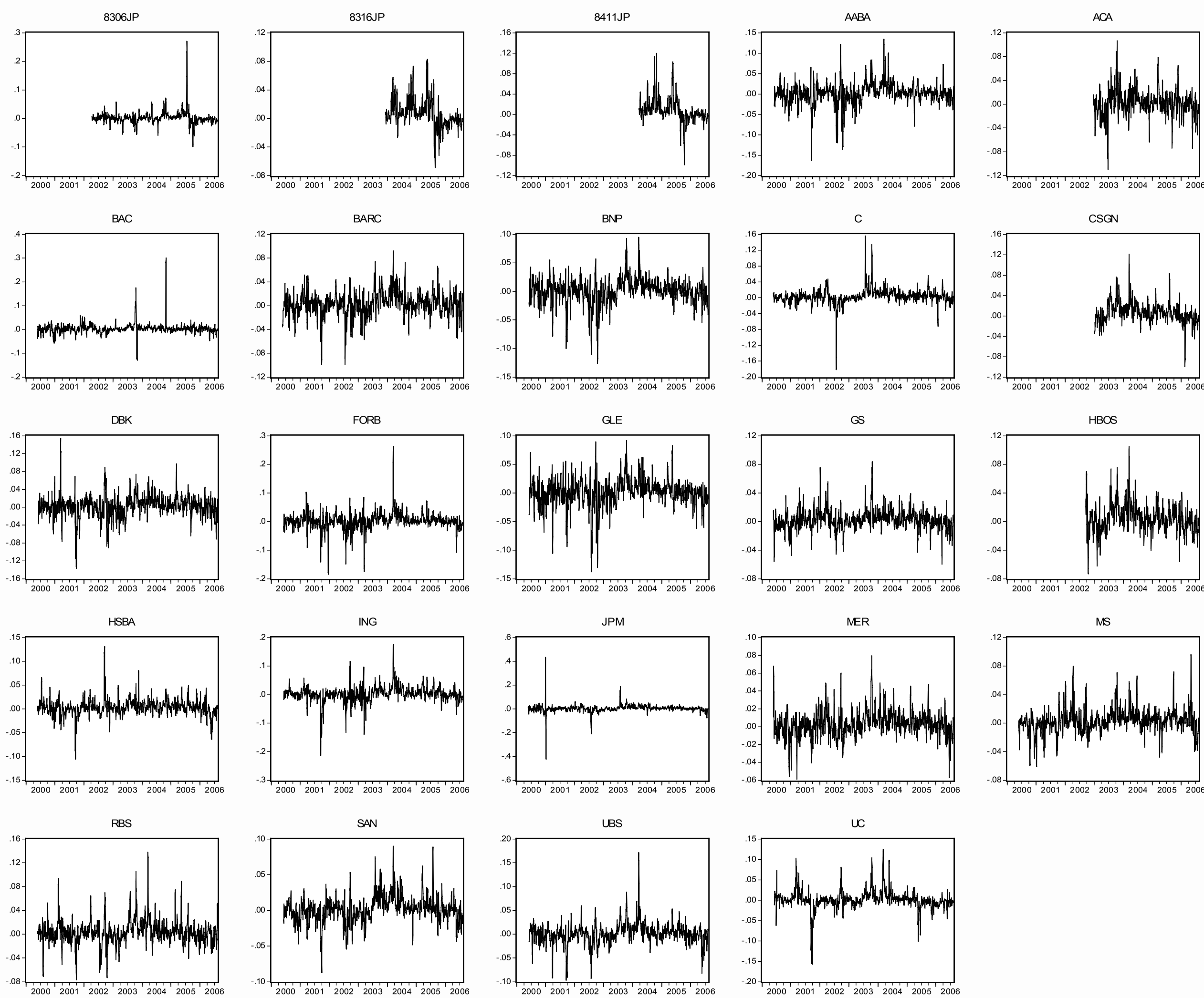
where yc_t is the term structure spread at time *t*.

Global Market Shocks

We apply a global stock market return volatility variable to control for common shocks affecting global markets. In this case, we use the weekly return volatility of the MSCI ACWI. This index is published in U.S. dollars, but is converted to the currency of the country in which the bank associated with the dependent variable is located. We use the same method as that for the local stock markets, and estimate the GARCH(1,1) volatility for the MSCI AWCI.

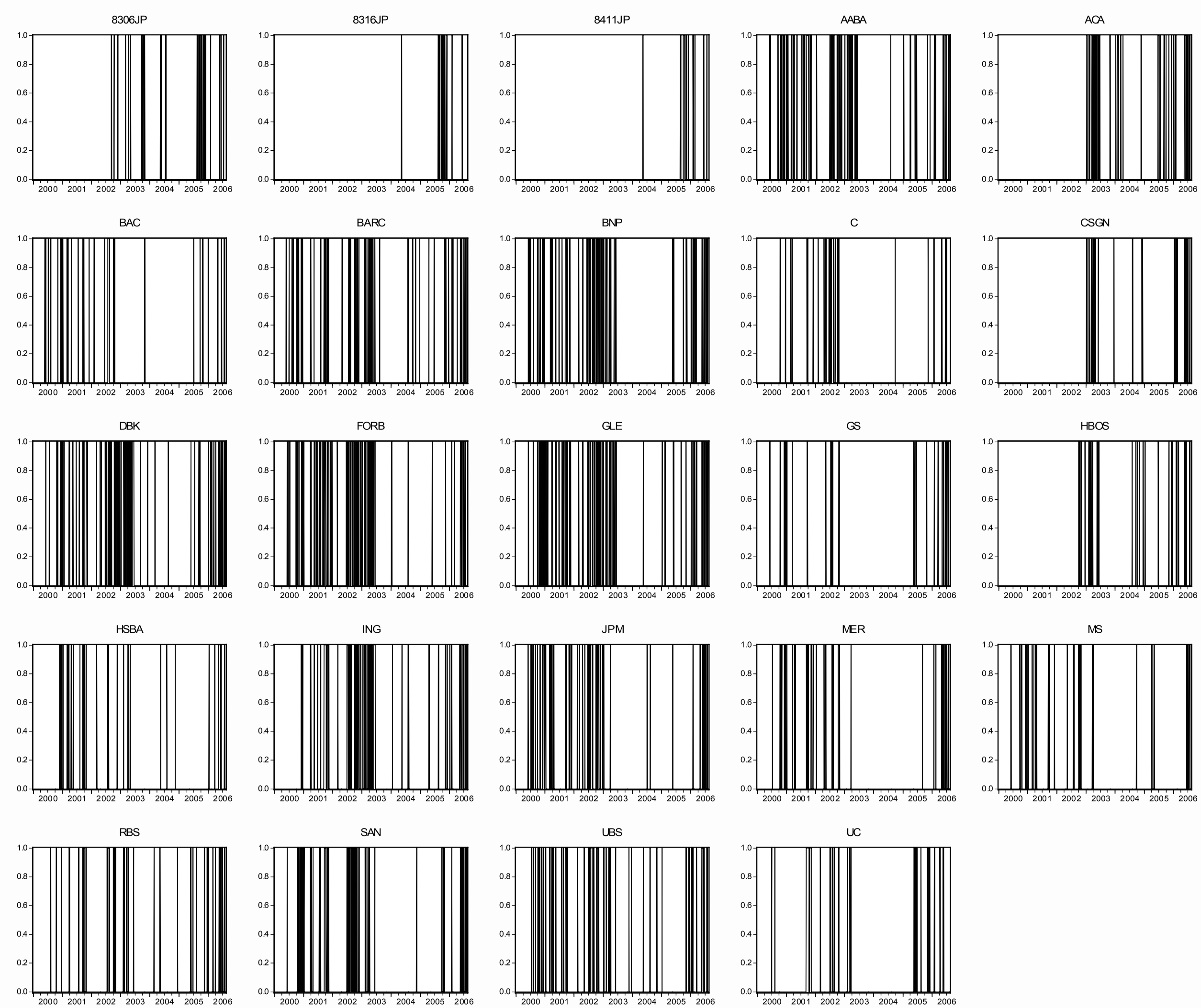
[48] See Table A.2, Appendix 4 for the list of government bonds used in our calculations.

Figure A.6. Changes in the Distances-to-Default of Individual Banks



Sources: Bankscope, Bloomberg L.P. and authors' calculations.

Figure A.7. Binomial LOGIT Representations of the 10th Percentile Left Tail (“Extreme Values” or “Exceedances”) of Individual Banks



Sources: Bankscope; Bloomberg L.P.; and authors’ calculations.

Appendix IV. Data Details

Table A.1. List of Exchange-Listed Banks

Rank by Total Assets as at End-2005	Banking Group	Nationality	Bloomberg Ticker	Date from which DD Data are Available
1.	Barclays PLC*	United Kingdom	BARC LN	May 17, 2000
2.	UBS AG*	Switzerland	UBSN VX	May 30, 2000
3.	Mitsubishi UFJ Financial Group Inc.	Japan	8306 JP	April 3, 2002
4.	HSBC Holdings PLC*	United Kingdom	HSBA LN	May 17, 2000
5.	Citigroup Inc.*	United States	C US	May 17, 2000
6.	BNP Paribas*	France	BNP FP	May 30, 2000
7.	ING Groep NV	Netherlands	INGA NA	May 30, 2000
8.	Royal Bank of Scotland Group PLC*	United Kingdom	RBS LN	May 17, 2000
9.	Bank of America Corporation*	United States	BAC US	May 17, 2000
10.	Crédit Agricole SA	France	ACA FP	December 16, 2002
11.	Mizuho Financial Group	Japan	8411 JP	March 12, 2004
12.	JP Morgan Chase & Co.*	United States	JPM US	May 17, 2000
13.	Deutsche Bank AG*	Germany	DBK GR	May 30, 2000
14.	ABN Amro Holding NV*	Netherlands	AABA NA	May 30, 2000
15.	Credit Suisse Group*	Switzerland	CSGN VX	January 1, 2003
16.	Société Générale*	France	GLE FP	May 30, 2000
17.	Banco Santander Central Hispano SA	Spain	SAN SM	May 30, 2000
18.	HBOS PLC*	United Kingdom	HBOS LN	September 11, 2002
19.	UniCredito Italiano SpA	Italy	UC IM	May 30, 2000
20.	Morgan Stanley*	United States	MS US	May 17, 2000
21.	Sumitomo Mitsui Financial Group, Inc.	Japan	8316 JP	December 3, 2003
22.	Fortis	Belgium	FORB BB	May 30, 2000
23.	Goldman Sachs Group, Inc.*	United States	GS US	May 17, 2000
24.	Merrill Lynch & Co., Inc.*	United States	MER US	May 17, 2000

* Identified by the Bank of England (BoE, 2006) as large, complex financial institutions (LCFIs), which carry out a diverse and complex range of activities in major financial centers.

Sources: Bankscope and Bloomberg L.P.

Table A.2. Stock Market Indices and Government Bond Yields

Country	Stock Market		Bond	
	Index	Bloomberg Ticker	Maturity	Bloomberg Ticker
Belgium	BEL 20	BEL20	EUR Belgium sovereign zero coupon yield, 1-year	I90001Y
			EUR Belgium sovereign zero coupon yield, 10-year	I90010Y
France	CAC 40	CAC	EUR France sovereign zero coupon yield, 1-year	I01401Y
			EUR France sovereign zero coupon yield, 10-year	I01410Y
Germany	DAX 30	DAX	EUR Germany sovereign zero coupon yield, 1-year	F91001Y
			EUR Germany sovereign zero coupon yield, 10-year	F91010Y
Italy	S&P MIB	SPMIB	EUR Italy sovereign zero coupon yield, 1-year	F90501Y
			EUR Italy sovereign zero coupon yield, 10-year	F90510Y
Japan	Nikkei 225	NKY	JPY Japan sovereign 10-30 year zero coupon yield, 1-year	F10501Y
			JPY Japan sovereign 10-30 year zero coupon yield, 10-year	F10510Y
Netherlands	AEX	AEX	EUR Netherlands sovereign zero coupon yield, 1-year	F92001Y
			EUR Netherlands sovereign zero coupon yield, 10-year	F92010Y
Spain	IBEX 35	IBEX	EUR Spain sovereign zero coupon yield, 1-year	F90201Y
			EUR Spain sovereign zero coupon yield, 10-year	F90210Y
Switzerland	SMI	SMI	CHF Switzerland sovereign zero coupon yield, 1-year	F25601Y
			CHF Switzerland sovereign zero coupon yield, 10-year	F25610Y
U.K.	FTSE 100	UKX	GBP United Kingdom zero coupon yield, 1-year	I02201Y
			GBP United Kingdom zero coupon yield, 1-year	I02210Y
U.S.	S&P 500	SPX	USD Treasury actives zero coupon yield, 1-year	I02501Y
			USD Treasury actives zero coupon yield, 10-year	I02510Y
World	MSCI All-Country World	MXWD		

Sources: Bloomberg L.P., individual country stock exchanges and Morgan Stanley Capital International.

Appendix V. Examples of Binomial LOGIT Results Output

Table A.3. United Kingdom: Binomial LOGIT Results Output for Barclays, HSBC and RBS (18-Bank Sample) May 30, 2000 − August 2, 2006

Dependent Variable: Barclays
Method: ML - Binary Logit (Quadratic hill climbing)
Date: 08/21/06 Time: 16:22
Sample (adjusted): 5/30/2000 8/02/2006
Included observations: 1612 after adjustments
Convergence achieved after 5 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Standard Error	z-Statistic	Probability
Constant	-3.78	0.19	-20.24	0.00
Barclays(-1)	3.03	0.31	9.80	0.00
Barclays(-2)	0.76	0.37	2.04	0.04
Barclays(-3)	0.16	0.42	0.38	0.70
Barclays(-4)	-0.36	0.44	-0.82	0.41
Barclays(-5)	-1.11	0.42	-2.63	0.01
Volatility_FTSE 100	327.86	120.87	2.71	0.01
Change in term structure	-0.02	0.03	-0.68	0.50
Volatility_MSCI_ACWI	-214.54	177.70	-1.21	0.23
RBS(-1)	1.17	0.37	3.19	0.00
HSBC(-1)	1.28	0.37	3.45	0.00
Citigroup(-1)	0.32	0.51	0.63	0.53
Bank_of_America(-1)	-0.90	0.50	-1.79	0.07
JPMorgan_Chase(-1)	0.28	0.36	0.79	0.43
Morgan_Stanley(-1)	1.49	0.42	3.53	0.00
Goldman_Sachs(-1)	-0.46	0.53	-0.86	0.39
Merrill_Lynch(-1)	-1.07	0.52	-2.05	0.04
BNP_Paribas(-1)	0.08	0.39	0.21	0.83
Societe_Generale(-1)	-0.96	0.39	-2.44	0.01
ABN_Amro(-1)	1.02	0.31	3.32	0.00
ING(-1)	0.61	0.36	1.67	0.09
Deutsche(-1)	0.05	0.35	0.13	0.90
Fortis(-1)	0.18	0.37	0.48	0.63
Santander(-1)	-0.02	0.39	-0.05	0.96
UBS(-1)	0.62	0.33	1.87	0.06
Unicredito(-1)	0.61	0.36	1.71	0.09

Mean dependent var	0.11	S.D. dependent var	0.32
S.E. of regression	0.23	Akaike info criterion	0.40
Sum squared resid	80.78	Schwarz criterion	0.49
Log likelihood	-296.32	Hannan-Quinn criter.	0.43
Restr. log likelihood	-574.46	Avg. log likelihood	-0.18
LR statistic (25 df)	556.28	McFadden R-squared	0.48
Probability(LR stat)	0.00		
Obs with Dep=0	1427	Total obs	1612
Obs with Dep=1	185		

Dependent Variable: HSBC
Method: ML - Binary Logit (Quadratic hill climbing)
Date: 08/21/06 Time: 16:22
Sample (adjusted): 5/30/2000 8/02/2006
Included observations: 1612 after adjustments
Convergence achieved after 6 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Standard Error	z-Statistic	Probability
Constant	-4.55	0.26	-17.67	0.00
HSBC(-1)	5.09	0.49	10.28	0.00
HSBC(-2)	0.60	0.66	0.92	0.36
HSBC(-3)	-1.18	0.70	-1.67	0.09
HSBC(-4)	-0.35	0.66	-0.53	0.60
HSBC(-5)	0.41	0.63	0.65	0.52
Volatility_FTSE 100	54.84	159.73	0.34	0.73
Change in term structure	-0.04	0.05	-0.66	0.51
Volatility_MSCI_ACWI	245.61	210.52	1.17	0.24
RBS(-1)	-1.90	0.64	-2.97	0.00
Barclays(-1)	1.27	0.46	2.75	0.01
Citigroup(-1)	-0.25	0.63	-0.40	0.69
Bank_of_America(-1)	0.92	0.54	1.69	0.09
JPMorgan_Chase(-1)	-0.19	0.48	-0.39	0.70
Morgan_Stanley(-1)	0.18	0.60	0.30	0.77
Goldman_Sachs(-1)	0.61	0.58	1.06	0.29
Merrill_Lynch(-1)	0.31	0.58	0.53	0.60
BNP_Paribas(-1)	-0.45	0.57	-0.79	0.43
Societe_Generale(-1)	-1.01	0.55	-1.82	0.07
ABN_Amro(-1)	-0.12	0.50	-0.25	0.81
ING(-1)	0.10	0.55	0.19	0.85
Deutsche(-1)	0.33	0.49	0.69	0.49
Fortis(-1)	0.55	0.51	1.07	0.28
Santander(-1)	0.55	0.54	1.03	0.31
UBS(-1)	0.42	0.43	0.97	0.33
Unicredito(-1)	0.71	0.51	1.38	0.17

Mean dependent var	0.06	S.D. dependent var	0.25
S.E. of regression	0.16	Akaike info criterion	0.25
Sum squared resid	42.66	Schwarz criterion	0.34
Log likelihood	-178.08	Hannan-Quinn criter.	0.29
Restr. log likelihood	-385.62	Avg. log likelihood	-0.11
LR statistic (25 df)	415.08	McFadden R-squared	0.54
Probability(LR stat)	0.00		
Obs with Dep=0	1508	Total obs	1612
Obs with Dep=1	104		

Dependent Variable: RBS
Method: ML - Binary Logit (Quadratic hill climbing)
Date: 08/21/06 Time: 16:22
Sample (adjusted): 5/30/2000 8/02/2006
Included observations: 1612 after adjustments
Convergence achieved after 6 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Standard Error	z-Statistic	Probability
Constant	-4.17	0.21	-19.77	0.00
RBS(-1)	3.62	0.40	9.02	0.00
RBS(-2)	-0.20	0.51	-0.39	0.70
RBS(-3)	0.42	0.56	0.75	0.45
RBS(-4)	-0.23	0.66	-0.35	0.73
RBS(-5)	-0.47	0.61	-0.77	0.44
Volatility_FTSE 100	406.61	147.27	2.76	0.01
Change in term structure	-0.08	0.05	-1.56	0.12
Volatility_MSCI_ACWI	-62.55	205.07	-0.31	0.76
HSBC(-1)	0.56	0.44	1.27	0.20
Barclays(-1)	0.99	0.37	2.68	0.01
Citigroup(-1)	0.55	0.56	0.98	0.33
Bank_of_America(-1)	0.69	0.47	1.47	0.14
JPMorgan_Chase(-1)	-0.07	0.44	-0.16	0.88
Morgan_Stanley(-1)	0.11	0.59	0.19	0.85
Goldman_Sachs(-1)	-0.62	0.63	-1.00	0.32
Merrill_Lynch(-1)	-0.50	0.65	-0.77	0.44
BNP_Paribas(-1)	0.58	0.45	1.27	0.20
Societe_Generale(-1)	-0.56	0.47	-1.20	0.23
ABN_Amro(-1)	-0.05	0.44	-0.12	0.91
ING(-1)	0.19	0.46	0.40	0.69
Deutsche(-1)	-0.55	0.45	-1.22	0.22
Fortis(-1)	0.35	0.45	0.79	0.43
Santander(-1)	0.28	0.48	0.57	0.57
UBS(-1)	0.66	0.40	1.65	0.10
Unicredito(-1)	0.04	0.45	0.08	0.93

Mean dependent var	0.08	S.D. dependent var	0.27
S.E. of regression	0.19	Akaike info criterion	0.31
Sum squared resid	57.75	Schwarz criterion	0.40
Log likelihood	-224.73	Hannan-Quinn criter.	0.34
Restr. log likelihood	-447.03	Avg. log likelihood	-0.14
LR statistic (25 df)	444.60	McFadden R-squared	0.50
Probability(LR stat)	0.00		
Obs with Dep=0	1484	Total obs	1612
Obs with Dep=1	128		

Sources: Bankscope; Bloomberg L.P.; and authors' calculations.

Appendix VI. Stock Market Capitalization

Table A.4. Market Capitalization of Stock Market Indices and Banks, August 2006

	Market Capitalization	
	Value in Local Currency	Percent of Index
Belgium (BEL 20)	***226.6***	
Fortis	39.1	17.3
Total		*17.3*
France (CAC 40)	***1,180.0***	
BNP Paribas	77.9	6.6
Crédit Agricole SA	49.5	4.2
Société Générale	55.9	4.7
Total		*15.5*
Germany (DAX 30)	***715.0***	
Deutsche Bank AG	45.9	6.4
Total		*6.4*
Italy (S&P MIB)	***547.9***	
UniCredito Italiano SpA	65.6	12.0
Total		*12.0*
Japan (Nikkei 225)	***342,900.0***	
Mitsubishi UFJ Financial Group Inc.	17,541.7	5.1
Mizuho Financial Group	11,468.5	3.3
Sumitomo Mitsui Financial Group, Inc.	9,577.2	2.8
Total		*11.3*
Netherlands (AEX)	***474.9***	
ING Groep NV	73.3	15.4
ABN Amro Holding NV	40.6	8.5
Total		*24.0*
Spain (IBEX 35)	***483.0***	
Banco Santander Central Hispano SA	75.7	15.7
Total		*15.7*
Switzerland (SMI)	***1,070.0***	
UBS AG	146.7	13.7
Credit Suisse Group*	85.4	8.0
Total		*21.7*
United Kingdom (FTSE 100)	***1,470.0***	
Barclays PLC	42.3	2.9
HSBC Holdings PLC	110.2	7.5
Royal Bank of Scotland Group PLC	56.0	3.8
HBOS PLC*	38.0	2.6
Total		*16.8*
United States (S&P 500)	***11,850.0***	
Citigroup Inc.	239.9	2.0
Bank of America Corporation	236.7	2.0
JP Morgan Chase & Co.	157.8	1.3
Morgan Stanley	71.8	0.6
Goldman Sachs Group, Inc	69.8	0.6
Merrill Lynch & Co., Inc.	66.8	0.6
Total		*7.1*

Sources: Bloomberg L.P.; and authors’ calculations.

Appendix VII. Binomial LOGIT Results for 24-Bank Sample

Table A.5. Contagion Risk among the World's Largest Banking Groups (24-Bank Sample), March 12, 2004 − August 2, 2006
(In percent level of significance)

Country		Contagion to: Belgium	France			Germany	Italy	Japan			Netherlands		Spain	Switzerland		United Kingdom				United States					
	Bank	Fortis	BNP Paribas	Credit Agricole	Societe Generale	Deutsche Bank	Unicredito	Mitsubishi UFJ	Mizuho	Sumitomo	ABN Amro	ING	Santander	Credit Suisse	UBS	Barclays	HBOS	HSBC	RBS	Bank of America	Citigroup	Goldman Sachs	JP Morgan Chase	Merrill Lynch	Morgan Stanley
	Initial shock to:																								
Belgium	Fortis				5.0																				
France	BNP Paribas					1.0										5.0								5.0	
	Credit Agricole		5.0			1.0																			
	Societe Generale	1.0		5.0			5.0		1.0	5.0			5.0												
Germany	Deutsche Bank																								
Italy	Unicredito										5.0	1.0				1.0									
Japan	Mitsubishi UFJ								1.0	5.0			5.0												
	Mizuho							5.0			1.0														
	Sumitomo							5.0																	
Netherlands	ABN Amro									5.0															
	ING																				5.0				
Spain	Santander	5.0		1.0				1.0	1.0						5.0										
Switzerland	Credit Suisse														5.0										
	UBS															1.0	1.0								
U.K.	Barclays																5.0		5.0						
	HBOS																								
	HSBC					1.0						5.0	1.0												
	RBS	1.0	1.0		5.0															5.0					
U.S.	Bank of America																				1.0				
	Citigroup	5.0		5.0			5.0						5.0					5.0						1.0	
	Goldman Sachs																						5.0		
	JP Morgan Chase																								
	Merrill Lynch																				5.0				
	Morgan Stanley	1.0									1.0		1.0			1.0						1.0			
Other factors	Constant	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Local market volatility	1.0		5.0				5.0	1.0	5.0		1.0	5.0		1.0										
	Change in term structure					1.0																			
	Global market volatility																								
	McFadden R^2	0.81	0.57	0.60	0.58	0.56	0.53	0.54	0.70	0.55	0.51	0.61	0.63	0.57	0.54	0.52	0.52	0.67	0.35	0.57	0.73	0.54	0.62	0.69	0.74

Notes: Columns represent dependent variables; rows represent explanatory variables.
Blank cells represent non-significance at any level below 5 percent.
represents significance at the 5 percent level or lower.
represents significance at the 1 percent level or lower.
represents significance (negative sign) at the 5 percent level or lower.
represents coefficients on own-lags, of up to 5 lags.
represents the grouping of major banks in any one country, where 3 or more banks are represented in the sample.
Given the short sample period, a few banks with very few co-exceedances with other banks have to be dropped for the estimation processes to converge.

Sources: Bankscope; Bloomberg L.P.; and authors' calculations.

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