FIW – Working Paper

FIW Working Paper N° 129
December 2013

Cross-Border Interbank Networks, Banking Risk and Contagion

Lena Tonzer[1]

Abstract

Recent events emphasize the role of cross-border linkages between banking systems in transmitting local developments across national borders. This paper analyzes whether international linkages in interbank markets affect the stability of interconnected banking systems and channel financial distress within a network consisting of banking systems of main advanced countries for the period 1993-2009. Methodologically, I use a spatial modelling approach to test for spillovers in cross-border interbank markets. The results suggest that foreign exposures in banking play a significant role in channelling banking risk: I find that countries which are linked through foreign borrowing or lending positions to more stable banking systems abroad are significantly affected by positive spillover effects. From a policy point of view, this implies that especially in stable times linkages in the banking system can be beneficial, while they have to be taken with caution in times of financial turmoil covering the whole system.

JEL: F21, F34, F65, G21, O16
Keywords: Financial contagion, financial integration, banking networks

Author

[1] European University Institute, Economics Department, Villa San Paolo, Via della Piazzuola 43, 50133 Florence, Italy. E-Mail: lena.tonzer@eui.eu

Cross-Border Interbank Networks, Banking Risk and Contagion*

Lena Tonzer†

December 2013

Abstract

Recent events emphasize the role of cross-border linkages between banking systems in transmitting local developments across national borders. This paper analyzes whether international linkages in interbank markets affect the stability of interconnected banking systems and channel financial distress within a network consisting of banking systems of main advanced countries for the period 1993-2009. Methodologically, I use a spatial modelling approach to test for spillovers in cross-border interbank markets. The results suggest that foreign exposures in banking play a significant role in channelling banking risk: I find that countries which are linked through foreign borrowing or lending positions to more stable banking systems abroad are significantly affected by positive spillover effects. From a policy point of view, this implies that especially in stable times linkages in the banking system can be beneficial, while they have to be taken with caution in times of financial turmoil covering the whole system.

Keywords: Financial contagion, financial integration, banking networks
JEL Classification: F21, F34, F65, G21, O16

---

*I am grateful to Elena Carletti and Massimiliano Marcellino for continuous advice and encouragement. A special thanks goes to Claudia Buch for many valuable suggestions. I also like to thank Söhnke M. Bartram, Sylvain Benoit, Peter Hansen, Marlene Karl, Katja Neugebauer, Marco Mazzoli, Gianni de Nicolò, Bruno Parigi, Eleonora Patacchini, Christian Pierdzioch, Esteban Prieto and conference participants at the European University Institute, the Otto von Guericke University of Magdeburg, the Oesterreichischen Nationalbank, the Helmut Schmidt University and the Università Politecnica delle Marche (MoFiR) for useful comments. Furthermore, I am thankful to the Bank for International Settlements for kindly providing data. All errors and inaccuracies are solely in my own responsibility.

†European University Institute, Economics Department, Villa San Paolo, Via della Piazzuola 43, 50133 Florence, Italy. E-Mail: lena.tonzer@eui.eu

1 Introduction

Banking has become more international over the last twenty years. While this development can have beneficial effects like channelling financial resources to their most productive uses or improving consumption smoothing and risk-sharing possibilities, it also raises a broad range of questions (Agénor, 2003; Allen et al., 2011). Amongst others, do cross-border links in banking make countries more susceptible to contagion risk and do interconnected systems facilitate the transmission of economic developments across national borders? Understanding dynamics in intertwined banking systems is thereby essential for the assessment of systemic risks in the financial system and the design of efficient regulatory answers. The relevance of this is also reflected in the international attention cross-border linkages receive during the ongoing sovereign debt crises due to the fear that they can quickly transmit increased instabilities in one country to financially connected banking systems.

From the related theoretical literature it is well-known that the network topology has an important effect on the probability of contagion (Allen and Gale, 2000; Allen et al., 2012; Gai and Kapadia, 2010). Applying network concepts helps to formalize interconnections and resulting contagion risk in the financial system. Nodes in the network correspond to banks that are connected through links taking the form of asset or liability exposures. The main message derived from network models is that the stability of one node or bank cannot be assessed in isolation but is determined by the structure of the links and properties of interconnected nodes. This implies that systemic stability can only be understood if the network structure of financial links is taken into account.

Under this perspective, it seems surprising that the existing empirical literature on this topic is relatively scarce. For example, Minoiu and Reyes (2013) study characteristics of the network structure of the global banking network and find that connectivity is relatively volatile with decreasing degrees of interconnectedness during and in the aftermath of systemic banking or sovereign debt crises. Their focus is, however, on descriptive statistics of network measures and the effect of characteristics of the network composition on stability is rarely analyzed in the international banking literature.[1] Thus, the aim of this analysis is to detect if cross-border interbank linkages as well as the degree of interconnectedness in the interbank network affect contagion risk.[2]

[1]Network analysis applied to the financial system can be found in Diebold and Yilmaz (2011) who describe the network structure of major US financial firms relying on variance decomposition. Billio et al. (2012) use econometric techniques like principal component analysis to study interconnectedness between financial sectors.

[2]In this paper, contagion relates to the idea that events in one country spillover to another country

The empirical part of the paper is related to different strands of literature. First, there is an increasing amount of studies analyzing cross-border exposures in banking. However, in terms of the theoretical argument, i.e. links between different nodes can channel instabilities from one unit to another and cause contagion, their analysis stops halfway. On the one hand, various papers analyse determinants of changes in cross-border exposures but leave unclear whether these changes have an effect on the stability of the related country. For example, Cetorelli and Goldberg (2011) show that cross-border lending to emerging economies diminished during 2007-2009. This was mainly the case if foreign lending banks were located in a country suffering an adverse liquidity shock. On the other hand, Lane and Milesi-Ferretti (2011) look at the effect of changes in financial linkages on economic stability but do not consider whether these linkages change in response to developments ongoing in another, interlinked country. Also, there are studies that analyse factors which might cause banking crises or determine the stability of banks while ignoring effects coming from international exposures of a banking system (Beck et al., 2006; Boyd et al., 2009).

Second, and in contrast to the previous mentioned literature, studies like Upper and Worms (2004) or Degryse et al. (2010) match more closely the basic idea of the theoretical models.[3] In their setup, a bank/ banking system suffers a shock which can be transmitted to other banks/ banking systems through linkages between the individual entities. Relying on simulation techniques, Degryse et al. (2010), for example, find that liquidity shocks specific to one entity can cause a breakdown of the whole financial system. Hence, this approach can be a useful tool in examining the effects of shocks of different size in systems with different degrees of interconnectedness. However, these studies are in most cases based on aggregate balance sheet positions of banks due to the lack of disaggregated data on exposures between banks. Mutual links are simulated under the assumption that total interbank positions are distributed equally across counterparties using the maximum entropy method. This is certainly a strong assumption which might drive the results. For example, Mistrulli (2011) has a dataset on bilateral links in the Italian interbank market. He uses it to compare results obtained under the maximum entropy method to those based on actual interbank exposures and finds that contagion tends to be underestimated. Additionally, these studies are most often restricted to the analysis of contagion risk within one country and for one time period.

The third strand resolves the last mentioned problem and analyses the transmission

through links in the banking sector which establish interdependencies between country pairs. Thus, contagion and spillovers are used as synonyms.

[3]See also Degryse and Nguyen (2007), Elsinger et al. (2006) or Upper (2011) who summarizes this literature.

of shocks across countries using real data. A recent example is Eickmeier et al. (2011) who study the impact of US financial shocks on nine major advanced economies. Instead of imposing shocks and simulating their impact in simplified model frameworks, they obtain shocks from a Financial Condition Index to trace out the resulting effects and the underlying transmission channels in a FAVAR model. Though moving towards a setup which yields results directly related to real world data, there is no specific focus on linkages between banking systems as well as the network structure is not considered.

This analysis, in turn, uses real data on bilateral cross-border exposures in banking to answer the following questions: Do cross-border interbank linkages have an effect on the stability of banking systems? And if so, does the stability of a country's banking system affect the soundness of a banking system in another but interlinked country and which role plays the underlying network structure? Methodologically, evaluating spillovers within a network is not straightforward as intertwined network structures have to be taken into account. For example, think of changes in fundamentals in country A that have an effect on its banking system. If country A maintains linkages to banks in country B, there can be a spillover to the banking system in country B. In continuation, country C which is linked to country B may also be affected by now both direct changes in B and indirectly by the events taking place in country A. This argument can be continued and indicates that a proper econometric modelling approach of banking stability faces the challenge to consider not only effects of country-specific characteristics but also the possibility of direct spillovers from connected systems as well as third country effects. To do exactly this, i.e. to consider both direct and indirect effects of cross-border linkages on banking stability, I make use of a spatial modelling approach similar to Cohen-Cole et al. (2011) or Liedorp et al. (2010). This econometric technique enables to analyse how banking stability in one country is affected by events in other countries while accounting for interbank linkages among them. Effects stemming from changes in interbank asset or liability positions can be separated from spillovers arising from lending or borrowing to more or less stable banking systems. The empirical analysis is based on annual data for banking systems of main OECD countries over the period 1993-2009.

The paper contributes to the existing literature in several ways. First, the analysis links the empirical estimation approach to the framework and results found in theoretical work, e.g. Allen and Gale (2000). Second, the empirical strategy specifies a spatial model. This estimation method enables to study spillovers of instabilities within a network but was rarely used in the related literature. Third, I use data on bilateral cross-border banking exposures from the locational banking statistics of the Bank for International Settlements (BIS). This is contrary to most of the existing literature which analyses cross-border contagion relying on either aggregate and not bilateral exposures or focusing on international trade and stock market data (Forbes and Rigobon, 2002; Kali and Reyes, 2010).

The results indicate that cross-border interbank linkages are indeed a significant channel of banking risk across countries. Thereby, not only credit risk arising from foreign asset positions but also exposures on the liability side of the balance sheet are decisive. Banking systems of countries which are linked to more stable counterparties seem to benefit from cross-border linkages. The paper is organized as follows. Section 2 gives the theoretical motivation behind the empirical analysis. In Section 3, the data used in the study is explained. The econometric approach is described in Section 4. In the following Section 5, I present the results and investigate their sensitivity. The final section concludes.

2 Theoretical Motivation

Theoretical network papers suggest that interconnections in the banking system create channels that can transmit shocks between different units within the system. A survey of this literature can be found in Allen et al. (2009) or, with a particular focus on networks, in Allen and Babus (2009) who point out that applying network theory to financial systems is a useful approach to evaluate systemic risk and explain liquidity shortages in banking systems. A straightforward application of these concepts is provided by Allen and Gale (2000). Their basic idea is that overlapping claims connect different regions. This facilitates redistributing liquidity between regions and provides liquidity insurance.[4] At the same time, excessive liquidity shocks can cause contagion through cross-holdings of deposits. An important result is that the probability of contagion depends on the degree of interconnectedness. It turns out that the probability of contagion is higher with increasing but incomplete integration. When the network is complete, the impact of an unexpected liquidity shock is spread across many connected neighbours. This reduces both the risk of individual failures and following default cascades, thus increasing network resilience. Similarly, Nier et al. (2007) model the banking system as a network with different degrees of connectedness. Conducting numerical simulations to study the impact of bank-specific shocks, they find a non-monotonic relationship between connectivity and contagion risk. At low levels of connectivity, additional link formation increases contagion risk due to a dominating

[4]In a similar context, Freixas et al. (2000) introduce credit risk and analyse the coordinating role of financial authorities to mitigate liquidity strains in interbank networks, Brusco and Castiglionesi (2007) introduce moral hazard problems or Freixas and Holthausen (2005) focus on asymmetric information and the efficiency of international interbank markets.

role of links as transmission channels of shocks. Forming additional links decreases, however, contagion risk if connectivity is already high as in this scenario more links help withstanding shocks. Gai and Kapadia (2010) adopt a similar approach and develop a network model in which agents are linked by financial claims on each other. They find a "robust yet fragile" property of interlinked interbank markets. In highly connected systems contagion becomes less probable because of improved diversification possibilities whereas the effect of contagion once it occurs can be widespread due to a high number of interlinkages. While Gai and Kapadia (2010) or Nier et al. (2007) analyse arbitrary network structures, in Babus (2013) the outcome of a network formation game determines how bilateral linkages are formed. Also here, better connected systems are more likely to resist contagion and the model predicts that there is a threshold of interconnectedness above which contagion risk vanishes.[5]

Although there was an increase in the theoretical literature on systemic risk and shock propagation in networks, a thorough understanding of how interactions in networks affect systemic stability is still missing (Schweitzer et al., 2009; European Central Bank, 2010). The more so, this holds in empirical terms. This is mainly due to the non-availability of disaggregated data but also a lack of appropriate empirical methods able to account for time-varying network structures and systemic interactions between network nodes. This paper intends to advance into this direction. The analysis develops an estimation setup to test key predictions derived from theoretical network models and examine their implications for contagion risk at the international level. The empirical model follows theoretical frameworks to the point that the sample consists of a network of national banking systems which are connected by cross-border exposures. The latter form links between nodes in the network and can have stabilizing effects but also transmit contagion risk. Compared to most of the theoretical network models, the concept of contagion is weakened. Instead of studying if a banking crisis in one country spills over to another through cross-border linkages, the analysis looks at whether fragility/ stability of a banking system is transmitted to a different but connected system. The reasoning goes back to the recent crisis during which, even without necessarily observing bankruptcies, international interbank linkages affected banking stability. Cross-linkages are likely to transmit shocks also in a more indirect way since the mere knowledge that a country has claims on an increasingly fragile banking system of another country can be sufficient to increase volatility in the lending country.

Without doubt, real data is subject to more influences than what theoretical frameworks would suggest. For example, the number of regions is not limited to four as in

[5]See Allen et al. (2012) and Cabrales et al. (2013) for analytical models on network formation, welfare considerations and the trade-off between insurance and contagion risk.

Allen and Gale (2000) and within the network there might be financial centres acting as common lenders. In general, the institutional environment, bank specific characteristics like the size of the banking system or concentration as well as macroeconomic developments can vary between countries and have an effect on the resilience of individual banking systems. Hence, these factors are taken into account in the empirical analysis. Despite the fact that theoretical models tend to be based on a set of simplifying assumptions limiting a one-to-one empirical implementation, they offer testable implications. These will be outlined in the following.

Hypothesis 1: *Interconnections in banking allow for improved risk-sharing possibilities among banks. At the same time, however, they can favour the spread of shocks through the banking system.*

This follows from the main argument made by Allen and Gale (2000) and outlined above. In tranquil times, cross-links between banks enhance risk-sharing and liquidity allocation whereas in times of crises the spread of shocks across regions is facilitated. In the context of cross-border banking, cross-links towards banking systems abroad can thus improve risk-sharing, lower the impact of domestic shocks and banking risk at home. This occurs as international connections in banking open up diversification possibilities of individual risks and reduce the probability of regional defaults. Risk-sharing is enhanced the higher the number of counterparties with which the initially hit banking system can share the shock. However, cross-links can be detrimental and cause feedback effects if they are maintained to banking systems under financial distress (see also Stiglitz 2010). This mirrors the opposite of the before mentioned and the trade-off between risk-sharing possibilities and contagion risk. Contagion is facilitated through the existence of cross-linkages and it should be analyzed if cross-links to more (less) stable banking systems have a positive (negative) effect on stability at home. In addition, common adverse shocks can be amplified if there are feedback effects between interconnected systems and the effect of being linked to other banking systems might vary between non-crisis times compared to periods in which financial markets as a whole are under distress (Georg 2011).

Hypothesis 2: *The trade-off between risk-sharing possibilities and contagion risk can be affected by the degree of diversification or interconnectedness.*

Following traditional theoretical arguments raised by e.g. Diamond (1984) or Winton (1999), diversification allows banks reducing risks and the general advice that follows is not to "put all eggs into one basket". As regards foreign asset holdings, this suggests that a more geographically diversified portfolio can lower the probability of distress events. While at first sight more diversified portfolios should be stability enhancing, foreign activities are likely to be related to higher monitoring and information costs especially if cultural and geographic proximity to the foreign counterparty is low. An expansion into additional foreign banking markets might thus lead to decreased effectiveness of monitoring, a weakened quality of the loan portfolio and increased solvency risk. Additionally, establishing more links implies a higher number of potential channels of contagion risk. The probability of spillovers can thereby be affected by the degree of diversification or interconnectedness. Theoretical results point towards a non-monotonic relationship (Allen and Gale, 2000; Cifuentes et al., 2005; Gai and Kapadia, 2010). Contagion risk tends to be highest in incomplete network structures while the benefits of diversification are likely to become evident in complete networks. In contrast, recent studies like Battiston et al. (2012) claim that a higher network density and increased risk diversification - while contributing to lower individual risk - increase systemic risk (see also Wagner (2010)). Whether increasing network density has a positive or negative net outcome on the resilience of the system is not clear a priori but depends on the network structure and the heterogeneity in financial characteristics of the network elements. For example, in their model a higher level of interdependence makes the system more stable if banks in the network are similar in their equity ratios. Yet, increasing connectivity can cause systemic collapses if banks are heterogenous and the average equity ratio is low. In the latter case, more connections spread instabilities more easily and cause a higher number of defaults as it is likely that already more fragile banks are hit. Hence, full integration in the international banking network might not necessarily be optimal if the risk of a system-wide breakdown is increased and proper regulation frameworks are missing in order to deal with these issues (Stiglitz (2010)).

Hypothesis 3: *Stronger links taking the form of larger interbank exposures tend to increase contagion risk.*

The effect of interbank connections might not only depend on how they are diversified across counterparties but also on their size. For example, Nier et al. (2007) show that for a given level of connectivity an increase in interbank asset exposures relative to total assets facilitates the propagation of shocks and causes a higher number of defaults. Notably, their result is obtained under the assumption that banks have to adjust their capital holdings against higher amounts of interbank asset exposures. In the same vein, Georg (2013) analyzes contagion risk in different types of networks and finds that interbank loan volumes above an upper threshold decrease systemic stability. Contagion risk increases as shocks propagate rapidly for large amounts of interbank liquidity. The threshold level depends, thereby, on the level of connectivity. Larger exposures are less likely to conflict with financial stability for higher levels of interconnectedness. In the case of cross-border banking, larger international exposures can be assumed to make banking systems prone to spillovers. Especially to unexpected withdrawals or sudden losses in cross-border claims, banking systems might not be able to withstand in the short run. In how far this holds true might depend on the level of network diversification. Thus, it will be tested if the amount of foreign claims directed towards a network of banking systems affects banking risk controlling for the degree of diversification achieved within the network.

3 Data and Descriptive Statistics

3.1 Data

Obtaining reliable and comparable data for characteristics of banking systems and mutual interconnectedness is not an easy task. Nevertheless, data availability allows to use a sample for the period 1993-2009 including 12 European countries, Canada, Japan and the United States.[6] All variables are on a yearly basis as this is for most variables the highest frequency provided by Bankscope.

3.1.1 Banks' international exposures

Data on banks' international balance sheet positions is obtained from the Bank for International Settlements (BIS). The locational banking statistics cover positions of banks located in a reporting country vis-à-vis counterparties outside the reporting country. Foreign positions can be denominated in local or foreign currency and include loans, deposits, debt securities and other asset positions. However, the main part of foreign positions consists of standard cross-border loans issued by banks in a reporting country vis-à-vis banks and non-bank institutions in a recipient country. Banks of a reporting country include all institutions allowed to receive deposits, grant credits and invest in securities on their account (BIS 2011). This definition comprises, amongst others, commercial banks, savings banks, credit unions but not central banks.

The data is disaggregated by type of counterparty, i.e. total cross-border positions as well as foreign positions towards the non-bank sector are reported. For this analysis, the difference between positions towards all sectors and the non-bank sector is used to get a measure for interbank exposures. As the data is reported on a quarterly basis, I take the average for a given year to obtain annual values for the stock data. Annual values for exchange rate adjusted changes in foreign exposures are calculated by summing up the corresponding values of the four quarters for a given year. This gives a measure for yearly capital flows. In contrast to aggregate international exposures of reporting

[6]The European countries are Belgium, Denmark, France, Germany, Italy, Ireland, Netherlands, Portugal, Spain, Sweden, Switzerland, United Kingdom. Thus, the sample includes only advanced economies and is rather homogenous from this point of view.

countries, bilateral cross-border positions towards individual recipient countries are not published in the locational banking statistics and have been made available by the BIS. The data aggregate bilateral cross-border asset and liability positions of all reporting institutions located in a reporting country but are disaggregated by recipient country such that the evolution of bilateral linkages over time and changes in the network structure can be examined.

It is to note that the locational banking statistics follow the balance of payment principle. This means that the reporting of aggregate cross-border assets and liabilities is based on the residence of the reporting bank. The data include positions towards foreign affiliates of domestic banks meaning that interoffice positions are not netted out. On the contrary, the consolidated banking statistics report cross-border positions of domestic banks and their foreign affiliates to counterparties residing outside the reporting country on a consolidated (net of interoffice positions) basis. Thus, this kind of data better reflects ultimate risk positions.

In this paper, I use bilateral data from the locational instead of the consolidated statistics as data on cross-border assets and liabilities is available for a long time horizon which is a valuable point given data restrictions due to the limited coverage of Bankscope.[7] Also, the locational banking statistics include exchange rate adjusted changes of cross-border exposures which can be taken as an approximation of changes in banks' stock data on international activities. Considering the spatial dimension of the research question, it seems furthermore reasonable to focus on the locational statistics which takes into account the geographic location of banks and thus the fact that banks residing in a reporting country form links to banks in other locations across space. For example, foreign affiliates might thus not only be affected by macroeconomic developments in their host country but also economic changes in the country of origin can be transmitted to them through balance sheet linkages to their headquarters and affect in turn stability in the host country.

3.1.2 Banking sector characteristics

Information on bank specific variables is obtained from the Financial Structure Database by Beck et al. (2009) who aggregate bank level data taken from Bankscope to the country level. Bankscope consists of harmonized balance sheet information on banks covering a wide range of countries and providing data from 1993 onwards. Although Bankscope does not include data on all banks in a given country, the coverage of the

[7] More information about data sources and transformations can be found in the Appendix.

database is on average 90% of all assets of commercial banks in a given country.[8] Thus, the data should be used carefully if indicators for the market structure are computed while fewer concerns arise if efficiency or stability measures are calculated.

The vector of variables to control for differences in size and structure, balance sheet positions and efficiency in banking systems across countries includes the ratio of assets of deposit money banks to GDP, concentration within the banking sector, private credit by deposit money banks to GDP and the cost to income ratio (Beck et al., 2011; Boyd et al., 2009). Larger banking systems should have better possibilities to diversify and cope with deteriorations in credit market conditions, which would result in a positive coefficient for the assets to GDP ratio. Not only the size characterizes a banking system but also its degree of concentration whereas the existing evidence on the relation between competition and fragility is contradictory. For example, the results of Boyd et al. (2009) indicate that there is no trade-off between bank competition and stability while Beck et al. (2006) find that more concentrated banking systems are less opposed to financial fragility as they face a lower probability of systemic crises. The ratio of private credit to GDP can be interpreted as a measure for financial development within the country such that higher levels should stabilize a banking system. However, excessive levels of credit expansion and lending booms tend to increase the number of bad quality loans in banks' balance sheets. Therefore, higher values of this variable can be negatively related to banking stability and the resulting sign of the respective coefficient is not obvious. Higher values of the cost to income ratio suggest lower efficiency such that a negative sign is expected.

3.1.3 Macroeconomic data

To control for cross-country differences in macroeconomic developments, I include information on main economic indicators like real GDP growth and real interest rates. Higher economic growth is expected to enter with a positive sign as better economic prospects and higher growth rates should stabilize the banking system. The effect of the level of real interest rates is ambiguous. On the one hand, banks might benefit from low rates as the real value of liabilities to be paid back decreases. On the other hand, lower real interest rates can be due to high inflation rates and an unproportional adjustment of nominal interest rates at the expense of lenders. In robustness tests, I also control for effects going back to an unsound increase in public debt, an unbalanced trade balance or the institutional environment.

[8] Compared to the definition of the BIS, variables in the Financial Structure Database coming from Bankscope include data on all commercial banks whereas the BIS includes data on banks defined as "deposit and credit granting institutions" which comprise all commercial banks but can in specific cases be referred to a broader set of financial institutions.

3.1.4 Indicator for banking risk

The dependent variable which is a measure of bank risk is the *z-score*.[9] The *z-score* for country i at time t is obtained from the Financial Structure Database of Beck et al. (2009) and defined as the average of

$$z - score_{kit} = \frac{ROA_{kit} + (E/A)_{kit}}{\sigma(ROA)_{kit}}$$

for all commercial banks k in country i at time t whereas ROA_{kit} denotes the return on assets, $(E/A)_{kit}$ is the equity to assets ratio and $\sigma(ROA)_{kit}$ is the standard deviation of returns on assets estimated as a 5-year moving average.[10] The *z-score* relates to the number of standard deviations by which returns have to fall below the mean to deplete bank equity. Thus, higher values for the *z-score* caused by either higher returns on assets, a lower volatility of returns or relatively more equity capital lower the probability of failures. As such, the *z-score* is based on balance sheet data. In contrast to a measure calculated from market data, this has the advantage that the underlying sample is not restricted to stock listed banks.

3.2 Descriptive Statistics

The development of cross-border interbank asset and liability positions (% of GDP) of the different banking systems can be seen in Figure 1. It becomes obvious that across all countries cross-border interbank exposures increased over the last decades. This is supported by the Kernel density distribution. Figure 2 shows the Kernel density for cross-border interbank assets and liability positions (% of GDP) based on data for the years 1995 and 2005 and we can see that banking systems moved to higher levels of integration in interbank markets. However, countries show differences in the timing, e.g. compare the United Kingdom and the Netherlands in Figure 1, as well as the share to GDP varies. For instance, see the United Kingdom with foreign interbank assets close to 150% of GDP and Italy with only around 20% of GDP in 2010. Though, this pattern clearly suggests that linkages to transmit shocks across national borders exist. Thereby, it is to note that the following analysis will focus on asset and liability positions separately. The reason for this is that they represent the role of a country in international lending and borrowing and thus two different types of transmission channels. While large cross-border asset exposures in interbank markets can be related to the risk of defaulting counterparties and credit losses, increased cross-border interbank

[9]The *z-score* is a commonly used indicator for risk in the banking sector, see for example Laeven and Levine (2009) or Boyd et al. (2009).

[10]Missing values for the year 2003 in Spain and Italy have been replaced by the average of the pre and post value.

borrowing positions make the banking system vulnerable to funding shortages.

In addition, the graphs show that net positions, i.e. foreign interbank asset minus liability positions, would be small with a rather stable pattern over time. This is explained by the fact that asset and liability positions are of similar size and in- and outflows in banking tend to counteract each other. For example, in "good times" foreign counterparties might be willing to lend more money to the domestic banking system while the latter is as well likely to increase asset positions abroad. Thus, both cross-border lending and borrowing positions go up while changes mutually net out. This demonstrates that net stocks can remain unchanged whereas gross exposures experience significant changes including disruptions in international lending and borrowing. Limiting attention to net stocks or flows would consequently neither reflect expansions, retrenchments or strains in cross-border interbank markets nor the source of the strain, respectively the transmission channel (for similar discussions see Borio and Disyatat (2011), Shin (2011)).

Following the predictions of network models not only the existence of bilateral linkages matters for causing contagion but also their spread across different counterparties. Hence, traditional measures for openness like the ratio of assets (liabilities) to GDP would fail to reflect the level of connectivity or diversification. Figure 3 shows the pattern of diversification for banking systems of different countries. Diversification is measured by the Herfindahl index (HHI) which shows similar and relatively low values across all countries.[11] This indicates that within the sample countries cross-border interbank exposures are not concentrated in few recipient countries but distributed more or less equally across various counterparties. Interestingly, the banking system of the United Kingdom is characterized by relatively low values particularly for its asset positions. This might be related to its role as a financial centre with many different counterparties.

The Kernel density distribution in Figure 4 reveals that the distribution describing the geographical allocation of interbank asset positions does not show major shifts whereas the banking systems of the sample countries moved towards a slightly more concentrated distribution regarding their interbank liability positions. However, one has to consider that the HHI measures diversification within the sample countries while countries might have become more interconnected with respect to foreign banking systems that are not covered. Nevertheless, as the vast majority of foreign interbank

[11] The Herfindahl index for country i at time t is constructed as $HHI_{it} = \sum_{j=1\setminus i}^{n} \omega_{ijt}^2$ where $\omega_{ijt} = \frac{x_{ijt}}{\sum_{j=1\setminus i}^{n} x_{ijt}}$ and x_{ijt} indicates the amount of cross-border interbank positions of country i towards country j. The HHI ranges between $1/(n-1)$ and one with lower values indicating a higher degree of interconnectedness and more equally distributed exposures across recipient countries.

exposures, which is around 70% on average across countries, is directed towards banking systems attributed to one of the sample countries, the coverage of the sample should account for main effects taking place within the banking network.[12]

The main hypothesis of the paper at hand is that internationalization of banking systems in the form of cross-linkages affects the stability of a banking system. In this sense, Figure 5 shows the evolution of foreign interbank exposures and the measure for banking stability averaged across the sample countries. Foreign interbank exposures are thereby calculated as the sum of cross-border interbank assets and liabilities to nominal GDP which resembles commonly used "openness" measures. It can be seen that while foreign interbank exposures show an upward trend, banking systems have become less stable on average. This is consistent with Figure 6 which shows the unconditional correlation between the openness measure as defined above but in % of GDP and the *z-score* (in logs) for the sample period. At first sight, this suggests that countries whose banks face larger foreign interbank exposures have lower values of the *z-score* which is a sign for higher levels of banking risk. A more detailed picture of this relationship for individual time periods and specific country groups can be found in Figures 7 and 8.

Figure 9 compares foreign interbank assets (liabilities) in % of GDP with the related values of connectivity or diversification (measured by the HHI) over the entire sample period. The figure indicates that there is no obvious relationship between the two variables such that they seem to account for different characteristics of the financial integration process. Also by looking at different country groups in Figures 10 and 11, we see that banking systems can have very different levels of diversification for similar degrees of openness and might thus be differently affected by dynamics in the network. This is in line with theoretical models which are based on the assumption that the network structure has to be considered to understand contagion and supports the empirical approach to control for not only the aggregate value of cross-border interbank exposures but also the distribution of positions across interlinked banking systems.

The relevance of this point is also reflected in Table 1 which shows for each reporting country the percentage share of banks' foreign claims vis-à-vis a recipient country relative to the reporting country's foreign claims towards all recipient countries in the sample for the year 2008.[13] First, it cannot be overseen that all countries face large

[12] Japan and the United States face on average only around 50% of foreign interbank asset exposures towards the considered banking systems. The same holds for Germany and the United States on the liability side. Interestingly, for most countries there is little variation over time in the share of cross-border exposures a banking system has directed to the remaining banking systems in the sample compared to all possible recipient countries.

[13] These results are based on publically available bilateral data on foreign claims towards all sectors from the Consolidated Banking Statistics of the BIS. Redoing the analysis with bilateral data on

exposures to the United Kingdom and the United States reflecting their key role in financial markets. Second, bilateral positions seem to be clustered within regions. For example, Table 1 shows Belgium having around 30% of bilateral assets in France and the Netherlands. Germany, France, Italy and Spain seem to be highly connected through mutual exposures. This reveals a high degree of financial integration within Europe. In sharp contrast, Canada has most of its foreign claims (72.6%) in the United States. This might be explained by geographic proximity and cultural similarities favouring cross-border capital flows.

Finally, different units in a network are not only characterized by different intensities of links they maintain to other network components but also by their overall, relative importance within the network. This becomes visible in Figure 12. The graph shows the network of banking systems included in the sample for the year 2008. Countries' banking systems are represented by circles whose dimension depends on the fraction of foreign interbank assets a banking system has compared to the total amount of cross-border interbank assets held by the banking systems under consideration. Obviously, the United Kingdom plays a special role covering close to 25% of total positions. Besides, Germany, France and the United States are part of the main actors.

Figure 12 is certainly not more than a snapshot in time and the network position might not be static and evolve over time. Tables 2 and 3 provide evidence for this. They rank banking systems according to their share of foreign interbank exposures to total interbank exposures channelled by the banking systems in the sample. Both for cross-border assets and liabilities held in interbank markets, the United Kingdom keeps its leading role. However, there are changes in the ranking of countries comparing the situation in 1993 to the one prevailing in 2008. For example, regarding cross-border interbank lending as shown in Table 2, Germany switches from rank five to three while Japan loses its position among the top five. On the liability side as shown in Table 3, France becomes one of the main borrowers.

In sum, these features show that banking systems are intertwined amongst each other. Thereby, the network structure is not symmetric but reveals heterogenous properties arising from clusters, financial centres and a disperse distribution of bilateral exposures across foreign counterparties. If the interest is in the relationship between international exposures of banks and financial stability, this suggests that it is not only the absolute size of foreign exposures that should be considered. Also the position of a banking system relative to other locations can influence the propagation of financial distress. In the same sense, it is not only important to consider to which banking sys-

positions towards banks from the Locational Banking Statistics would not change the conclusions.

tems abroad links are established but also how large they are and how they are spread across interlinked systems. Only then, the overall implications that arise from such a network structure for financial stability can be assessed.[14]

4 Econometric Approach

4.1 Banking Integration and Network Spillovers

To test whether banking (in)stability in one country is transmitted to another country through connections in the interbank market, I make use of a panel data model augmented by a spatial interaction term. Adopting a spatial modelling approach enables to analyse spillovers, also in the light of third country effects, and to the best of my knowledge this approach has hardly been used in the international banking literature.[15] The empirical specification is similar to Cohen-Cole et al. (2011) as well as Liedorp et al. (2010). It differs in the way that the focus is not on bilateral data on banks' assets/ liabilities and contagion risk within a country/ between individual banks but between banking systems across countries. The basic model is thus specified as follows

$$y_{it} = \alpha_i^{country} + \sum_{c=1}^{C} \beta_c x_{it-1}^c + \sum_{b=1}^{B} \beta_b q_{it-1}^b + \phi \sum_{j=1 \setminus i}^{n} \omega_{ijt} y_{jt} + \epsilon_{it},$$

where the dependent variable y_{it} for country i at time t is the *z-score*, a country specific indicator for banking stability with lower values indicating a lower level of financial stability. As the *z-score* tends to be skewed, in the estimations I take the logarithm. Country fixed effects are controlled for by including $\alpha_i^{country}$. The vector x_{it-1}^c captures aggregate country specific variables that can have an effect on financial stability like GDP growth as well as banking specific characteristics that control for size, structure and efficiency of the banking system of a country.[16] Variables related to interbank exposures between national banking systems are described by q_{it-1}^b. The information hidden in this vector will reveal to what extent cross-border exposures have an effect on the soundness of banking systems. All variables in x_{it-1}^c and q_{it-1}^b are included with one lag to reduce simultaneity concerns.

[14] The importance to consider the network structure of the international banking network in order to evaluate effects on efficiency and stability is, for example, emphasized by von Peter (2007).

[15] One exception is Neugebauer (2011) who uses a spatial estimation approach to analyze the effect of distance on cross-border exposures in banking. Spatial techniques are more recently applied to study economic growth and convergence, see e.g. Bouayad-Agha and Védrine (2010) or Elhorst et al. (2010). In the contagion literature, Hernández and Valdés (2001) or Baldacci et al. (2013) use a spatial approach to assess contagion in sovereign bond markets. Kelejian et al. (2006) focus on spillovers among emerging markets during currency crises. In the social network literature, Calvó-Armengol et al. (2009) study the effect of social networks on education outcomes.

[16] For more information on the included control variables see the data description in Section 3.1.

The vector q_{it-1}^{b} controls, in particular, for foreign asset (liability) positions of a reporting country's banking system. As most countries show an upward trending behaviour for the ratio of cross-border assets (liabilities) to GDP, I try to avoid problems related to non-stationarity by including changes in interbank asset (liability) stock data in the baseline regression. Including changes in lending and borrowing positions separately reflects the fact that not only claims in other countries can be the driving force behind spillovers (as in Allen and Gale (2000)). Also funding risk plays a critical role for stability (Goldsmith-Pinkham and Yorulmazer, 2010; Gale and Yorulmazer, 2013). For example, a loss of confidence in the market might lead banks to hoard liquidity and not renew (usually) short-term interbank loans. As a consequence, interbank market functioning deteriorates and liquidity provision diminishes. Banks relying on wholesale funding come under pressure and might be forced to sell long-term assets at fire-sale prices. Thus, a negative coefficient on cross-border interbank borrowing, which is most often short-term, would provide evidence on the fact that increased funding risk can deteriorate the stability of a banking system.

To take network effects into account and to detect if banking stability in a particular country i is affected by the riskiness of the banking systems of all countries j to which banks in the given country lend or from which they borrow, I make use of a spatial interaction term (Anselin, 1988; LeSage and Pace, 2009). The inclusion of a spatial interaction term allows examining more directly whether cross-border activities act as a transmission channel and facilitate spillovers of financial risk between banking systems. Thereby, *z-scores* of banking systems in the sample to which banks in country i maintain linkages are weighted by the corresponding relative exposures.[17] The regression equation therefore includes a term for network effects

$$\phi \sum_{j=1\backslash i}^{n} \omega_{ijt} y_{jt},$$

where n is the number of banking systems in the network, ω_{ijt} is the respective element of the weighting matrix and denotes the relative fraction of interbank exposures between banking system i and j at time t, y_{jt} is the measure for banking stability in country j at time t. It is to expect that banking stability in a country is positively affected given it maintains linkages to countries with more stable banking systems.

[17] The spatial interaction term is included contemporaneously having in mind that annual data is used and effects in banking are transmitted relatively fast. See the Appendix for details on the construction of the weighting matrix. Due to data availability the weighting matrix changes dimension over time. This is corrected for by weighting bilateral exposures by total exposures towards the included sample countries.

This would be reflected by a positive sign of ϕ and coincide with *Hypothesis 1*.

4.2 Diversification and Network Exposures

Following the theoretical part, the risk of spillovers can depend on the structure of the network whereas not only the total amount of lending or borrowing but also the degree of diversification can influence financial resilience. To see where the main effects stem from, the bilateral data is used to construct measures for diversification and network exposures. The degree of diversification in banking a country is exposed to is measured by Herfindahl indices (HHI). As explained under *Hypothesis 2*, the sign of the coefficient is at first sight not obvious. On the one hand, relying on more counterparties and being less concentrated reduces funding or credit risk. On the other hand, more linkages can increase the potential number of contagion channels. A negative sign would imply that a decrease in diversification, i.e. an increase in the HHI, and more concentrated exposures go hand in hand with an increase in bank risk. This seems reasonable in the way that even small shocks in country i might spillover to an interconnected country j if it maintains relatively strong links to the former one. If there are relevant non-monotonic effects, this will be captured by the inclusion of the HHI squared. Network exposures are accounted for by including both the relative importance of the country's banking system in the cross-border interbank network reflected by relative node-out or node-in strength and the total amount of cross-border interbank lending or borrowing within the network as a ratio to GDP.[18] Following *Hypothesis 3*, larger exposures have a higher potential to channel risks such that a negative relationship with bank stability is expected.

4.3 Simultaneity Issues and the Weighting Matrix

Given this econometric specification, two points have to be noticed. First, although the spatial interaction term reminds of a first-order autoregressive process, it is different in the way that the dependent variable enters contemporaneously on the right hand side and is weighted by the corresponding elements of the weighting matrix. Obviously, the inclusion of a spatial interaction term raises endogeneity problems as the dependent variables are determined simultaneously.[19] This causes standard OLS estimates to be biased. Omitting the spatial dimension is, however, no solution as spatial dependencies would be shifted to the error term such that valid estimates could only be obtained if individual country pair observations are not affected by each other (Anselin (1988)).

[18]Formally, relative node-out (node-in) strength for country i at time t corresponds to $\frac{x_{it}}{\sum_{j=1}^{n} x_{jt}}$ with x denoting a banking system's cross-border interbank assets (liabilities) held within the network.

[19]For a demonstration of this point see Kukenova and Monteiro (2008).

This seems a doubtful assumption considering the predictions on which the underlying research question is based.[20] Thus, besides OLS regressions and to control for possible endogeneity, I use an instrumental variables (IV) approach as described in the next section.

Second, and different from commonly estimated spatial models, the weighting matrix does not consist of fixed values like distances but receives an economic interpretation. Specifying the weights in terms of cross-border interbank exposures causes the weighting matrix to be time-varying. On the one hand, this specification has a clear economic intuition and allows interactions between countries to be related to the strength of financial linkages among them. On the other hand, time varying weighting matrices are until now not considered extensively in spatial econometrics. Therefore, to check the robustness of the results, I follow the standard approach in the literature and estimate the model (i) with constant economic weights to overcome endogeneity issues by imposing the structure of the interbank data either at the beginning of the sample or on average across the sample period and (ii) using inverse distances between capitals of country pairs when defining the weighting matrix (see also Neugebauer (2011)).[21] This assumes stronger spillovers if countries are located more closely to each other in geographic terms. Defining the weights in geographic distances has a strong advantage from the econometric point of view as geographic distances are clearly exogenous. Thus, standard estimation techniques for spatial panels as provided by Elhorst (2003, 2010) can be applied. And also under economic considerations using distances seems reasonable having in mind the finding of e.g. Buch (2003) or Papaioannou (2009) that distance is a significant determinant of international capital flows. Hence, closely located countries are likely to have stronger links that can cause spillovers.

4.4 Estimation Strategy

The model is estimated by both ordinary least squares and a least squares dummy variable approach to control for country fixed effects. As pointed out above, the inclusion of the spatial interaction term raises endogeneity concerns. A first option to control for endogeneity is to include the spatial interaction term not contemporaneously but with a time lag. Additionally, I account for possible endogeneity by exploiting the panel dimension of the model and using a two stage least squares IV estimator whereas the spatial interaction term is instrumented with its own lagged value. A final test is provided by a generalized method of moments IV estimator which has the advantage that

[20] Alternatively to the spatial lag or spatial autoregressive model, a spatial error model can be used. It accounts for spatial correlation in the errors but not for feedback effects in the dependent variable across countries.

[21] Data on geographical distances between countries comes from CEPII 2011.

it does not require distributional assumptions and is easily adapted to different specifications including endogenous regressors by modifying the set of moment restrictions. The explanatory variables are treated as exogenous and serve as their own instruments. The spatial interaction term is assumed to be endogenous and instrumented by its first and second lagged value. This approach is similar to Bouayad-Agha and Védrine (2010) or Kukenova and Monteiro (2008) who estimate dynamic spatial panel data models using generalized method of moments techniques. It is to note that the GMM estimator only gives consistent estimates if the instruments are valid, i.e. the orthogonality condition between errors and lagged values as instrumental variables has to hold. Thus, the validity of the instruments is tested by the Hansen χ^2 test statistic.[22]

5 Results

5.1 Banking Integration and Network Spillovers

Table 4 shows the results for the benchmark model. First, I run simple OLS regressions augmenting them with the variables related to banking integration (columns 2 and 3). Second, the specifications including the variables of interest are estimated by a least squares dummy variable approach to control for country fixed effects (columns 4 to 5). In Table 5, I take possible endogeneity of the spatial interaction term into account. The equation is estimated including the spatial interaction term not contemporaneously but instead its one period lagged value (columns 1 and 2). Also, a two stage least squares (2SLS) instrumental variables approach is taken (columns 3 and 4). Alternatively, I controlled for endogeneity estimating the model by a generalized method of moments (GMM) and adapting the moment restrictions accordingly (columns 5 and 6).[23]

For the control variables, we can see that GDP growth has a positive sign but turns insignificant as soon as the banking variables are added. The interest rate does not show any significant effects. The banking sector related variables show the expected signs whereas their significance depends on the chosen estimation technique. Changes in interbank positions turn out to have a negative effect on banking soundness, i.e. countries in which the banking system faces higher in- or outflows of interbank exposures run the risk of lowering banking stability. However, direct repercussions of

[22] The model with the imposed moment restrictions is estimated by the one-step GMM estimator due to better finite sample properties (Cameron and Trivedi (2005)).

[23] In general, simple least squares estimations are the preferred choice due to small sample size and resulting problems in GMM estimations if the number of variables (and instruments) is relatively large. Using a GMM IV approach and estimating the model in first differences to eliminate country fixed effects did not show major changes in the results. All models are estimated with a constant which is not reported in the tables.

changes in cross-border interbank exposures seem to be negligible as the coefficient is not significant at conventional significance levels.

The spatial interaction effect shows a positive sign indicating that being linked to more stable counterparties benefits stability in the home country. Interestingly, both banking systems that lend to less risky banks abroad and banking systems that are linked to more stable foreign counterparties through borrowing positions face positive spillover effects. This indicates that not only credit risk is mitigated through cross-border lending to more stable banks but also funding risk. Banking systems borrowing from more stable counterparties benefit from positive spillover effects. Hence, this points towards the importance of well-functioning interbank credit and funding markets and implies that internationally integrated and open banking systems are no risk to stability per se. However, the result can also be interpreted vice versa namely that links to less stable banking system can worsen financial stability at home. This suggests that it matters to whom linkages are maintained and in this way the result supports *Hypothesis 1.* The result also emphasizes that network interactions should not be neglected and provides evidence for spillover effects through network links as proposed in the theoretical literature cited above. Consistent with theoretical predictions, it is consequently not enough to consider only aggregate cross-border exposures in order to evaluate systemic stability.

The coefficient of the spatial interaction term stays significantly different from zero accounting for country fixed effects.[24] Controlling for endogeneity in Table 5, we see that the spatial term remains highly significant. For the GMM IV estimation, the Hansen χ^2 test supports the validity of the instruments. However, standard tests for endogeneity do not reject the null that the spatial term is exogenous and to keep efficiency losses inherent in instrument variables estimators small, the following estimations are based on pooled OLS estimations accounting for country specific heterogeneity by including fixed effects. For all estimation results, it is important to keep in mind that due to data availability the obtained findings relate to a limited number of countries and the interpretation of resulting network dynamics is restricted to the included banking systems. Results obtained following changes in the sample composition can be found in the robustness section.

[24]Not reported regression results show that all variables lose significance if year dummies are added. This can be due to small sample size and too little information in the data. Alternatively, it might suggest that common time developments play a role in the underlying dynamics such that their relevance is further discussed in the robustness section. The spatial term stays significant if the errors are adjusted for serial correlation within country groups.

5.2 Diversification and Network Exposures

Table 6 shows the results for the model focusing on the total amount of cross-border lending and borrowing within the network of banking systems (columns 5-10) as well as the corresponding level of diversification (columns 1-4). Following *Hypothesis 2*, the degree of diversification can affect the net outcome of spillover risk. The result for the HHI tells that countries whose banks have concentrated linkages towards few counterparties increase financial risk. In contrast, being more diversified and distributing cross-border exposures equally across interlinked banking systems has a positive effect on stability. Yet, the significance of the coefficient of the HHI is restricted to few specifications and there are no relevant effects on the significance of the spatial term. This suggests that diversification if measured by the HHI plays a minor role for banking risk and spillovers. The non-significant result for the squared term of the HHI does not support the existence of non-linear effects as often found in theory.

Strengthening the relative role as lender or borrower within the international interbank network seems to have destabilizing effects. This follows from the negative sign for relative node strength and is in line with *Hypothesis 3*, i.e. stronger links taking the form of larger cross-border interbank exposures tend to increase contagion risk. The results in terms of significance indicate that rather the total amount of network exposures relative to GDP than the banking systems relative importance as a lender or borrower within the interbank network determines bank risk. Effects are thereby found both on the asset and the liability side. At the same time, it is to note that the network effect captured by the spatial interaction term tends to lose significance if network exposures as a ratio to GDP are included.

To trace out effects coming from changes in cross-border interbank activities relative to possible expansions in total balance sheet positions of banks, I redo the analysis focusing on cross-border interbank asset positions towards the banking systems in the network or all possible recipient countries expressed as a ratio to the banking system's total assets. Data on total asset positions comes from the Bank Profitability Statistic of the OECD and is only available for a smaller set of countries such that the number of observations is reduced. The sign of the corresponding coefficients is consistent with the previous results while an effect that is significantly different from zero is only obtained for a banking system's total amount of cross-border interbank assets relative to the aggregate size of the banking system's balance sheet.

5.3 Robustness

This section briefly outlines the results obtained from robustness tests. As the sample consists mainly of European countries and the relationship between network effects and stability can be different within this group of countries, I first estimate the model based on a network excluding Canada, Japan and the United States. Alternatively, I control for membership in the EU or the Euro area by including dummy variables. Across all columns in Table 7, results remain stable and suggest that geographical proximity or a common currency play minor effects regarding the question under analysis. In contrast, being a member of the European Union stands in a positive relationship with banking stability.

Second, besides testing the sensitivity of the results with respect to the sample composition, different time periods as well as time effects can drive the results. To account for common time trends, in Table 8, I include control variables that are likely to affect all countries simultaneously like OECD growth and the change in the S&P500 price index. Although the common controls show the expected sign, i.e. better growth prospects and positive developments in stock markets should stabilize banking systems, they are not significant. The network effect, in turn, seems to pick up common economic patterns as it loses significance if OECD growth is added to the model. The role played by linkages among countries regarding the transmission of instabilities can without doubt be different in tranquil times compared to periods of financial turmoil. This becomes obvious if the sample period omits recent crisis years. Interestingly, under this specification it is rather an expansion in foreign interbank exposures than network effects that have a significant but negative effect on stability. The coefficient of IB assets (IB liabilities) turns significant while the spatial interaction term loses its significance. Similarly, including a country specific crisis dummy assigns a less dominant role to effects coming from the network membership.

Third, the set of control variables is varied to find out if specific characteristics of the banking sector, financial markets or the macroeconomic environment, e.g. concentration within or the size of the banking system, the institutional environment or the role of a country as a financial centre, as well as the soundness of the public budget or the trade balance, affect the conclusions drawn so far. Results can be found in Table 9. In general, there are no major changes in the sign or significance of the variables of interest. It is interesting to note that being a financial centre raises the risk of banking distress while at the same time positive network spillovers can be possible and the spatial interaction term stays significant at the 1% level.[25] With respect to the additional

[25]According to the Global Financial Centre Index by Z/Yen Group and City of London Corporation,

control variables, only the size of the banking system measured as the ratio of deposit money banks assets to GDP reveals significant effects whereas larger banking systems are more exposed to financial distress.[26] For banking systems with a higher degree of efficiency and independence from governmental intervention as captured by a larger financial freedom index, spillover effects are reduced in their economic and statistical significance.

Until now the analysis was based on data reflecting exposures towards the bank sector and considering the asset and the liability side of the balance sheet separately. To see effects stemming from openness in gross terms, I reestimate the model by including changes in gross foreign interbank exposures (the sum of asset and liability flows to GDP) or gross exposures (the sum of asset and liability stocks to GDP) and weighting banking risk in interconnected countries accordingly (Table 10). If cross-border exposures to the non-bank or total foreign positions (towards all sectors) affect banking stability differently and play, for example, a less significant role in causing spillovers, this should be captured by the coefficients in the last four columns of Table 10, in which the banking variables are based on total or non-bank foreign exposures.[27] Again, the key driver behind stability goes back to effects coming from the spatial interaction term whereas changes in different types of cross-border exposures, i.e. towards the non-bank sector or towards all sectors, as well as gross flows towards the bank sector remain insignificant. The spatial interaction term keeps its predominant effect but the less so if total cross-border interbank positions (column 2) and not the change in foreign interbank exposures is included. In line with the descriptive analysis in Section 3.2, this commonly used measure for openness seems to be negatively related to bank risk. This points in the direction that it is not necessarily foreign interbank lending and borrowing flows but rather the amount of overall exposures that determine how the stability of a banking system is affected.

Finally, I estimate the model with panel data techniques developed by Elhorst (2003, 2010) for spatial lag models with constant weight matrices.[28] The robust Lagrange multiplier (LM) test supports the inclusion of the spatial interaction term. As cor-

London, New York, Tokyo and Zurich are, since the start of the survey, continuously ranked among the top ten financial centres besides cities like Hong Kong and Singapore.

[26] As the ratio of assets to GDP is highly correlated with the ratio of private credit to GDP, the latter variable was dropped from the regression.

[27] However, it is to note that the proxy for a reporting country's cross-border interbank exposures accounts on average for 60% to 80% of total foreign positions (towards all sectors) such that positions of banks towards the non-bank sector constitute only a small fraction of cross-border exposures and no major changes are expected if total foreign exposures of reporting countries are used to calculate network effects.

[28] This requires a balanced panel such that the sample is restricted to 12 countries over the period 1993-2008 for which full coverage of data on foreign bilateral exposures and the *z-score* is guaranteed.

responding Likelihood ratio tests also give strong evidence for spatial fixed effects, I include them into the estimations. From Table 11, it can be seen that when using a weight matrix composed of inverse distances (column 3), the spatial interaction term is insignificant. It gains significance if the weight matrix consists of foreign interbank liabilities at the beginning of the sample period or reflects the average pattern of cross-border interbank exposures over the sample period. In sum, the choice of the weight matrix seems to matter for the existence of spillover effects and the results indicate that not necessarily geographical distance but the more so links between banking systems favour feedback effects. This holds even if interbank weights are held constant and endogeneity is controlled for by using spatial maximum likelihood estimation techniques.

6 Concluding Remarks

Cross-border linkages between banks of different countries relate without doubt to transmission channels of systemic risk. Though there is an increasing theoretical literature on interlinkages in banking networks and their implication for systemic stability, less evidence is provided by empirical work. Thus, starting from the theoretical literature and testing empirical implications of these issues is the main objective of this paper. For the empirical analysis, I use a spatial modelling approach which allows disentangling direct effects of cross-border exposures from their role as transmission channels of banking distress within the considered network of 15 banking systems during the period 1993-2009. From a theoretical point of view, it is to expect that interconnections between different nodes offer, on the one hand, risk-sharing possibilities and thus stability enhancing effects. On the other hand, they might propagate shocks within the network. The outcome of this trade-off can thereby be affected by the network topology and descriptive statistics reveal properties of the cross-border interbank network which can influence the propagation of shocks or the maintenance of systemic stability.

In this sense, the empirical analysis examines the relationship between cross-border links among banking systems and financial stability taking the network structure into account. The results suggest that the effect of integration in international interbank markets on stability is ambiguous. Larger cross-border exposures are likely to increase bank risk while higher levels of diversification can have counterbalancing effects. I find evidence that countries which face foreign interbank exposures to more stable counterparties tend to experience a shift towards a more stable banking system. Notably, this holds for linkages arising from exposures on both the liability and the asset side of the balance sheet and highlights that bilateral linkages can have a beneficial effect on stability; above all if banks are linked to less risky systems. This result remains stable controlling for endogeneity, country specific heterogeneity and a broad range of alternative explanatory variables. Obviously, the outlined effect holds also vice versa and the fact that the significance of this relationship partly depends on the inclusion of recent crisis years points towards the potential of cross-border links to cause negative spillovers when the stability of the financial system is low. This suggests a trade-off between stability and systemic risk. Although being connected to stable banking systems abroad can improve banking soundness at home, larger cross-border interbank positions and adverse spillover or feedback effects can have destabilizing effects in times of distress.

The analysis has relevant policy implications as it reveals that the resilience of the banking system is affected both positively and negatively by interdependencies in the banking network. The main objective of policymakers should thus be to keep the benefits of international risk-sharing as well as geographical diversification gains while limiting fragility costs. A proper risk evaluation of banking systems requires, thereby, not only focusing on idiosyncratic risks. If international exposures facilitate feedback effects and the spread of idiosyncratic shocks or the amplification of common shocks, also the structure of cross-border exposures as well as their contribution to stability and systemic risk has to be considered. This opens up questions into various dimensions whereas the final comments concentrate on two central points. First, it raises the debate in how far efficient supervision and regulation for internationally active banks can only take place at the international level. Second, reliable measures that trace out the contribution of cross-border activities in banking and resulting interwoven network structures to benefits and costs of internationalization have to be developed to evaluate their optimality and desirability. This is certainly not an easy task as diversification gains take place more silently than sudden costs arising from systemic failures. However, even if a better picture of the net effects of financial integration is hard to obtain and provides scope for further research, nothing precludes from finding regulatory frameworks that reduce inherent risks and increase systemic stability.

References

Agénor, P.-R. (2003). Benefits and costs of international financial integration: Theory and facts. *The World Economy*, 26(8):1089–1118.

Allen, F. and Babus, A. (2009). Networks in finance. In *Network-based Strategies and Competencies*, pages 367–382. P. Kleindorfer and J. Wind (ed.).

Allen, F., Babus, A., and Carletti, E. (2009). Financial crises: Theory and evidence. *Annual Review of Financial Economics*, 1(1):97–116.

Allen, F., Babus, A., and Carletti, E. (2012). Asset commonality, debt maturity and systemic risk. *Journal of Financial Economics*, 104(3):519–534.

Allen, F., Beck, T., Carletti, E., Lane, P., Schoenmaker, D., and Wagner, W. (2011). Cross-border banking in Europe after the crisis. CEPR Policy Report.

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

Anselin, L. (1988). *Spatial Econometrics: Methods and Models*. Springer.

Babus, A. (2013). The formation of financial networks. Discussion paper 2006-093/2, Tinbergen Institute.

Baldacci, E., Dell'Erba, S., and Poghosyan, T. (2013). Spatial spillovers in emerging market spreads. *Empirical Economics*, 45(2):735–756.

Battiston, S., Gatti, D. D., Gallegati, M., Greenwald, B., and Stiglitz, J. E. (2012). Default cascades: When does risk diversification increase stability? *Journal of Financial Stability*, 8(3):138–149.

Beck, T., Demirguc-Kunt, A., and Levine, R. (2006). Bank concentration, competition, and crises: First results. *Journal of Banking and Finance*, 30(5):1581–1603.

Beck, T., Demirguc-Kunt, A., and Levine, R. (2009). Financial institutions and markets across countries and over time - Data and analysis. Policy Research Working Paper Series 4943, The World Bank.

Beck, T., Jonghe, O. D., and Schepens, G. (2011). Bank competition and stability: Reconciling conflicting empirical evidence. Research paper 97, Paolo Baffi Centre.

Billio, M., Getmansky, M., Lo, A. W., and Pelizzon, L. (2012). Econometric measures of connectedness and systemic risk in the finance and insurance sectors. *Journal of Financial Economics*, 104(3):535 – 559.

Borio, C. and Disyatat, P. (2011). Global imbalances and the financial crisis: Link or no link? BIS Working Papers 346, Bank for International Settlements.

Bouayad-Agha, S. and Védrine, L. (2010). Estimation strategies for a spatial dynamic panel using GMM. A new approach to the convergence issue of European regions. *Spatial Economic Analysis*, 5(2):205–227.

Boyd, J. H., Nicolò, G. D., and Jalal, A. M. (2009). Bank competition, risk and asset allocations. IMF Working Papers 09/143, International Monetary Fund.

Brusco, S. and Castiglionesi, F. (2007). Liquidity coinsurance, moral hazard, and financial contagion. *Journal of Finance*, 62(5):2275–2302.

Buch, C. M. (2003). Information or regulation: What drives the international activities of commercial banks? *Journal of Money, Credit and Banking*, 35(6):851–69.

Cabrales, A., Gottardo, P., and Vega-Redondo, F. (2013). Risk-sharing and contagion in networks. Economics Working Papers ECO2013/01, European University Institute.

Calvó-Armengol, A., Patacchini, E., and Zenou, Y. (2009). Peer effects and social networks in education. *Review of Economic Studies*, 76(4):1239–1267.

Cameron, A. C. and Trivedi, P. K. (2005). *Microeconometrics: Methods and Applications*. Cambridge University Press, New York.

Cetorelli, N. and Goldberg, L. S. (2011). Global banks and international shock transmission: Evidence from the crisis. *IMF Economic Review*, 59(1):41–76.

Cifuentes, R., Shin, H. S., and Ferrucci, G. (2005). Liquidity risk and contagion. *Journal of the European Economic Association*, 3(2-3):556–566.

Cohen-Cole, E., Patacchini, E., and Zenou, Y. (2011). Systemic risk and network formation in the interbank market. CEPR discussion papers 8332.

Degryse, H. and Nguyen, G. (2007). Interbank exposures: An empirical examination of contagion risk in the Belgian banking system. *International Journal of Central Banking*, 3(2):123–171.

Degryse, H. A., Elahi, M. A., and Penas, M. F. (2010). Cross-border exposures and financial contagion. *International Review of Finance*, 10(Financial):209–240.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *Review of Economic Studies*, 51(3):393–414.

Diebold, F. X. and Yilmaz, K. (2011). On the network topology of variance decompositions: Measuring the connectedness of financial firms. NBER working papers, National Bureau of Economic Research, Inc.

Eickmeier, S., Lemke, W., and Marcellino, M. (2011). The changing international transmission of financial shocks: Evidence from a classical time-varying FAVAR. Discussion paper series 1: Economic studies 2011,05, Deutsche Bundesbank, Research Centre.

Elhorst, P., Piras, G., and Arbia, G. (2010). Growth and convergence in a multiregional model with space time dynamics. *Geographical Analysis*, 42(3):338–355.

Elsinger, H., Lehar, A., and Summer, M. (2006). Risk assessment for banking systems. *Management Science*, 52(9):1301–1314.

European Central Bank (2010). Financial networks and financial stability. *Financial Stability Review*.

Forbes, K. J. and Rigobon, R. (2002). No contagion, only interdependence: Measuring stock market comovements. *Journal of Finance*, 57(5):2223–2261.

Freixas, X. and Holthausen, C. (2005). Interbank market integration under asymmetric information. *Review of Financial Studies*, 18(2):459–490.

Freixas, X., Parigi, B. M., and Rochet, J.-C. (2000). Systemic risk, interbank relations, and liquidity provision by the central bank. *Journal of Money, Credit and Banking*, 32(3):611–38.

Gai, P. and Kapadia, S. (2010). Contagion in financial networks. *Proceedings of the Royal Society*, (466):2401–2423.

Gale, D. and Yorulmazer, T. (2013). Liquidity hoarding. *Theoretical Economics*, 8(2).

Georg, C.-P. (2013). The effect of the interbank network structure on contagion and common shocks. *Journal of Banking & Finance*, 37(7):2216 – 2228.

Goldsmith-Pinkham, P. and Yorulmazer, T. (2010). Liquidity, bank runs, and bailouts: Spillover effects during the Northern Rock episode. *Journal of Financial Services Research*, 37(2):83–98.

Hernández, L. F. and Valdés, R. O. (2001). What drives contagion: Trade, neighborhood, or financial links? *International Review of Financial Analysis*, 10(3):203–218.

Kali, R. and Reyes, J. (2010). Financial contagion on the international trade network. *Economic Inquiry*, 48(4):1072–1101.

Kelejian, H., Tavlas, G., and Hondroyiannis, G. (2006). A spatial modelling approach to contagion among emerging economies. *Open Economies Review*, 17(4):423–441.

Kukenova, M. and Monteiro, J.-A. (2008). Spatial dynamic panel model and system GMM: A Monte Carlo investigation. MPRA Paper 11569, University Library of Munich, Germany.

Laeven, L. and Levine, R. (2009). Bank governance, regulation and risk taking. *Journal of Financial Economics*, 93(2):259–275.

Lane, P. R. and Milesi-Ferretti, G. M. (2011). The cross-country incidence of the global crisis. *IMF Economic Review*, 59(1):77–110.

LeSage, J. P. and Pace, R. K. (2009). *Introduction to Spatial Econometrics*. Chapman & Hall/CRC.

Liedorp, F. R., Medema, L., Koetter, M., Koning, R. H., and van Lelyveld, I. (2010). Peer monitoring or contagion? Interbank market exposure and bank risk. DNB Working Papers 248, Netherlands Central Bank, Research Department.

Minoiu, C. and Reyes, J. A. (2013). A network analysis of global banking: 1978-2009. *Journal of Financial Stability*, 9(2):168 – 184.

Mistrulli, P. E. (2011). Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns. *Journal of Banking and Finance*, 35(5):1114–1127.

Neugebauer, K. (2011). Banks in space: Does distance really affect cross-border banking? ERSA conference papers ersa11p1227, European Regional Science Association.

Nier, E., Yang, J., Yorulmazer, T., and Alentorn, A. (2007). Network models and financial stability. *Journal of Economic Dynamics and Control*, 31(6):2033–2060.

Papaioannou, E. (2009). What drives international financial flows? Politics, institutions and other determinants. *Journal of Development Economics*, 88(2):269–281.

Schweitzer, F., Fagiolo, G., Sornette, D., Vega-Redondo, F., Vespignani, A., and White, D. R. (2009). Economic networks: The new challenges. *Science*, 325(422).

Shin, H. S. (2011). Global banking glut and loan risk premium. Mundell-Fleming Lecture, presented at the 2011 IMF Annual Research Conference.

Stiglitz, J. E. (2010). Risk and global economic architecture: Why full financial integration may be undesirable. *American Economic Review*, 100(2):388–92.

Upper, C. (2011). Simulation methods to assess the danger of contagion in interbank markets. *Journal of Financial Stability*, 7(3):111–125.

Upper, C. and Worms, A. (2004). Estimating bilateral exposures in the German interbank market: Is there a danger of contagion? *European Economic Review*, 48(4):827–849.

von Peter, G. (2007). International banking centres: A network perspective. *BIS Quarterly Review*.

Wagner, W. (2010). Diversification at financial institutions and systemic crises. *Journal of Financial Intermediation*, 19(3):373–386.

Winton, A. (1999). Don't put all your eggs in one basket? Diversification and specialization in lending. Working Paper 9903, University of Minnesota.

Appendix

The Weighting Matrix

The weighting matrix determines the structure of spatial dependence between the sample countries. If the weights are constructed from bilateral interbank exposures among n countries, the $n \times n$ spatial weight matrix W_t for time period t looks as

$$W_t = \begin{bmatrix} 0 & \omega_{12t} & \cdots & \omega_{1nt} \\ \omega_{21t} & 0 & \cdots & \omega_{2nt} \\ \vdots & \vdots & \ddots & \vdots \\ \omega_{n1t} & \omega_{n2t} & \cdots & 0 \end{bmatrix}$$

with ω_{ijt} denoting the weight which corresponds to country pair ij. In particular, we have $\omega_{ijt} = \frac{x_{ijt}}{\sum_{j=1\setminus i}^{n} x_{ijt}}$ such that the interbank asset (liability) positions x_{ijt} of country $i's$ banking system towards banks in country j are divided by the total asset (liability) positions country i has against all other countries j in the sample at time t. Thus, the weighting matrix is row standardized. Under a network theoretical perspective, this way of defining the weights generates an adjacency matrix of a weighted and directed network as exposures from one node (country i) directed to another node (country j) are considered. If distances d_{ij} between country pairs are used to form the weights, we have $W_t = W_{t+1}$ and ω_{ijt} is replaced by $1/d_{ij}$ $\forall t$. Specifically, the weighting matrix based on the inverse of bilateral distances has the form

$$W = \begin{bmatrix} 0 & 1/d_{12} & \cdots & 1/d_{1n} \\ 1/d_{21} & 0 & \cdots & 1/d_{2n} \\ & & & \\ 1/d_{n1} & 1/d_{n2} & \cdots & 0 \end{bmatrix},$$

whereas for the estimations, the distance matrix is row standardized.

Data Description

Variable	Definition	Source
Macroeconomic variables		
GDP growth	Annual change in real GDP (%)	IMF
Real interest rate	Nominal interest rate-Inflation (%)	OECD, IMF
Government debt	Annual change in debt/GDP	Abbas et al. 2010, IMF
Current account	% of GDP	IMF
Financial freedom	Index (0-100)	Heritage Foundation
OECD growth	Annual change in real GDP (%)	OECD
ΔS&P500	Annual change in S&P500 price index (%)	Datastream
Distance	Between capitals of country pairs	CEPII 2011
Banking specific variables		
Size of banking system	Deposit money bank assets/GDP	Beck et al. 2009
Assets of banking system	mn USD	OECD, Datastream
Private credit	Private credit by deposit money banks/GDP	Beck et al. 2009
Cost to income	Total costs/total income of commercial banks	Beck et al. 2009
Concentration	Assets of three largest banks as a share of assets of all commercial banks	Beck et al. 2009
z-score	(Return on assets+$\frac{equity}{assets}$)/Std(Return on assets)	Beck et al. 2009
Banking integration		
IB assets (Flow)	Annual exchange rate adjusted changes/GDP	BIS, IMF
IB liabilities (Flow)	towards bank sector	BIS, IMF
IB gross flows	towards bank sector (assets+liabilities)	BIS, IMF
IB gross stocks	Assets and liabilities to bank sector/GDP	BIS, IMF
Assets (Flow)	Annual exchange rate adjusted changes/GDP	BIS, IMF
Liabilities (Flow)	to all sectors or only non-bank sector	BIS, IMF
Cross-border interbank network		
Herfindahl index (HHI)	Index measuring diversification	BIS
Network exposures/GDP	Assets or liabilities in the network/GDP	BIS, IMF
Relative node strength	Network exposures$_{it}/\sum_{j=1}^{n}$ network exposures$_{jt}$	BIS

Sample Countries and Coverage: Belgium, Canada (until 2008), Denmark, France, Germany, Italy, Ireland (2004-2008), Japan, Netherlands, Portugal (from 2004 onwards), Spain (until 2008), Sweden (from 2001 onwards), Switzerland, United Kingdom, United States.

Crisis Dates: Crisis dates to construct the crisis dummy are obtained from Laeven and Valencia (2010). For the sample countries a crisis is observed for Belgium (2008-2009), Denmark (2008-2009), France (2008-2009), Germany (2008-2009), Ireland (2008-2009), Japan (1997-2001), Netherlands (2008-2009), Portugal (2008-2009), Spain (2008-2009), Sweden (1991-1995, 2008-2009), Switzerland (2008-2009), United Kingdom (2007-2009), United States (2007-2009).

Data Analysis

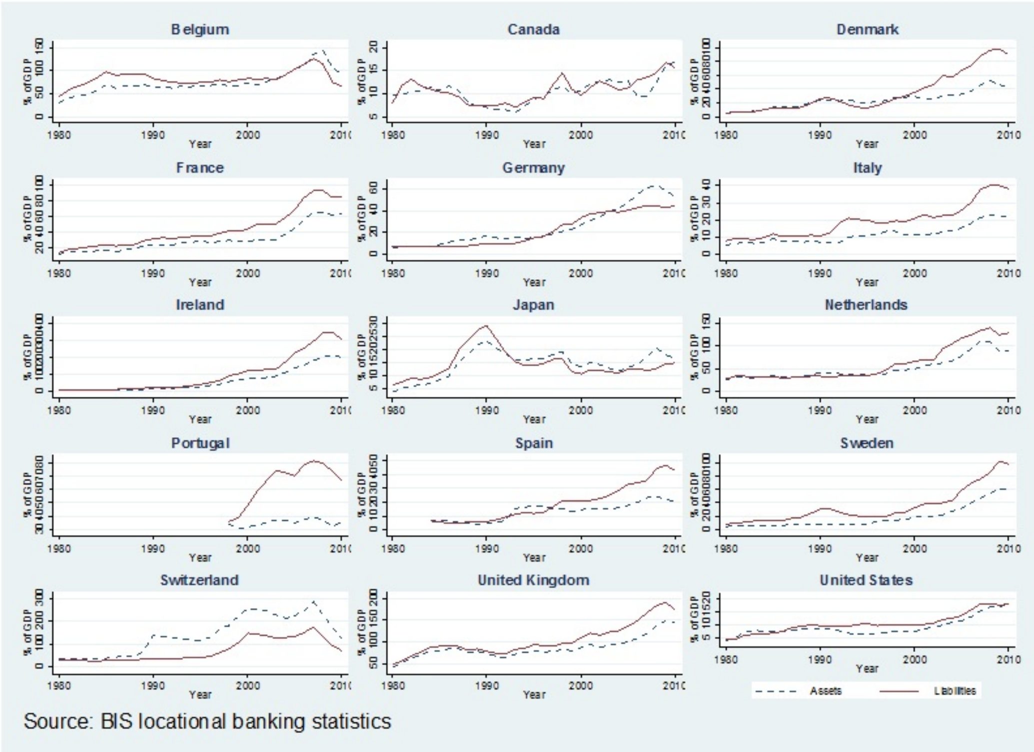

Figure 1: Cross-Border Interbank Exposures (% of GDP)

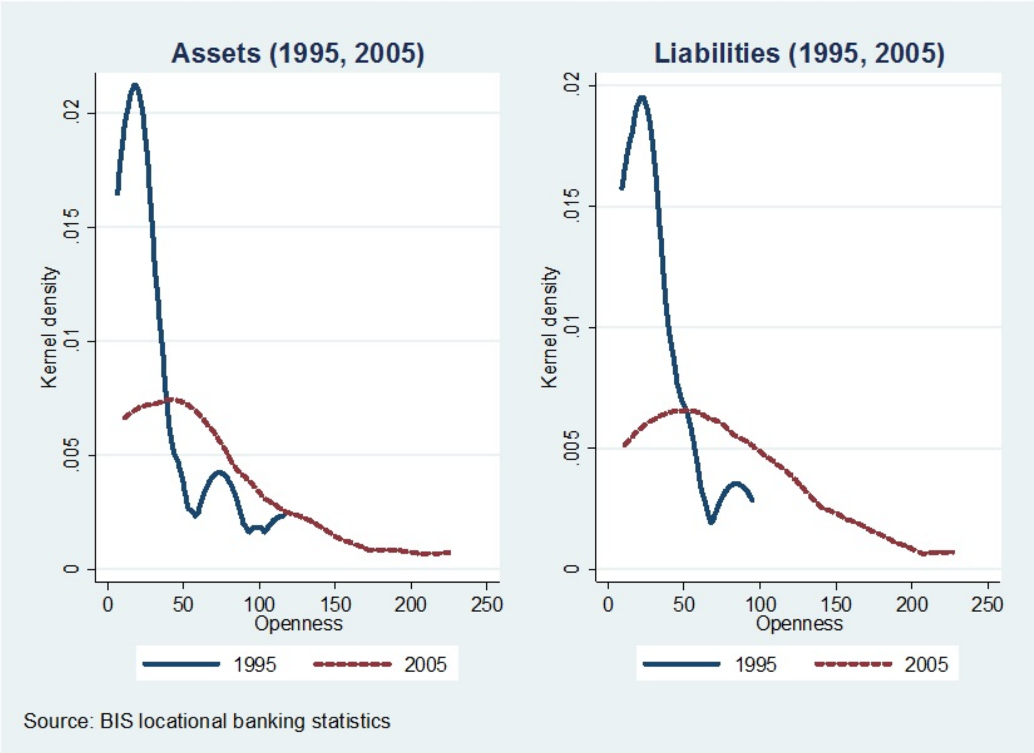

Figure 2: Kernel Density Cross-Border Interbank Exposures

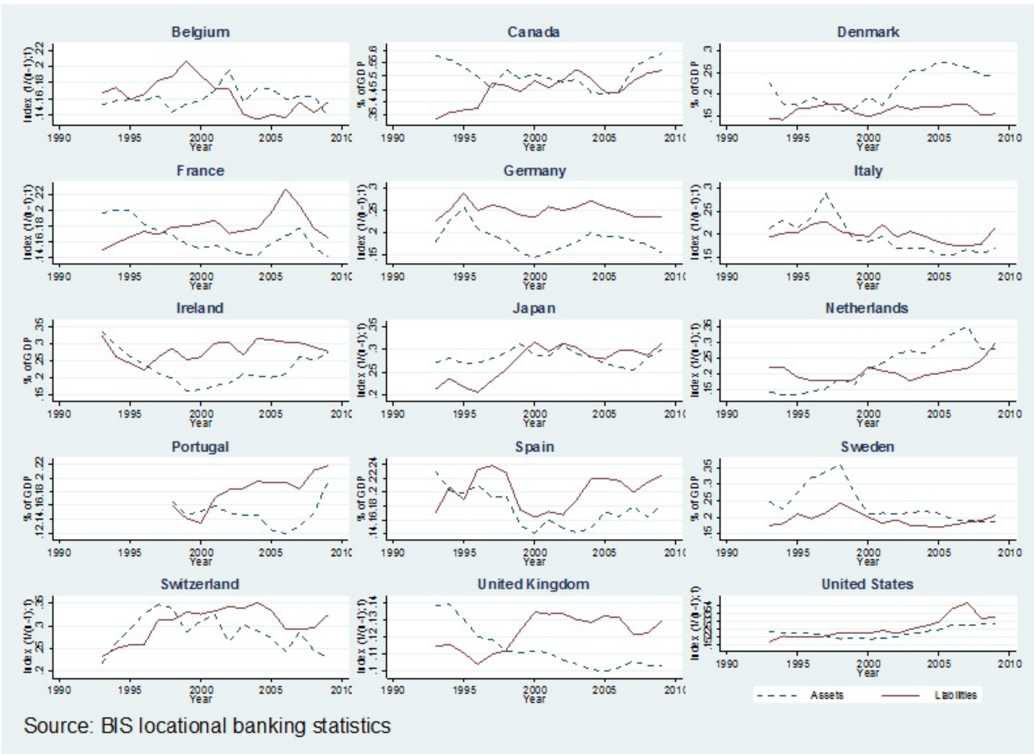

Figure 3: Diversification (HHI)

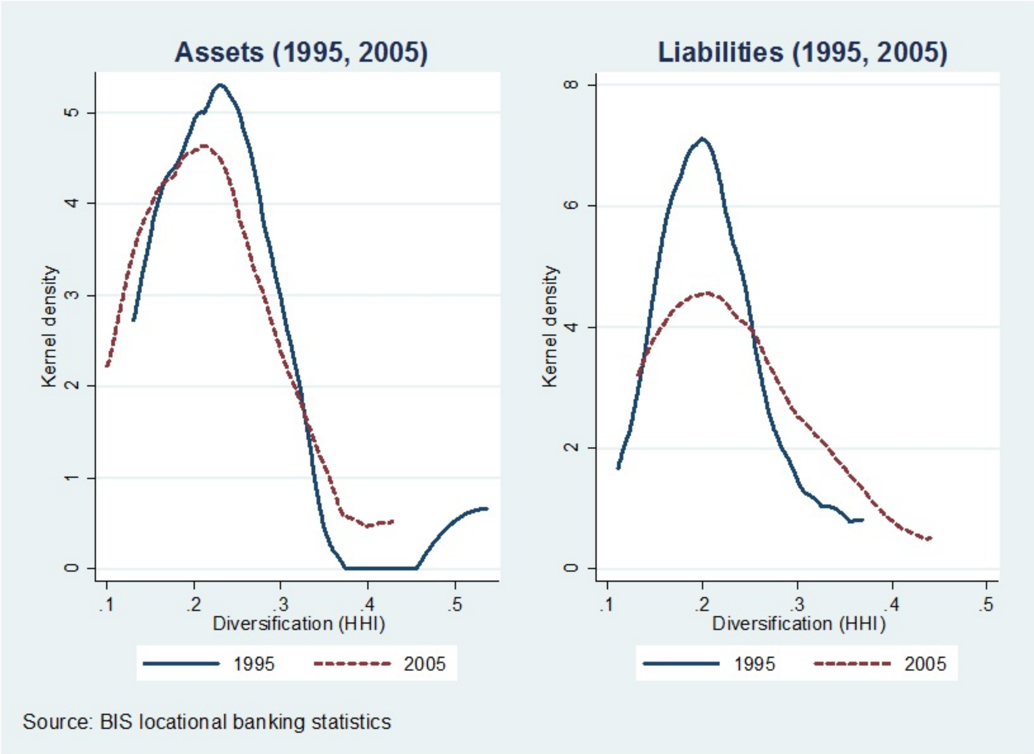

Figure 4: Kernel Density Diversification (HHI)

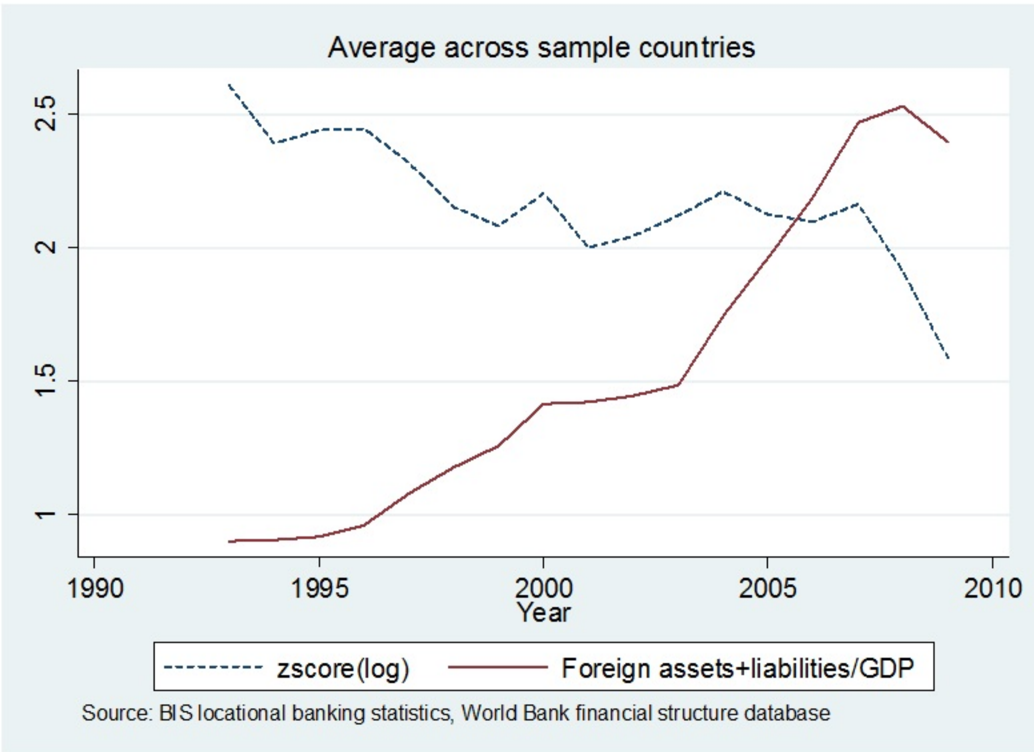

Figure 5: Cross-border Interbank Exposures and Banking Stability

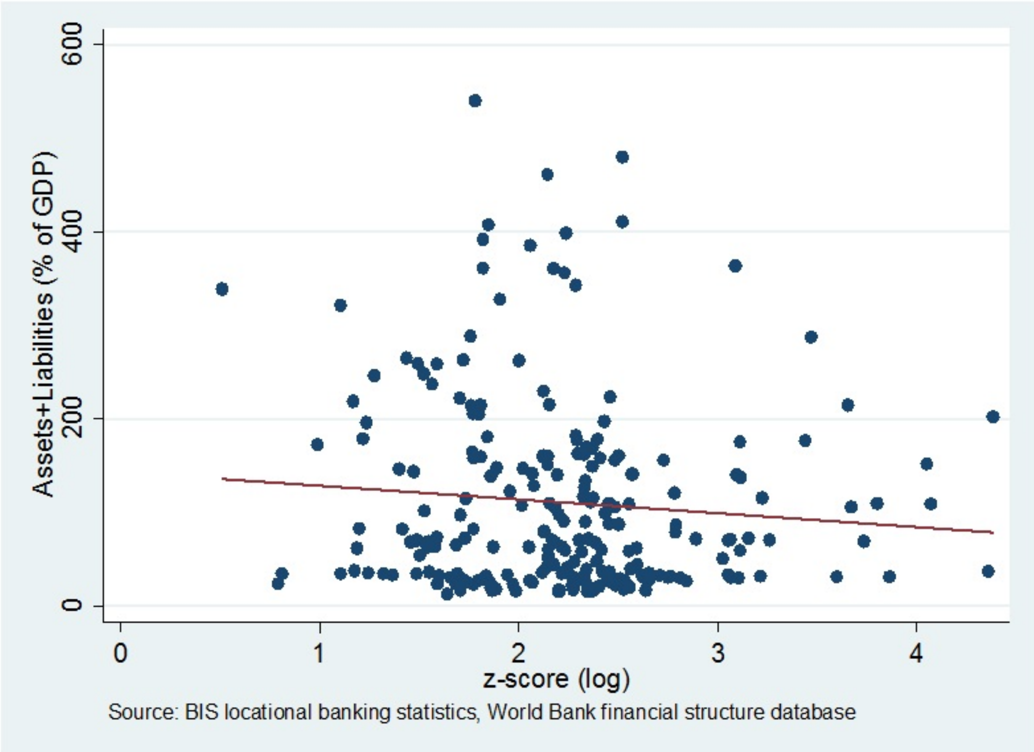

Figure 6: Interbank Openness and Banking Stability

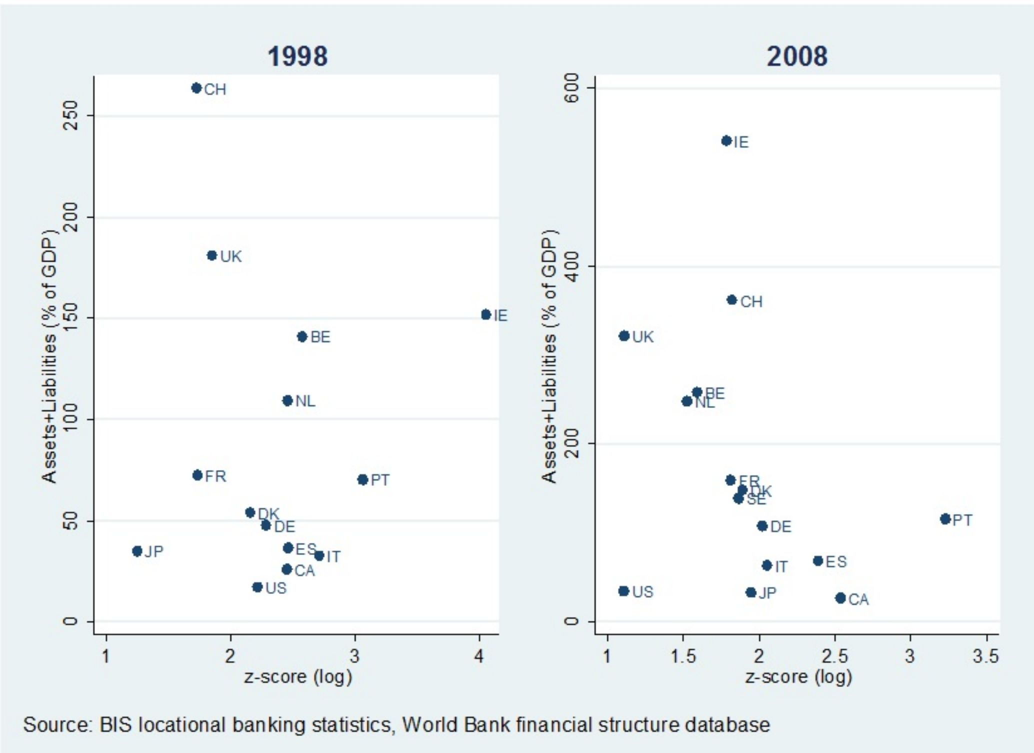

Figure 7: Interbank Openness and Banking Stability - 1998 versus 2008

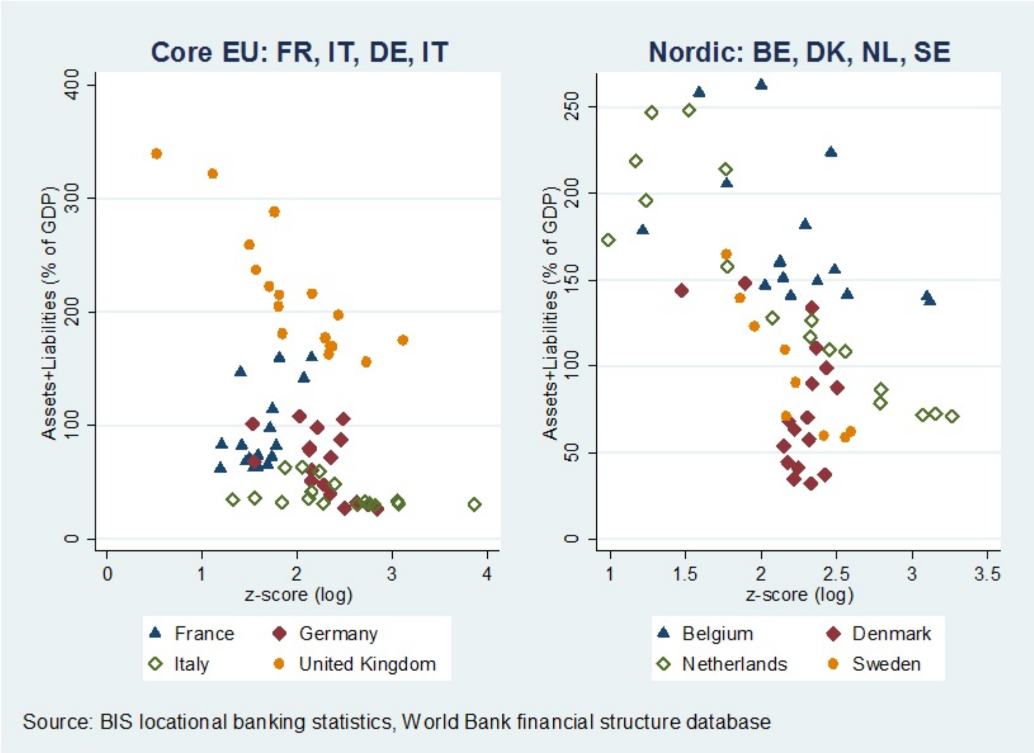

Figure 8: Interbank Openness and Banking Stability - Country Groups

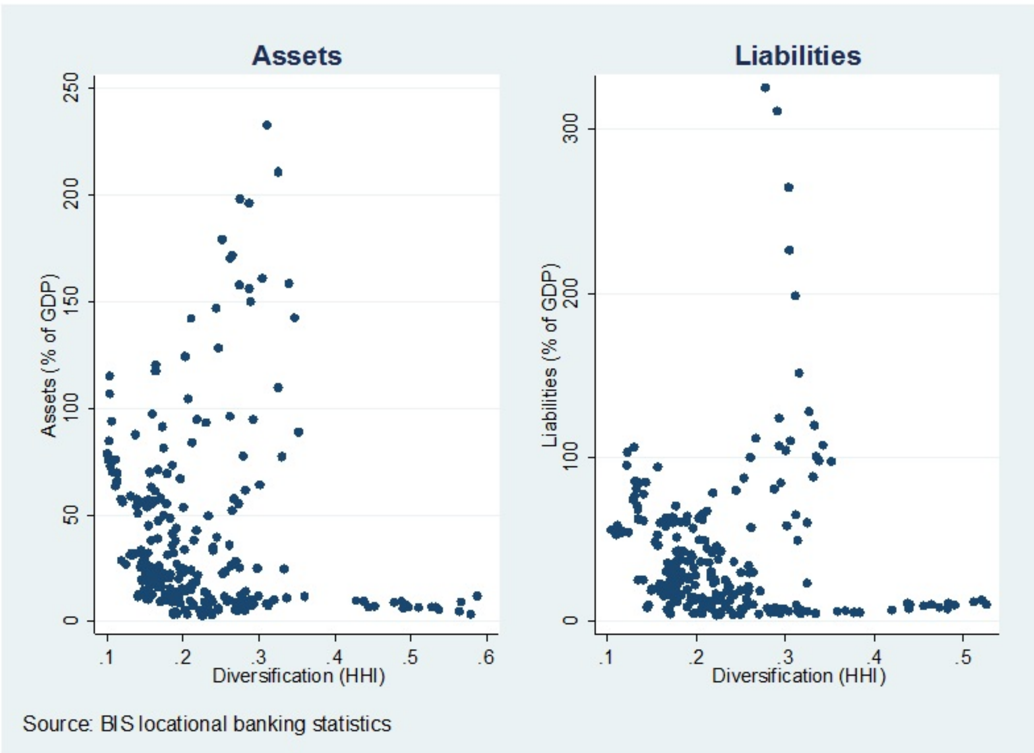

Figure 9: Interbank Openness versus Diversification - A Comparison

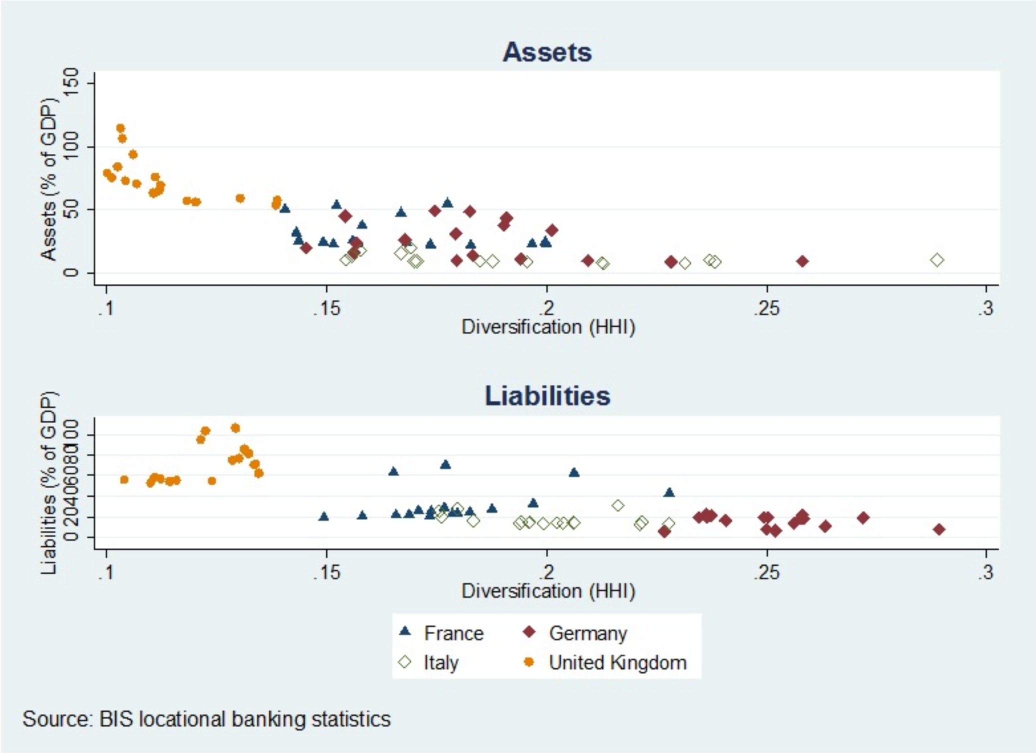

Figure 10: Interbank Openness versus Diversification - Core EU

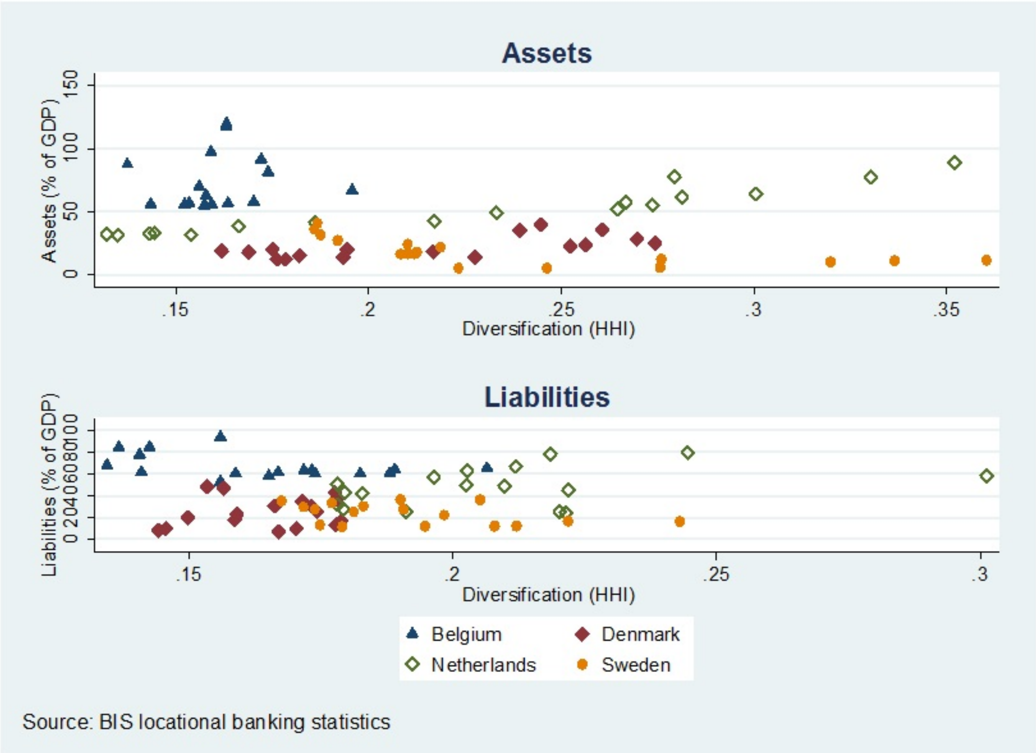

Figure 11: Interbank Openness versus Diversification - Nordic EU

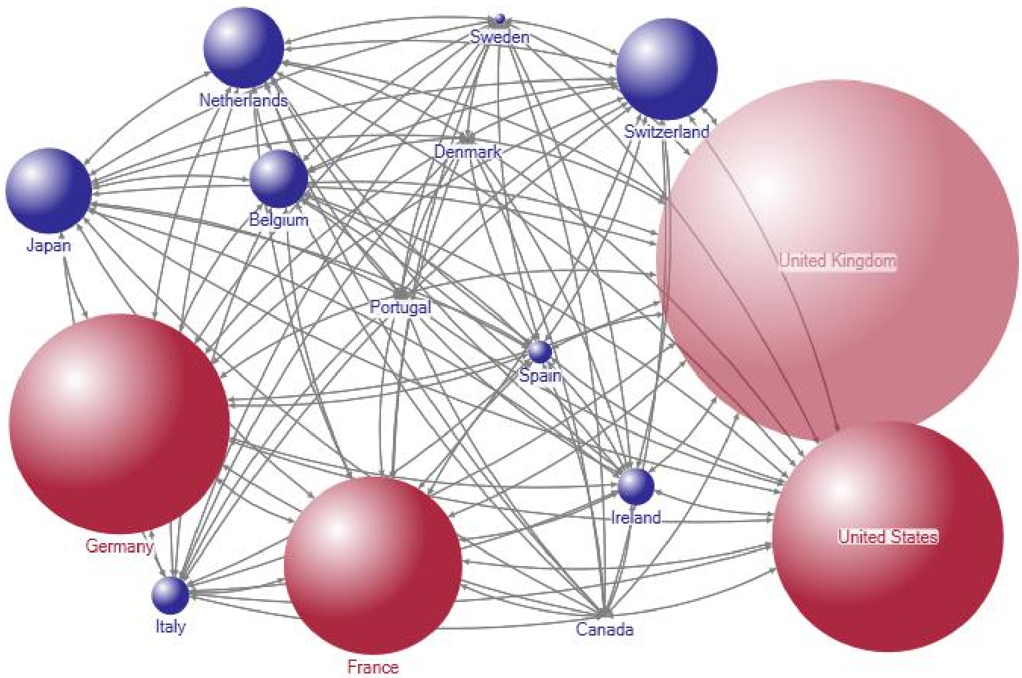

Figure 12: Relative Importance as a Foreign Lender

Table 1: Distribution of Banks' Foreign Claims (2008) - Reporting Countries vis-à-vis Recipient Countries

Claims towards Reporting country	BE	CA	DK	FR	DE	IR	IT (% of total)	JP	NL	PT	ES	SE	CH	UK	US
Belgium		0.7	0.7	11.8	7.9	10.1	5.2	0.4	21.1	0.9	4.9	0.3	1.6	19.1	15.2
Canada	0.7		0.2	1.9	2.1	3.1	0.6	0.7	1.3	0.1	0.6	0.3	0.5	15.2	72.6
Denmark	2.0	0.2		3.3	6.9	12.2	0.6	0.1	1.7	0.1	3.1	33.7	1.0	28.8	6.2
France	4.2	1.0	0.4		9.6	3.4	17.0	7.7	4.7	1.1	6.8	0.6	1.9	16.0	25.7
Germany	1.7	1.5	1.9	7.8		7.4	8.0	2.8	5.9	1.6	9.5	1.4	2.4	23.6	24.7
Ireland	1.5	2.0	0.8	4.4	7.8		8.1	3.0	2.9	0.9	5.6	1.0	0.5	43.3	18.3
Italy	2.2	0.3	0.4	9.0	53.4	4.3		0.6	4.3	1.0	4.3	0.3	2.0	11.3	6.6
Japan	1.7	3.0	0.8	6.6	9.5	2.4	3.4		3.9	0.2	1.9	0.9	1.3	13.2	51.3
Netherlands	9.6	2.6	0.9	10.0	11.8	2.8	6.2	2.5		0.9	8.2	0.7	1.4	17.4	25.1
Portugal	1.9	0.2	1.7	8.0	8.6	11.2	5.0	0.2	6.4		32.7	0.7	2.5	12.0	9.0
Spain	2.0	0.3	0.3	7.5	6.4	2.4	5.8	0.1	5.7	9.9		0.4	0.8	43.5	14.8
Sweden	1.3	0.6	35.6	3.3	22.4	1.8	1.0	0.1	3.1	0.2	2.4		1.5	14.8	11.9
Switzerland	1.1	1.4	0.4	5.5	4.8	1.6	1.7	7.9	2.6	0.2	1.0	0.5		18.3	52.9
United Kingdom	1.8	3.4	0.5	10.0	5.5	8.3	3.3	4.5	4.0	0.9	5.2		1.3		51.2
United States	2.8	7.1	1.7	7.1	11.3	4.1	3.6	13.7	7.0	0.3	4.1	1.1	1.9	34.0	

Source: BIS consolidated banking statistics, immediate borrower basis, bilateral claims towards all sectors.

Table 2: Relative Importance as a Foreign Lender

	Foreign interbank assets (% of total)			
Rank	1993	1998	2003	2008
1	United Kingdom 20.9	United Kingdom 25.1	United Kingdom 24.7	United Kingdom 22.6
2	Japan 20.5	Japan 15.2	United States 15.6	United States 14.8
3	United States 13.2	United States 13.0	Germany 13.9	Germany 14.1
4	France 10.8	Switzerland 10.3	Switzerland 10.6	France 11.6
5	Germany 9.4	Germany 9.3	France 8.0	Switzerland 7.1

Table 3: Relative Importance as a Foreign Borrower

Rank	1993	1998	2003	2008
	Foreign interbank liabilities (% of total)			
1	United Kingdom 23.5	United Kingdom 25.9	United Kingdom 27.3	United Kingdom 26.7
2	Japan 18.9	United States 15.8	United States 15.9	France 14.3
3	United States 17.7	Japan 11.4	Germany 11.4	United States 13.8
4	France 12.3	France 11.3	France 11.0	Germany 8.8
5	Italy 6.1	Germany 10.9	Netherlands 6.1	Netherlands 6.6

Source: BIS locational banking statistics, aggregate positions towards all sectors minus non-bank sector.

Regression Results

Table 4: Banking Integration and Network Spillovers[a]

Model		Spatial effect		Fixed effects	
	(1)	(2)	(3)	(4)	(5)
Control variables					
GDP growth$_{t-1}$	0.069**	0.002	0.003	0.006	0.009
	(0.034)	(0.030)	(0.031)	(0.025)	(0.025)
Real interest rate$_{t-1}$	0.040	-0.001	-0.003	0.013	0.009
	(0.025)	(0.026)	(0.027)	(0.024)	(0.025)
Private credit$_{t-1}$	-0.211**	-0.162	-0.156	-0.433***	-0.416***
	(0.105)	(0.099)	(0.099)	(0.120)	(0.120)
Cost to income$_{t-1}$	-0.894**	-0.912**	-0.936**	-1.034***	-1.092***
	(0.367)	(0.358)	(0.383)	(0.339)	(0.351)
Cross-border banking variables					
IB assets (Flow)$_{t-1}$		-0.266		-0.375	
		(0.284)		(0.318)	
IB liabilities (Flow)$_{t-1}$			-0.200		-0.427
			(0.336)		(0.318)
Spatial effect (Assets)		0.408***		0.352***	
		(0.126)		(0.102)	
Spatial effect (Liabilities)			0.410***		0.358***
			(0.121)		(0.099)
R-squared	0.140	0.113	0.115	0.367	0.369
Observations	228	216	216	216	216
Country FE	-	-	-	Yes	Yes

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term. The first three columns show OLS estimates without fixed effects, columns four and five control for country fixed effects. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors are reported in parentheses.

Table 5: Banking Integration and Network Spillovers[a]

Model	Spatial effect$_{t-1}$		IV (2SLS)		IV (GMM)	
	(1)	(2)	(3)	(4)	(5)	(6)
Control variables						
GDP growth$_{t-1}$	0.018	0.015	0.016	0.019	0.027	0.027
	(0.026)	(0.026)	(0.029)	(0.029)	(0.041)	(0.042)
Real interest rate$_{t-1}$	0.003	-0.002	-0.001	-0.006	-0.004	-0.004
	(0.024)	(0.025)	(0.024)	(0.025)	(0.032)	(0.035)
Private credit$_{t-1}$	-0.461***	-0.453***	-0.138	-0.134	-0.121	-0.109
	(0.113)	(0.114)	(0.091)	(0.094)	(0.108)	(0.099)
Cost to income$_{t-1}$	-0.884***	-0.918***	-0.724**	-0.757**	-0.606*	-0.671*
	(0.337)	(0.345)	(0.333)	(0.363)	(0.362)	(0.380)
Cross-border banking variables						
IB assets (Flow)$_{t-1}$	-0.261		-0.296		-0.390	
	(0.317)		(0.268)		(0.292)	
IB liabilities (Flow)$_{t-1}$		-0.269		-0.242		-0.456
		(0.331)		(0.337)		(0.337)
Spatial effect (Assets)	0.366***		0.538***		0.527***	
	(0.116)		(0.173)		(0.163)	
Spatial effect (Liabilities)		0.386***		0.500***		0.506***
		(0.117)		(0.147)		(0.153)
R-squared	0.347	0.349	0.097	0.101	0.086	0.094
Observations	201	201	201	201	186	186
Country FE	Yes	Yes	-	-	-	-
Endogeneity test			1.223	1.186	0 .644	0.458
$p-value$			0.269	0.276	0.422	0.499
Hansen test					0 .000	0.057
$p-value$					0.997	0.811

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period. In columns one and two country fixed effects are controlled for and the spatial interaction term appears as a lag. Columns three to six show IV (2SLS or one-step GMM) regression results. The spatial interaction term is included contemporaneously and instrumented by its own lagged value in case of the 2SLS IV approach, its first and second lagged value in case of the GMM IV estimation. The Hansen χ^2 statistic tests for instrument validity. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors are reported in parentheses.

Table 6: Diversification and Network Exposures[a]

Model	HHI		HHI^2		Relative node strength		Network exposures (to GDP)		Cross-border interbank assets (to banking system's assets)	
Cross-border interbank	*Assets*	*Liabilities*	*Assets*	*Liabilities*	*Assets*	*Liabilities*	*Assets*	*Liabilities*	*Assets within network*	*Total foreign assets*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Control variables										
GDP $growth_{t-1}$	-0.005	-0.001	-0.005	-0.001	-0.008	0.002	0.006	0.010	-0.005	-0.004
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.026)	(0.024)	(0.024)
Real interest $rate_{t-1}$	0.020	0.004	0.020	0.002	0.021	0.006	0.021	0.010	0.023	0.026
	(0.025)	(0.024)	(0.025)	(0.024)	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Private $credit_{t-1}$	-0.434***	-0.487***	-0.434***	-0.484***	-0.416***	-0.443***	-0.375***	-0.371***	-0.352***	-0.364***
	(0.115)	(0.112)	(0.118)	(0.112)	(0.117)	(0.119)	(0.110)	(0.110)	(0.112)	(0.107)
Cost to $income_{t-1}$	-1.032***	-1.022***	-1.032***	-1.010***	-1.036***	-1.024***	-0.868**	-0.918***	-0.716**	-0.634*
	(0.339)	(0.340)	(0.340)	(0.343)	(0.340)	(0.341)	(0.337)	(0.338)	(0.336)	(0.332)
Cross-border banking variables										
Spatial effect	0.302***	0.305***	0.302***	0.308***	0.317***	0.320***	0.187	0.222*	0.298***	0.226**
	(0.102)	(0.107)	(0.102)	(0.109)	(0.100)	(0.108)	(0.116)	(0.118)	(0.105)	(0.111)
HHI_{t-1}	-1.645*	-0.275	-1.623	4.032	-1.508	-0.418	-1.042	-0.020	-2.033**	-2.122**
	(0.971)	(1.085)	(2.524)	(4.392)	(0.970)	(1.104)	(0.986)	(1.134)	(0.962)	(0.959)
HHI^2_{t-1}			-0.041	-7.135						
			(3.681)	(6.474)						
Relative node $strength_{t-1}$					-1.967	-1.399				
					(1.558)	(1.502)				
Network exposures/GDP_{t-1}							-0.576***	-0.496***		
							(0.187)	(0.181)		
Network exposures/$Assets_{t-1}$									-1.056	-2.249**
									(0.830)	(0.906)
R-squared	0.389	0.385	0.385	0.386	0.388	0.383	0.406	0.396	0.344	0.357
Observations	204	204	204	204	204	204	204	204	182	182

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term. The columns show OLS estimates with country fixed effects. To control for effects from diversification and network exposures, the HHI (columns 1-4), relative node-out/-in strength (columns 5-6) as well as cross-border interbank exposures directed towards the considered network relative to GDP (columns 7-8) are included. Column 9 (column 10) controls for cross-border interbank assets directed towards the considered network (towards all possible recipient countries) relative to the aggregate size of the balance sheet of the banking system. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors in parentheses.

Table 7: European Network and Controls[a]

Model	European network		Euro area		EU member	
	(1)	(2)	(3)	(4)	(5)	(6)
Control variables						
GDP growth$_{t-1}$	-0.000	0.004	0.004	0.007	0.006	0.009
	(0.030)	(0.029)	(0.025)	(0.025)	(0.025)	(0.025)
Real interest rate$_{t-1}$	0.008	0.006	0.005	0.003	0.013	0.009
	(0.029)	(0.029)	(0.026)	(0.026)	(0.024)	(0.025)
Private credit$_{t-1}$	-0.486***	-0.480***	-0.423***	-0.409***	-0.433***	-0.416***
	(0.146)	(0.148)	(0.118)	(0.118)	(0.120)	(0.120)
Cost to income$_{t-1}$	-0.993***	-1.038***	-1.003***	-1.061***	-1.034***	-1.092***
	(0.356)	(0.370)	(0.334)	(0.345)	(0.339)	(0.351)
Cross-border banking variables						
IB assets (Flow)$_{t-1}$	-0.302		-0.318		-0.375	
	(0.304)		(0.313)		(0.318)	
IB liabilities (Flow)$_{t-1}$		-0.360		-0.377		-0.427
		(0.319)		(0.318)		(0.318)
Spatial effect (Assets)	0.314***		0.335***		0.352***	
	(0.118)		(0.108)		(0.102)	
Spatial effect (Liabilities)		0.313***		0.340***		0.358***
		(0.116)		(0.109)		(0.099)
Dummy variable			-0.105	-0.088	1.038***	1.129***
			(0.128)	(0.132)	(0.279)	(0.275)
R-squared	0.376	0.377	0.366	0.368	0.367	0.369
Observations	166	166	216	216	216	216

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term. The columns show OLS estimates with country fixed effects. The first two columns are based on a sample of European countries only. The remaining columns include dummies for membership in the Euro area or the EU. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors in parentheses.

Table 8: Time Effects[a]

Model	Common control				Omit recent crisis		Crisis dummy	
	ΔS&P500		OECD growth					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Control variables								
GDP growth$_{t-1}$	0.005	0.008	0.001	0.004	-0.001	-0.001	0.008	0.010
	(0.026)	(0.026)	(0.027)	(0.027)	(0.029)	(0.029)	(0.025)	(0.025)
Real interest rate$_{t-1}$	0.016	0.013	0.027	0.022	0.018	0.008	0.031	0.027
	(0.024)	(0.025)	(0.025)	(0.026)	(0.026)	(0.028)	(0.025)	(0.026)
Private credit$_{t-1}$	-0.414***	-0.400***	-0.390***	-0.382***	-0.404***	-0.415***	-0.290**	-0.286**
	(0.124)	(0.124)	(0.118)	(0.118)	(0.148)	(0.151)	(0.137)	(0.138)
Cost to income$_{t-1}$	-0.984***	-1.052***	-0.950***	-1.028***	-0.744	-0.786	-0.924***	-0.987***
	(0.354)	(0.365)	(0.338)	(0.350)	(0.492)	(0.487)	(0.337)	(0.349)
Cross-border banking variables								
IB assets (Flow)$_{t-1}$	-0.405		-0.484		-1.473***		-0.404	
	(0.313)		(0.308)		(0.414)		(0.292)	
IB liabilities (Flow)$_{t-1}$		-0.453		-0.517*		-1.205***		-0.436
		(0.311)		(0.304)		(0.444)		(0.303)
Spatial effect (Assets)	0.308***		0.221		0.181		0.228**	
	(0.104)		(0.146)		(0.148)		(0.108)	
Spatial effect (Liabilities)		0.319***		0.240		0.220		0.235**
		(0.098)		(0.147)		(0.159)		(0.110)
Common control$_t$	0.002	0.001	0.037	0.032			-0.273**	-0.257**
	(0.002)	(0.002)	(0.028)	(0.029)			(0.110)	(0.115)
R-squared	0.366	0.367	0.369	0.370	0.288	0.282	0.379	0.379
Observations	216	216	216	216	189	189	216	216

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term and common time control variables. The columns show OLS estimates with country fixed effects. The first four columns include common time controls. Columns five and six omit the recent crisis years 2008-2009. In the last two columns dummies for banking crises are included (see data description above for crisis dates). *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors are reported in parentheses.

Table 9: Market Structure, Sovereign Debt and Current Account[a]

Model	Concentration		Banking system size		Financial freedom		Financial centre		Government debt		Current account	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Control variables												
GDP growth$_{t-1}$	0.007	0.009	0.010	0.013	-0.012	-0.008	0.006	0.009	-0.002	-0.001	0.006	0.009
	(0.026)	(0.026)	(0.025)	(0.025)	(0.031)	(0.030)	(0.025)	(0.025)	(0.030)	(0.030)	(0.025)	(0.026)
Real interest rate$_{t-1}$	0.014	0.010	0.016	0.012	0.026	0.022	0.013	0.009	0.016	0.013	0.013	0.009
	(0.024)	(0.025)	(0.024)	(0.025)	(0.028)	(0.028)	(0.024)	(0.025)	(0.025)	(0.026)	(0.024)	(0.025)
Private credit$_{t-1}$	-0.423***	-0.404***			-0.496***	-0.474***	-0.433***	-0.416***	-0.431***	-0.413***	-0.426***	-0.411***
	(0.122)	(0.122)			(0.135)	(0.134)	(0.120)	(0.120)	(0.120)	(0.119)	(0.120)	(0.120)
Cost to income$_{t-1}$	-1.059***	-1.119***	-1.070***	-1.132***	-1.093***	-1.137***	-1.034***	-1.092***	-1.023***	-1.084***	-1.022***	-1.087***
	(0.341)	(0.352)	(0.351)	(0.362)	(0.362)	(0.372)	(0.339)	(0.351)	(0.339)	(0.351)	(0.342)	(0.353)
Cross-border banking variables												
IB assets (Flow)$_{t-1}$	-0.389		-0.418		-0.167		-0.375		-0.412		-0.413	
	(0.327)		(0.332)		(0.280)		(0.318)		(0.349)		(0.304)	
IB liabilities (Flow)$_{t-1}$		-0.427		-0.467		-0.311		-0.427		-0.464		-0.445
		(0.321)		(0.325)		(0.302)		(0.318)		(0.327)		(0.316)
Spatial effect (Assets)	0.361***		0.374***		0.243**		0.352***		0.358***		0.356***	
	(0.105)		(0.100)		(0.120)		(0.102)		(0.103)		(0.103)	
Spatial effect (Liabilities)		0.371***		0.380***		0.265**		0.358***		0.365***		0.359***
		(0.102)		(0.096)		(0.114)		(0.099)		(0.102)		(0.099)
Control variable$_{t-1}$	0.271	0.301	-0.377***	-0.361***	0.002	0.002	-1.038***	-1.129***	-0.004	-0.004	0.008	0.005
	(0.328)	(0.327)	(0.117)	(0.117)	(0.004)	(0.004)	(0.279)	(0.275)	(0.007)	(0.007)	(0.015)	(0.015)
R-squared	0.366	0.369	0.358	0.361	0.390	0.397	0.367	0.369	0.365	0.367	0.364	0.366
Observations	216	216	216	216	176	176	216	216	216	216	216	216

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term. The columns show OLS estimates with country fixed effects. Further controls like a measure for bank concentration, the size of the banking system, the financial freedom index, a financial centre dummy (assigned to Japan, Switzerland, UK and USA), changes in public debt positions and the current account balance are included. See also data description above for more detailed information on the variables. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors in parentheses.

Table 10: Alternative Definition of BIS Data[a]

Model	IB gross positions		Cross-border exposures			
	flows	stocks	to non-banks		to all sectors	
	(1)	(2)	(3)	(4)	(5)	(6)
Control variables						
GDP growth$_{t-1}$	-0.002	0.006	-0.007	0.001	-0.004	-0.001
	(0.023)	(0.024)	(0.023)	(0.023)	(0.023)	(0.023)
Real interest rate$_{t-1}$	0.013	0.021	0.015	0.015	0.014	0.010
	(0.024)	(0.024)	(0.025)	(0.024)	(0.024)	(0.024)
Private credit$_{t-1}$	-0.400***	-0.287**	-0.428***	-0.400***	-0.398***	-0.387***
	(0.119)	(0.116)	(0.119)	(0.119)	(0.121)	(0.118)
Cost to income$_{t-1}$	-0.982***	-0.791**	-0.948***	-0.879**	-0.949***	-0.969***
	(0.341)	(0.324)	(0.339)	(0.343)	(0.338)	(0.338)
Cross-border banking variables						
Assets (Flow)$_{t-1}$			-0.262		-0.278	
			(1.137)		(0.266)	
Liabilities (Flow)$_{t-1}$				-1.324		-0.340
				(0.942)		(0.263)
IB gross positions$_{t-1}$	-0.200	-0.231***				
	(0.159)	(0.085)				
Spatial effect (Assets)			0.380***		0.403***	
			(0.098)		(0.102)	
Spatial effect (Liabilities)				0.385***		0.407***
				(0.093)		(0.092)
Spatial effect (Gross)	0.396***	0.249**				
	(0.096)	(0.118)				
R-squared	0.382	0.396	0.374	0.384	0.380	0.388
Observations	216	216	216	216	216	216

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term. The columns show OLS estimates with country fixed effects. The first two columns include gross foreign interbank exposures (assets+liabilities) measured as either stocks or flows. The weighting matrix for the computation of the spatial term is for all cases based on stock data. The remaining columns break foreign positions down by assets and liabilities to either the non-bank sector or all sectors (non-bank and bank). See also data description above for more detailed information on the variables. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Robust standard errors in parentheses.

Table 11: Alternative Weight Matrices[a]

Model	Time varying weights		(Distance^{-1})	Constant weights (1993)		(Average 1993-2008)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Control variables							
GDP growth$_{t-1}$	0.002	0.003	-0.011	-0.006	-0.005	-0.007	-0.005
	(0.076)	(0.106)	(-0.385)	(-0.205)	(-0.188)	(-0.239)	(-0.172)
Real interest rate$_{t-1}$	0.013	0.012	0.035 *	0.031	0.028	0.027	0.025
	(0.525)	(0.467)	(1.686)	(1.545)	(1.388)	(1.342)	(1.231)
Private credit$_{t-1}$	-0.449***	-0.441***	-0.342***	-0.320***	-0.321***	-0.311***	-0.309***
	(-3.745)	(-3.705)	(-2.918)	(-2.754)	(-2.766)	(-2.681)	(-2.682)
Cost to income$_{t-1}$	-1.011***	-1.017***	-0.690*	-0.705**	-0.717**	-0.699*	-0.710**
	(-3.008)	(-3.022)	(-1.906)	(-1.963)	(-2.000)	(-1.950)	(-1.992)
Cross-border banking variables							
Spatial effect (Distance)			0.097				
			(0.839)				
Spatial effect (Assets)	0.349 ***			0.157		0.192 *	
	(3.444)			(1.505)		(1.919)	
Spatial effect (Liabilities)		0.348 ***			0.189 *		0.229 **
		(3.529)			(1.764)		(2.345)
R-squared	0.366	0.367	0.303	0.310	0.312	0.314	0.320
Observations	216	216	192	192	192	192	192
robust LM test			10.92	11.76	8.52	10.21	9.46
$p - value$			0.001	0.001	0.004	0.001	0.002
Country/ spatial FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a]Note: The dependent variable is *ln(z-score)*, all control variables are lagged by one period except for the spatial interaction term. The first two columns show OLS estimates with country fixed effects. The remaining columns show spatial ML estimates with constant weight matrices whereas spatial fixed effects are included. In column three, the weights are composed of inverse distances between capitals of country pairs. Alternatively, I use relative interbank exposures in 1993 (columns 4-5) or their average across the sample period (columns 6-7). More detailed information on the construction of the weighting matrix can be found at the beginning of the Appendix. *,**,*** denotes statistical significance at the 10%, 5% and 1% level, respectively. Corresponding t-values are in parentheses.