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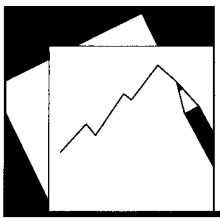

IMF Working Paper

Real and Financial Vulnerabilities from Crossborder Banking Linkages

Kyunghun Kim and Srobona Mitra

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Monetary and Capital Markets Department

Real and Financial Vulnerabilities from Crossborder Banking Linkages[1]

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Authorized for distribution by James Morsink

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Abstract

This paper looks at the vulnerabilities stemming from banking sector linkages between countries and their macroeconomic effects. It finds that credit risks (from a banking system's claims on other countries) and funding risks (from a banking system's liabilities to another) have declined over the past five years. It also finds that funding vulnerabilities have real effects. During normal times, funding vulnerabilities are associated with significant positive GDP growth surprises. During crisis times, funding vulnerabilities are associated with significant negative GDP growth surprises. The results tell us that policymakers should pay more attention to understanding crossborder funding risks.

JEL Classification Numbers: G01, G15, G21. Keywords: Network Linkages; Banking; Funding Risks; Credit Risks; GDP surprises. Author's E-Mail Addresses: hunkim@ucdavis.edu; Smitra@imf.org.

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I. INTRODUCTION

The Global Financial Crisis made it clear that financial shocks could be quickly transmitted through global banks. The tightly interconnected financial systems were put through several tests during the global financial crisis. The banking linkages, by far the largest and the deepest segment of financial flows, saw reduced flows.

Against this backdrop, we ask two questions. First, how have countries' vulnerabilities arising from banking network linkages changed in the last five years? We look at two kinds of risks—credit risk and funding risk. These risks are related to the nature of the interlinkages—credit risks materialize through a banking system's claims on other countries, funding risks arise through banking systems's liabilities to another. The vulnerabilities are related to both *exposures* to these risks and the *capital* buffers available against these risks. Second, what are the macroeconomic effects of these vulnerabilities? That is, are these specific vulnerabilities associated with real GDP growth beyond what is expected in macroeconomic forecasts?

We explore the financial risks of crossborder banking linkages using network analysis. Rather than just identifying and quantifying linkages, we simulate the impact on capital levels of the credit and funding shocks that could be transmitted through direct and indirect (domino effect) banking linkages. We ask whether the potential impact on capital—summarized by vulnerability indices—has changed in the last five years. Using network analysis (Espinosa-Vega and Sole, 2010), we show the trends in the financial systems' vulnerability to network effects of shocks on either side of the balance sheet.

The paper then asks whether the vulnerability of a banking system from interconnections influences output. For the network analysis to have macro-financial implications, the real effects of higher vulnerability to network shocks are estimated using an econometric model. Specifically, a set of panel fixed effect regressions examine the relationship between vulnerability to crossborder credit or funding shocks and GDP growth rate surprises, measured by the difference between actual GDP growth and Consensus Forecasts.

We have two main findings. First, vulnerabilities of banking systems to both credit and funding risks have declined since the crisis. This decline is due to both lower exposures and increases in capital for the global banking system. Second, funding vulnerabilities have real effects. During normal times, funding vulnerabilities are positively associated with GDP growth surprises; during crisis, the same vulnerabilities exacerbate the negative GDP growth surprises. Credit vulnerabilities, on the other hand, are not associated with GDP surprises.

The rest of the paper is organized as follows. The related literature is discussed in the next section; the methodology and the data in Section III; the findings on the vulnerability trends and the association of the vulnerabilities with GDP growth surprises are discussed in Sections IV and V, respectively; and, Section VI concludes.

II. RELATED LITERATURE

Our work builds on the recent literature on crossborder financial interconnectedness and its implications for financial stability and real output. Kalemli-Ozcan, Papaioannou et al. (2012) find that higher banking linkages are associated with more divergent output cycles during normal times; however, this relationship becomes weaker during financial crisis. Abiad et al (2013) distinguish between traditional financial linkages and common shocks to show that output co-movement across countries—synchronized output collapses—occurs during financial crises through common shocks. Cetorelli and Goldberg (2010) show how the United States financial crisis was transmitted to other countries through the relationship between multinational banks and their foreign affiliates. Albertazzi and Bottero (2014) suggest that the foreign banks restricted credit supply more than their domestic counterpart using disaggregated Italian bank-firm data. De Haas and Van Lelyveld (2014), Giannetti and Laeven (2012), and Popov and Udell (2012) have empirical evidence to show that multinational banks restricted credit supply in the host countries during the recent financial crisis.

Cihák, Scuzzarella et al. (2011) show M-shaped relationship between financial stability of a country's banking sector and its crossborder interconnectedness measured by network centrality measures—starting from low integration, increases in global interconnectedness for the banking system are associated with a reduced probability of a banking crisis. A banking system whose interconnectedness is over a certain value, increases in interconnectedness can increase the probability of a banking crisis. Relatedly, Minoiu et al. (2013) show that increases in a country's own connectedness and decreases in its neighbors' connectedness are associated with a higher probability of banking crises. Nier, Yang et al. (2007) investigate how systemic risk is affected by the structure of the banking system using network models.

Espinosa-Vega and Solé (2010) show that network analysis can be used as a tool for cross-border financial surveillance. By simulating credit or funding shocks, they obtain vulnerability indices for each banking system. Using the tool, Espinosa-Vega, Sole, and Kahn (2010) also propose a framework for capital requirements for those banks that have a large contribution to systemic risk in a network. Cerutti, Claessens and McGuire (2011) highlights data needed for properly analyzing contagion risk, an exercise similar in spirit to the network analysis, and Cerutti (2013) proposes two new measures for better capturing creditor banking system's foreign credit exposures and borrower countries' reliance on foreign bank credit, by combining BIS data with bank-level data.

Ours is the first paper to distinguish between crossborder risks arising from the asset and the liability side of the banking system's balance sheet and relate these different risks to macroeconomic effects. We apply the methodology proposed by Espinosa-Vega and Solé (2010) to a dataset which covers 20 countries over 2006–2012 and show the real impacts for the countries receiving the shocks. We document how the crossborder vulnerabilities of the banking system have evolved since 2006 and show how the vulnerability index from the network analysis is associated with output shocks during normal times and crisis.

III. DATA AND METHODOLOGY

The vulnerability from interconnections goes beyond the simple mapping of exposures between countries. The vulnerability or susceptibility to network effects is measured by the potential capital shortfall in the event of a tail risk in which one banking system fails. It is measured by the average change in the capital level in percentage of the pre-shock capital due to the direct and domino effects of every banking system failing. Therefore, the vulnerability of any country to a shock in another banking system depends upon four factors: effects through direct bilateral links, domino effects through indirect network links, own capital levels, and capital levels in the major shock-propagating countries. Vulnerability goes up with stronger banking bilateral links and gets magnified by domino effects running through link-of-links. Lower capital buffers in the shock-recipients, as well as in shock-propagators increases vulnerability in any given country. Of course, the use of aggregate data might not capture potential systemic vulnerabilities arising from individual large institutions.

Data

To run the network analysis, we need data on the *matrix* of exposures between countries. This means, we need a banking system's credit (claims) and liabilities vis-à-vis another country's banking system. We use the Bank for International Settlements (BIS) consolidated banking statistics (Table 9B) for the purpose. Since it does not have data on crossborder *liabilities* of banking systems, we proxy that by looking at the claims of the counterparty banking systems. The liabilities side, therefore, is measuring the liabilities of all sectors of the economy to BIS reporting banks with headquarters in another country. Even though it is imprecise, we are assuming that most of these liabilities are sourced through the banks and measures the banking system's indirect liabilities to the BIS reporting banks in the other country. This is the best we can do with the published data, which is available for 20 countries.[2]

We have a 20 by 20 matrix for each of the years 2005 through 2012. For instance, in 2008, the United States banks lent USD268 billion to the United Kingdom and the United States (all sectors) borrowed USD 1217 billion from the United Kingdom. By 2012, the United States lent more than twice to the United Kingdom and borrowed less from the United Kingdom (Table 1).

In order to understand the *vulnerabilities* from crossborder exposures, one needs to weigh the exposures against the financial *buffers*. So, we need data on capital, which we get from Bankscope. We take the sum of the capital that each banking system's commercial banks, saving banks, cooperative banks, real estate & mortgage banks, investment banks, other non-banking credit institutions, and specialized governmental credit institutions own. We cast a

[2] Confidential bilateral data based on the BIS Locational Statistics, which was available for 2012Q3, provides the breakdown by bank and nonbank exposures. On average, 60 percent of the crossborder claims of the BIS reporting banks resident or located in a certain country are on the banking sector; the average is higher for the G7 countries.

wide net to capture data on capital from as many institutions residing and headquartered in a country to get a sense of buffers.

Methodologies

Deriving Vulnerability Indices based on Network Analysis

The network model used in this paper was developed in Chapter 2 of the April 2009 Global Financial Stability Report of the IMF and described in Sole and Espinosa-Vega (2010). The model runs simulations using the data on exposures and capital. Specifically, it lets each banking system fail and calculates the impact of the credit risk from such a failure on other banking systems' capital. Similarly for funding risk. There are both direct and domino effects of a banking system's failure on others.

The method can be illustrated by means of a stylized balance sheet of a banking system, say A (Figure 1). For credit risk (left panel), if, another banking system B's banks fail due to some unexplained event, it is unable to repay λ (assumption is 0.5 in the baseline) of its dues to all other countries. These assets then go 'bad' for all the creditor banking systems, A is one of them, and these should have sufficient capital to absorb this loss. If they don't, then the banking systems are said to fail, and these then trigger domino impacts on all others. The simulation goes on until there are no more failures.

For funding risk (right panel): If B fails, it is unable to rollover ρ (assumption is 0.5 in the baseline) times other countries' liabilities, including A's. A, and other countries then try to fire sell their assets at a haircut (assumption is half, which translates into δ=1) and takes a hit on capital. If it fails, it triggers further failures. Again, the domino goes on until there are no more failures.

The network model produces vulnerability indices. The index is simply the average capital depletion if other banking systems fail. This number is derived by running the network model for each country, at each point of time, 2005–2012, separately for credit risk and funding risk. So, we have a credit vulnerability index and a funding vulnerability index for each country. Then we have a global index (for all 20 countries) that takes a weighted average of the indices for each country, weighted by the sum of gross credit and liabilities of each country.

The vulnerability index has a practical meaning. The credit index tells us the potential capital loss (in percent of pre-shock capital) of a banking system's opening up to foreign expansions, increasing foreign claims or not having adequate capital buffers against those claims. The funding index informs us on the potential capital loss rate of a banking system due to opening up to higher foreign funding (liabilities risk) without adequate capital buffers to withstand fire sales if necessary. The index itself is influenced by four factors for given levels of the parameters, λ, ρ, and δ: direct linkages, indirect linkages, own capital levels, and those of others.

Deriving Macroeconomic Effects of Crossborder Vulnerability Indices

We use panel fixed effects regressions to look at the association between GDP growth surprises and the vulnerability indices, for 20 countries, for seven years 2006–2012. The GDP growth surprises are calculated by taking the difference between actual GDP growth and the forecast of GDP growth made in the previous December by Consensus Economics. The average growth surprises for the twenty countries show the large negative surprises during the crisis years—2008 and 2009 (Figure 2). The regressions take the growth surprise as the dependent variable, and regresses it on a dummy variable that takes the value of 1 for the two crisis years, the vulnerability index and a term that interacts the vulnerability index with the crisis dummy (see equation 1).

$$(1)\ \hat{y}_{it} = \alpha_i + \beta * crisis_{2008-09} + \gamma * VUL^{v}_{it-1} + \lambda * VUL^{v}_{it-1} * crisis_{2008-09} + \varepsilon_{it}$$

where, $\hat{y}$ is GDP Growth Surprise=Actual Real GDP Growth - Consensus Forecast

VUL^{v}: Vulnerability index for Credit risk or Funding risk

$crisis_{2008-09}$ = 1 for 2008 and 2009

If the crossborder credit and funding risks are well understood by macroeconomic forecasters, we would not expect the indices to affect the growth surprises. This is because the GDP forecasts would already take account the risks that could affect a country through the crossborder banking channels so that the residuals, the GDP growth surprises, should not be correlated with information available at the time of making these forecasts.

To check if data on overall exposures (foreign claims + foreign liabilities) and capital, separately would have delivered similar results, obviating the need to run the network analysis, we add a second set of regressions using these components, instead of the vulnerability indices (equation 2). If higher exposures and lower capital helped explain growth surprises, then understanding these components of the network analysis would be beneficial by themselves.

$$(2)\ \hat{y}_{it} = \alpha_i + \beta * crisis_{2008-09} + \gamma_1 * Cap_{it-1} + \lambda_1 * Cap_{it-1} * crisis_{2008-09} + \gamma_2 * Exp_{it-1} + \lambda_2 * Exp_{it-1} * crisis_{2008-09} + \varepsilon_{it}$$

where, Cap: Capital/GDP

Exp: (Foreign claims + Foreign liabilities)/GDP

IV. Is the World Safer from Crossborder Banking Linkages?

The matrix of banking exposures across countries reveals notable changes between 2008 and 2012 (Table 1). The financial exposures and funding of non-European countries are on the rise, especially of Canada, Japan and the United States. The Euro Area countries have all

seen a drop in both crossborder exposures and funding; this is especially so for France and Germany. This phenomenon, often called 'fragmentation,' has left policymakers worried about the cost of funds and the availability of credit in European countries. Whether the world is safer from crossborder banking connections depends upon bilateral exposures, network exposures through domino effects, own and other countries' capital levels.

Vulnerability of the overall global banking system to network shocks was high before 2008 (Figures 3 and 4). Going back to 2006, about 25–30 percent of capital, on an average in a country could have been impaired due to network effects of credit and funding shocks. Since then, countries' susceptibility to these shocks started coming down till 2008, and then fell after that. The decrease till 2008 was mostly due to the lower volume of flows between advanced countries since mid-2007. The vulnerabilities in 2006, based on published balance sheet data on the banking network, could have served as early warning on the extent of losses that banking systems would suffer if there were to be an extreme event.

Since end-2008, banking systems were generally less vulnerable to ripple effects from network shocks due to two reasons. With the collapse of Lehman Bros. and the severance in some linkages due to the materialization of the adverse shocks, individual banking systems now had lower volume of inflows through banks. And, capital levels had increased on the aggregate after the crisis so that for any inflow the buffers were greater across countries, in general, to absorb the shocks.

To show that higher buffers were not entirely responsible for the lower vulnerability levels, the network analysis is repeated for 2009–2012 assuming that the capital levels are constant at the 2008 levels (Figures 3 and 4). Even after adjusting for capital, the vulnerability indices (weighted by total exposures of countries) have trended down for both credit and funding shocks, which suggest that actual strength and number of interconnections had also fallen.

The aggregate results mask wide cross-country differences in vulnerability trends on credit shocks. There are three groups of countries depending upon whether vulnerabilities on crossborder assets have trended down or up or largely remained unchanged since 2008 (Figure 5):

- Belgium and Ireland started from high levels of susceptibility to shocks on their crossborder investments, and these have come down significantly. The downward trend is mainly due to lower volume of crossborder investments than due to higher capital levels. In addition, the United Kingdom, France, Italy, Germany, Switzerland and other countries in the middle of Figure 5 have also seen downward trends.

- In Greece, the susceptibility to network credit effects of crossborder investments has increased over time.

- The United States, Japan, Canada, Australia, India and Turkey are some countries in the middle, where crossborder credit risks have not significantly changed since 2008.

Interestingly, higher capital buffers seem to have largely contributed towards lower vulnerability to funding shocks, especially for two emerging economies for which we have published data. For India and Turkey and some larger countries, vulnerability to funding shocks came down since the crisis mainly due to higher capital levels. Simulations show that if capital (for all the banking systems) was held constant at the end-2008 levels, then the vulnerability to bank funding flow reversals would have been going up. For the funding shock scenario, there could be two broad groups of countries—vulnerabilities trending down and unchanged (Figure 6):

- The European countries in crisis—Ireland, Spain, Portugal, Greece—along with some others like the United Kingdom, India and Turkey have been trending downwards in their susceptibility to funding shocks. Among these, higher capital buffers seemed to have made a significant difference to India, Turkey, Canada and the United Kingdom—making these countries more resilient to crossborder funding shocks.

- In Austria, Germany and Australia, crossborder funding vulnerability is largely unchanged.

There are also fewer propagators of network shocks than before. Comparing the global banking network in end-2008 to that in end-2012 (Figures 7 and 8), the number of "arrows" showing the direction of contagion have dropped. Back in 2008, the United States, United Kingdom, France and Germany were the main potential propagators (leading to at least 10 failures or half the network) of credit shocks; France, Italy and Germany the main contributors to funding shocks. In 2012, United States and United Kingdom remain the key potential contributors of credit shocks. If the United States and United Kingdom were to fail, there would be large ripple effects and failures in the rest of the world mainly from their borrowings from the rest of the world. Even though there are no longer major propagators of funding shocks, the United States, United Kingdom, France and Germany are still capable of having large impacts on at least two other economies due to funding shocks.[3]

Are the real effects of crossborder banking linkages well understood by macroeconomic forecasters? In what follows, we try to gauge whether greater vulnerability to crossborder banking network shocks are already taken into account in the GDP growth forecasts or whether there are major surprises. We find that the answer depends upon whether the connections are on the assets or the liabilities side of the balance sheet.

[3] India and Turkey do not fall in the path of ripple effects through funding shocks from the US, UK, France or Germany in 2012. Banking linkages do not help explain the turmoil in capital flows to India and Turkey experienced during the Fed tapering fears mid-2013.

V. WHAT IS THE OUTPUT COST OF VULNERABILITY TO BANKING INTERLINKAGES?

Extensive crossborder banking linkages bring both benefits and costs. Banking systems can share risk by diversifying their investments across borders so that there is no excessive reliance on good prospects at home. At the same time, banking systems have often relied on foreign funds to sponsor domestic credit growth when times are good or when banks are competing with other banks for market share in a specific loan segment. Both crossborder investments (asset-growth) and funding (liabilities-growth) carry the risk of reversal during a global crisis or a crisis from the other country. So, during good times, banking systems can grow and contribute to output growth. However, during stress in other countries, the crossborder credit and funding channels are conduits for bringing home crisis from other countries and could have negative GDP growth surprises for the recipient banking system.

Crossborder banking linkages on the credit side do not seem to produce GDP surprises. A panel regression with country fixed effects is estimated to find out whether vulnerabilities to crossborder credit and funding risks explain GDP growth surprises for the 20 countries in the sample (Table 2).[4] The results show that crossborder credit linkages and the risks stemming from the linkages seem to be well understood by those making GDP forecasts. While the 2008-2009 crisis had negative growth surprises on average for all countries, exposure to credit risk from other banking systems did not significantly make countries better off during normal times, nor did it inflict damage, beyond what was expected, during crisis (Table 2, columns 1 and 2).

By contrast, the real effects of possible funding reversals due to crossborder interlinkages during crisis are not well understood. In good times, countries experience higher growth (surprises) by taking up crossborder funding risks, for instance by extending domestic credit funded from crossborder sources. The estimates (Table 2, columns 3 and 4) show that during normal (or non-crisis) times, every percentage point potential shortfall in capital levels contributes to 0.05 percentage point increase in GDP growth surprise. During crisis, however, the benefits could reverse much more, leading to a 0.07 percentage point decrease in GDP growth surprises over and above the average negative surprises. The same vulnerability reverses the good outcomes during crisis although the Wald test on the sum of the coefficients on the funding vulnerability and the cross-term is not always significantly different from zero.[5,6]

[4] Growth surprise for a country is calculated by actual GDP growth rate *minus* the forecast of GDP growth rate from Consensus Forecasts.

[5] The Wald test on the difference between normal and crisis times cannot reject the null hypothesis (H0: coefficient on funding vulnerability + coefficient on interaction with crisis dummy = 0).

[6] A set of regressions with trade linkages was estimated but is not included in Table 2. The trade linkage is measured by (export to and import from the other 19 countries)/GDP. Trade linkages between these countries

(continued…)

As is shown below, a random-effects specification yields an even stronger result for the funding vulnerability—every percentage point of potential capital depletion due to higher funding vulnerability increases surprises by 0.03 percentage point during normal times, and reduces surprises by 0.06 of a percentage point during crisis and this effect is economically significant (the null hypothesis for the Wald test is rejected strongly).

Having higher capital buffers of the countries receiving the shocks helps during crisis, and has no material impact on real growth surprises during normal times. To see if the measure on network vulnerabilities can be substituted by data on exposures and capital separately, a third set of regressions (Table 2, columns 5 and 6) was estimated.7 Results show that higher capital does not lead to lower growth surprises and higher exposures do not contribute to positive growth surprises, in general. However, during crisis, having higher capital buffers help to cushion the (negative) surprise impact.

Robustness

The above results are generally robust to different assumptions on parameters for the network analysis and different specifications for the regressions.

- Indices constructed with different lambda and rho: The movement of the indices is similar to the original indices if different parameters are used. Our initial vulnerability measures are highly correlated (above 0.9) to the new indices constructed with different parameters. The trends in these indices are similar between various assumptions on the parameters for their construction: λ and ρ (Figures 9 and 10).

- In the regression part, the findings regarding the funding and credit vulnerability indices are robust to various assumptions on the parameter values (λ and ρ) for the network analysis. The cross-product terms (crisis * vulnerability) are also still significant for most parameter values. Table 3 shows one such set of parameters.

- Re-running the regressions using random, instead of fixed, effects gives a stronger result on the funding risk (Table 4). As mentioned above, higher funding vulnerability significantly exacerbates negative output surprises. In general, results of panel regressions with random effect are overall similar to the baseline result.

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do not seem to matter for growth surprises during good times or bad times, nor do trade linkages change the outcomes for credit and funding vulnerabilities on growth surprises. This is because trade linkages are typically well documented and included in the dataset while making GDP growth forecasts.

[7] Financial openness or exposure measured by aggregate statistics (foreign claims + foreign liabilities)/GDP is a standard regressor in a growth regression.

- The result that higher capital buffers help cushion negative output surprises during crisis is robust to different model specifications and different data on capital from the IMF Financial Soundness Indicators database, where the data start in 2008, instead of Bankscope.

VI. CONCLUSIONS

To summarize, we find that banking systems' vulnerabilities from crossborder network linkages have decreased in the last five years. For both asset and liability side vulnerabilities, on average for the global banking system, the potential for capital depletion arising from credit risks and funding risks have come down since the global financial crisis. The reduction is mainly due to lower exposures, but is also partly due to higher capital buffers around the world.

While the trend is similar for individual countries, the reason for the decline in vulnerabilities differs between countries and between credit and funding for particular countries. We also find that, compared to 2008, the number of countries as core propagators of credit and funding shocks have dropped. The United Kingdom and the United States would still be the major propagators of credit shocks in 2012.

Funding risks have significant positive effects on growth surprises during normal times, and significant negative effects on growth surprises during crisis times. More than the risks from crossborder credit, risks from crossborder borrowing have significant impacts on real growth surprise. Therefore, they need much more analysis and understanding than just looking at overall external funding volumes. In particular, taking on higher funding risks (by borrowing more from crossborder sources) generally exacerbates the negative output surprise during crisis. This finding is robust to different values of the parameters used to create the vulnerability indices and different specifications and estimation methods of the regression model.

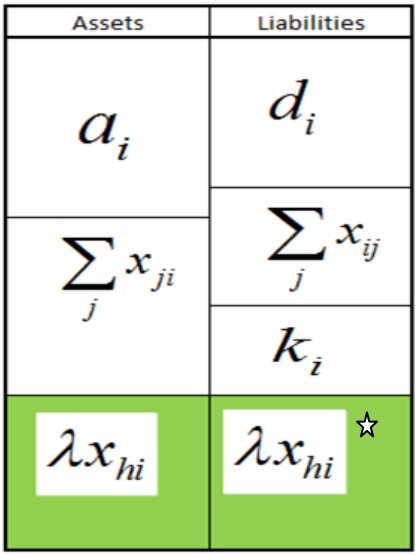
Regardless of network effects, higher capital helps during a crisis, and it does not hurt to raise it during normal times. Higher capital buffers help mitigate negative GDP surprises during crisis, but the same buffers might not have a real impact during normal times. These findings give additional reasons for strengthening buffers during normal times, since it does not seem to have a significant impact on output surprises.

Future research could try to explain why funding risks appear to matter more than credit risks. One reason could be the transparency of credit links apparent with the published BIS data and a general understanding of the crossborder credit exposures of banks from certain countries. For instance, it is well known that the Spanish and Austrian banks have large credit exposures in Latin America and Central and Eastern Europe, respectively. However, it is less well documented which countries Spanish and Austrian banks (and other sectors) borrow from. The BIS Consolidated Statistics do not provide liabilities-side information. As

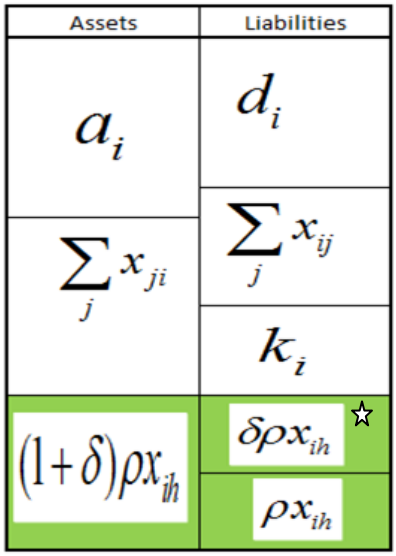
mentioned before, we only derive such information by making assumptions. Policymakers need to understand the specific vulnerabilities from funding linkages while making macroeconomic forecasts, and we have made the case for the need to access better data.

Figure 1. Credit Shock and Funding Shock Illustrated with Stylized Banking System Balance Sheets

Credit Shock



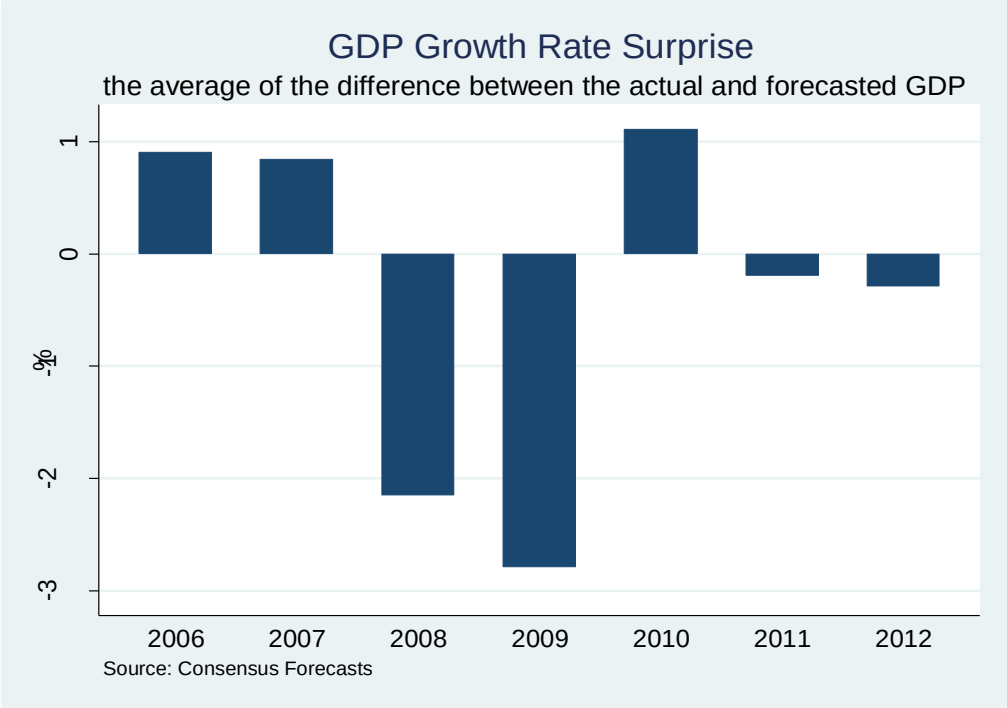
Funding Shock



Source: Based on Chapter 2, *Global Financial Stability Report*, April 2009 and Sole and Espinosa-Vega (2010).

Note: *x*: crossborder credit and funding; *a*: other assets; d: other liabilities, like customer deposits and debt; *k*: capital; λ: fraction of interbank loans that does not get repaid (0.50 in the baseline); ρ: fraction of interbank liabilities that does not get rolled over (0.50 in the baseline); δ: haircut on interbank assets that need to be fire-sold to replace the fraction of interbank funding that is not rolled over (1 in the baseline). A "☆" represents the amount by which capital, *k*, will be hit in the first round.

Figure 2. Growth Rate Surprise (average for 20 countries, in percentage points)



Note: GDP growth rate surprise = actual GDP growth rate (WEO)—GDP growth rate forecast (Consensus Forecasts, average of the GDP growth rate forecasted over the previous December).

Figure 3. Vulnerability to Credit Shock[1]

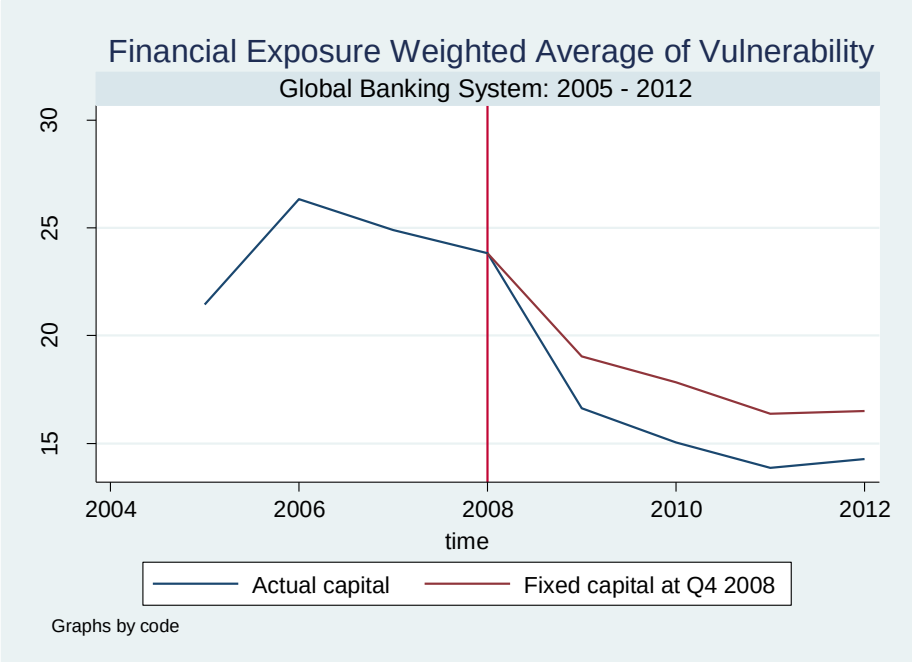
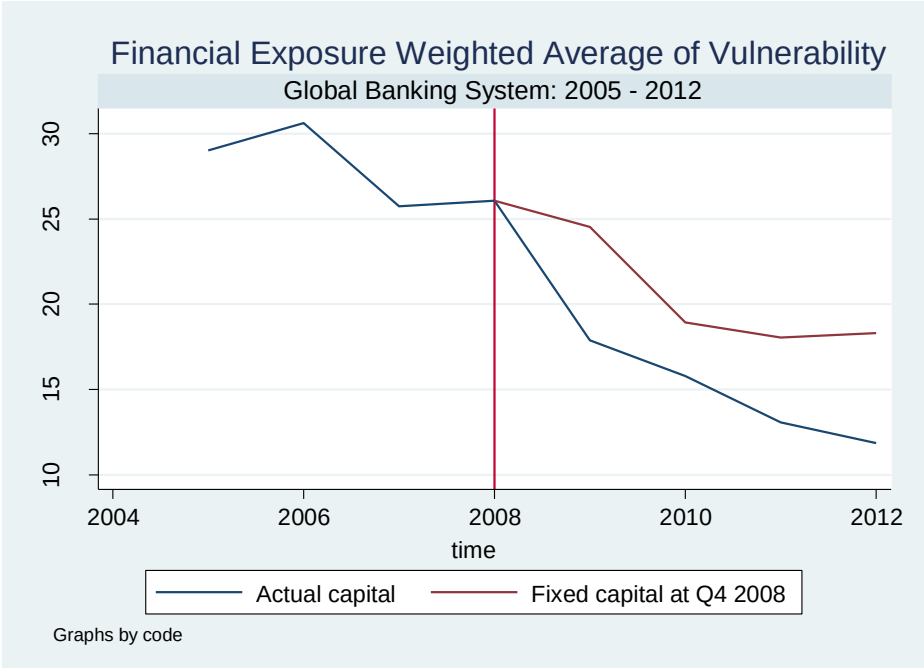
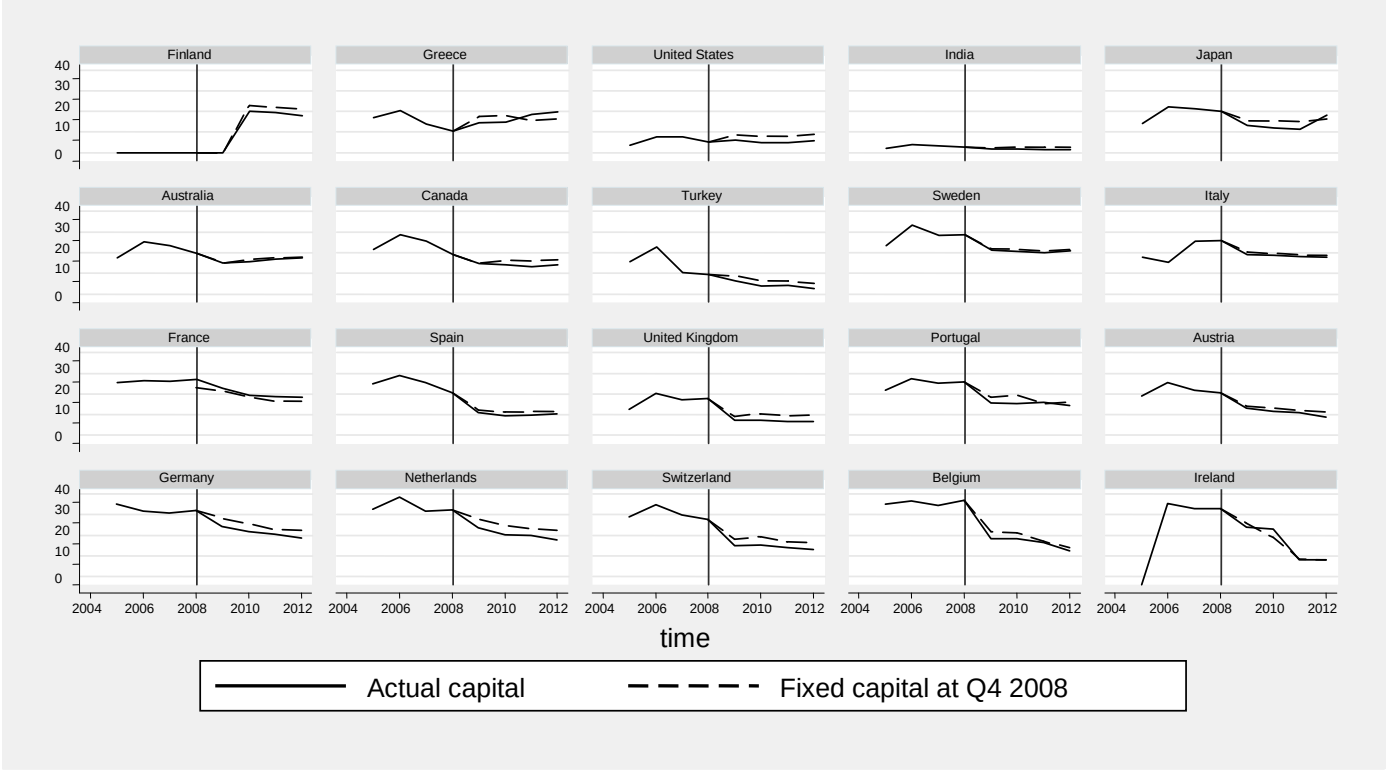


Figure 4. Vulnerability to a Funding Shock[1]



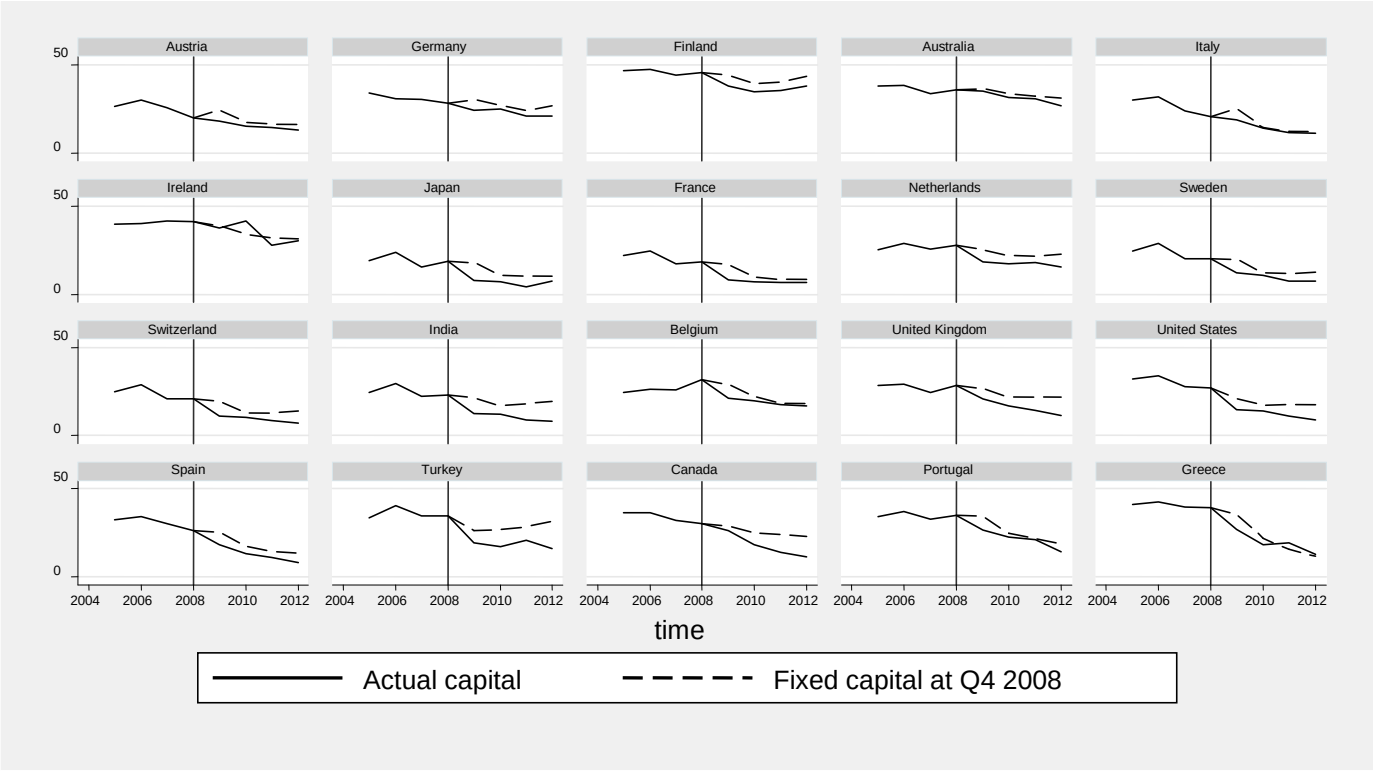
[1] The index of vulnerability shows the percentage of capital impairment in a banking system due to the failure of other banking systems. The aggregate index shown above is the weighted average of the vulnerability indices of the 20 countries in the sample, weighted by the country's total financial exposure.

Figure 5. Individual Banking System's Vulnerability to the Credit Shock



Note: 1. Foreign claims of Finland are available after 2010.
2. The graphs are placed in order of difference between Q4 2008 and Q4 2012 (ascending).

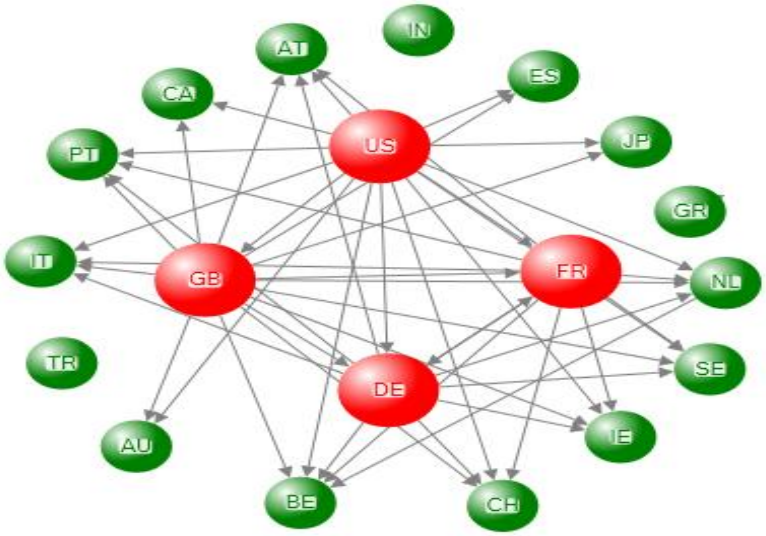
Figure 6. Individual Banking System's Vulnerability to the Funding Shock



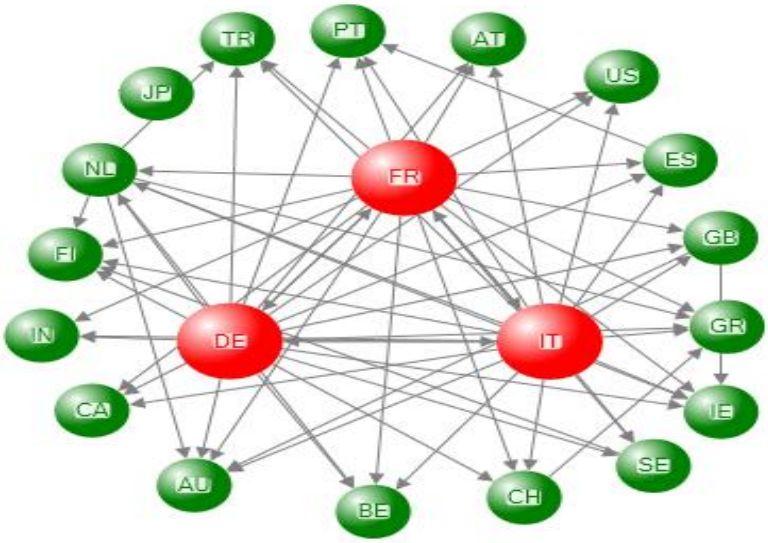
Note: 1. Foreign claims of Finland are available after 2010.
2. The graphs are placed in order of difference between Q4 2008 and Q4 2012 (ascending).

Figure 7. Contagion to the Credit Shock and Funding Shock, Q4 2008[1]

Credit shock



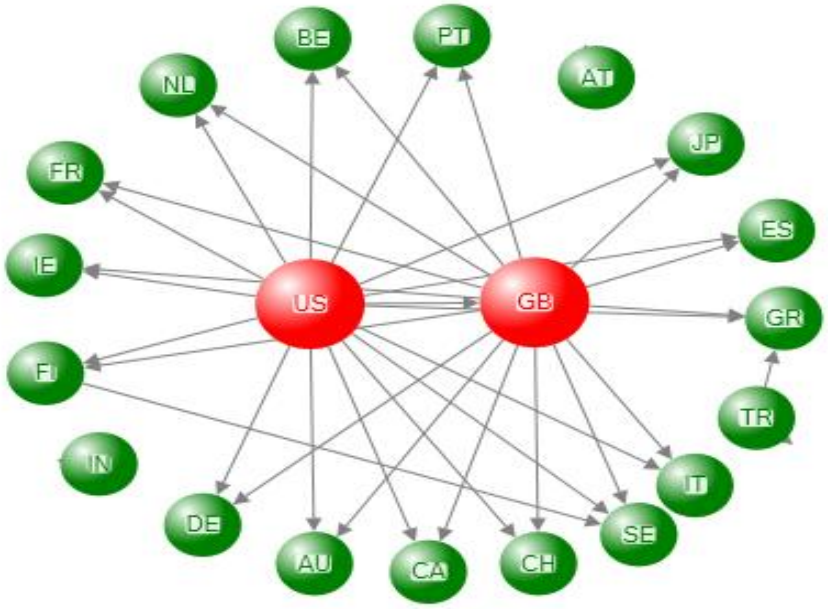
Funding shock



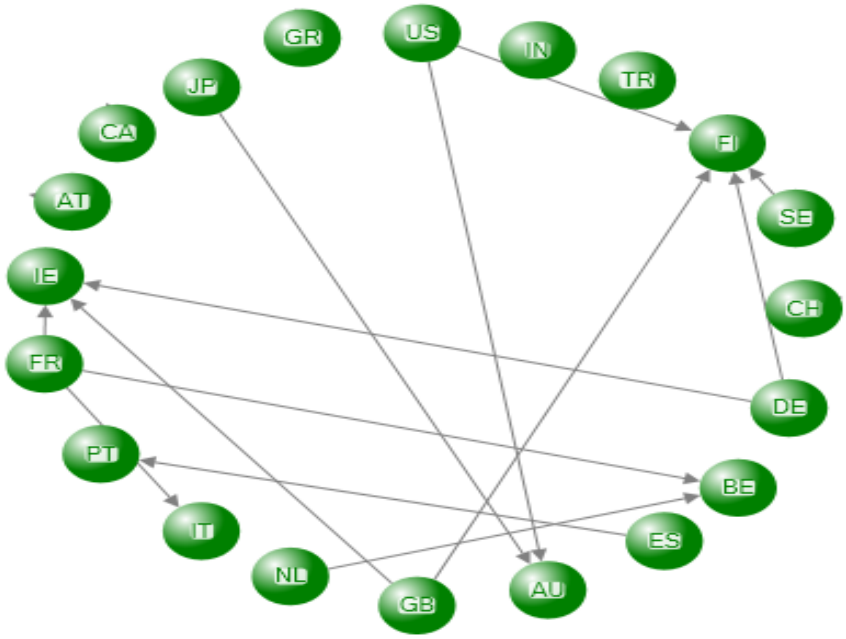
[1] Red sphere indicates the banking system that leads to more than 10 (that is half of the number of countries in the dataset) induced banking failures. Arrows represent how shocks that lead to failure of the banking system are propagated. The figures are constructed with our data using the excel add-in available at nodexl.com.

Figure 8. Contagion to the Credit Shock and Funding Shock, Q4 2012[1]

Credit shock



Funding shock



[1] Red sphere indicates the banking system that leads to more than 10 (that is half of the number of countries in the dataset) induced banking failures. Arrows represent how shocks that lead to failure of the banking system are propagated. The figures are constructed with our data using the excel add-in available at nodexl.com.

Figure 9. Credit Vulnerability indices—Varying λ

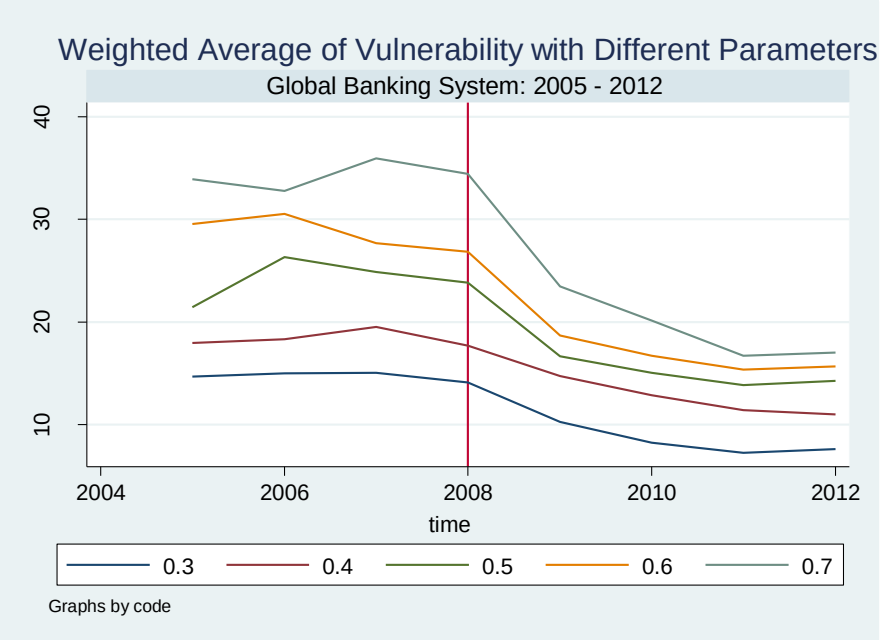


Figure 10. Funding Vulnerability Indices—Varying ρ

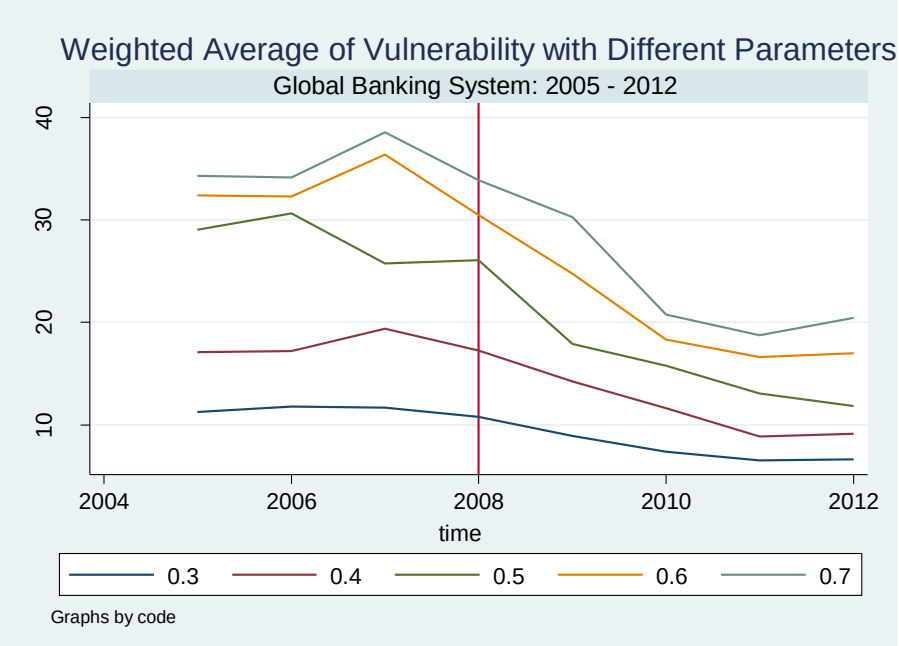


Table 1. Data—Capital and Financial Exposure between Banking Systems (USD millions, column countries' claims on rows)

2008Q4

Capital	Country	AU	AT	BE	CA	FI	FR	DE	GR	IN	IE	IT	JP	NL	PT	ES	SE	CH	TR	GB	US
41,858	Australia		2124	5065	10350	NaN	43577	50961	35	522	7727	1409	52082	72562	593	3597	2572	21597	24	100324	45287
56,095	Austria	1191		5117	1358	NaN	20522	105679	173	231	5806	146042	6757	9203	840	3100	1815	13724	425	12487	4550
39,476	Belgium	2779	2985		5055	NaN	111135	41295	173	997	8203	11687	21091	152364	1828	12203	4122	18067	778	43500	26415
59,702	Canada	6439	1849	7263		NaN	26155	41701	141	2307	12385	2496	45193	39731	284	1656	2530	19071	19	80756	66152
3,615	Finland	503	1068	2746	218		6676	14044	7	26	NaN	1665	6357	4021	47	1755	107380	2945	2	6409	3880
368,163	France	10738	10879	125644	12430	NaN		193246	673	863	25496	55253	124562	124615	7261	46326	11399	66233	1260	241107	77068
183,041	Germany	11372	52427	58893	12242	NaN	279538		2228	1972	49714	337447	158334	174138	9854	47118	74498	113691	5190	159978	92620
15,083	Greece	480	5617	10175	395	NaN	75224	38389		19	8480	9513	6176	12868	6376	1012	1310	69552	135	12713	6753
52,769	India	1473	761	5397	NaN	NaN	11355	19498	40		NaN	764	13168	22020	157	1155	307	5319	0	49672	38313
30,583	Ireland	1651	5097	45550	14233	NaN	68115	202202	323	263		24439	23857	35438	3781	14832	5247	20387	98	190440	33014
154,393	Italy	10490	17628	51951	2334	NaN	468850	207194	278	486	46537		48270	66955	3483	48680	3912	19946	763	74839	25526
363,573	Japan	2397	486	2797	6225	NaN	218920	65619	12	716	17228	NaN		28170	21	1214	943	121091	211	113158	123333
108,956	Netherlands	6998	12068	85453	10545	NaN	128186	167279	807	964	17550	24364	45822		8985	21375	9352	51784	2840	129601	52599
18,026	Portugal	318	2539	12040	NaN	NaN	29918	44492	40	49	6341	6197	3056	13842		77424	569	7524	3	21952	1848
141,955	Spain	2107	7919	43964	3050	NaN	176421	253676	265	166	33704	28463	25711	124773	28655		7106	20360	245	124572	33458
54,611	Sweden	725	1611	2581	1349	NaN	16154	37935	17	170	6173	1988	14505	8197	901	1917		7810	80	16425	8323
105,385	Switzerland	3551	10923	9840	3877	NaN	57483	67469	454	307	7415	11342	24846	18879	2250	5436	5545		477	44909	22865
18,582	Turkey	104	2517	15610	NaN	NaN	12355	16072	18317	105	NaN	NaN	3386	21229	906	131	300	4159		17340	12806
468,068	United Kingdom	103958	23560	127774	64156	NaN	394557	509133	6965	3600	222201	49898	164072	180607	7639	349916	38713	219202	3418		268187
1,088,470	United States	41931	21060	113161	430465	NaN	766345	640501	3953	7789	122477	32711	911642	335920	8882	132623	42703	827133	5136	1217127	

2012Q4

Capital	Country	AU	AT	BE	CA	FI	FR	DE	GR	IN	IE	IT	JP	NL	PT	ES	SE	CH	TR	GB	US
43,058	Australia		792	1957	22219	369	18053	23724	69	1043	715	2265	130606	79332	24	2515	2352	28206	28	72924	115419
71,233	Austria	279		730	1096	320	14618	75685	963	57	315	101145	6170	9839	124	4824	1933	8570	198	7819	11998
48,663	Belgium	882	1550		2331	581	222983	27924	276	1153	524	4427	19291	116618	441	5226	2378	6374	163	18016	18469
103,774	Canada	18838	982	1340		150	16901	27668	166	2799	371	3833	62639	10056	168	1695	2467	21860	11	104838	129360
5,107	Finland	864	869	452	1948		7434	18404	168	34	NaN	1200	4400	5687	55	2014	151832	4515	1	10263	12242
462,704	France	8251	11727	25319	27236	2715		195139	1670	754	5227	45764	166368	67377	6990	31531	8030	57918	957	221012	213807
237,477	Germany	21718	43746	12749	25595	2706	197643		3510	2078	2299	237073	145811	185007	2159	57395	80606	71785	3057	273571	217456
8,310	Greece	95	331	32	NaN	NaN	2798	5293		4	113	902	404	2343	7400	779	76	1527	90	5631	3201
93,048	India	9606	382	404	5852	NaN	15422	23581	1		NaN	2297	25422	13876	13	290	256	10938	6	84264	80077
31,989	Ireland	2531	1399	20000	4591	399	37954	81581	405	101		10207	23486	12726	3978	6047	1560	14735	2	121975	46515
174,556	Italy	578	15675	10339	4636	274	343207	129200	520	146	955		37068	33068	2839	27740	1433	19981	62	49227	42716
275,686	Japan	26875	NaN	795	15745	2	92689	45681	104	578	184	NaN		8029	22	3092	956	68161	913	130355	372517
153,016	Netherlands	9960	8127	23600	13282	2295	158134	157528	3095	1381	2235	19810	65250		9392	19351	10501	35214	2636	171369	106970
22,274	Portugal	132	791	716	NaN	139	16916	21670	17	40	473	1725	1178	4500		71567	190	1503	0	17337	4765
189,093	Spain	891	3018	9471	2513	433	108033	120717	218	103	4085	22977	21221	53686	22674		2792	17550	208	82863	49436
61,728	Sweden	2525	1539	605	2727	3462	21303	34873	88	157	530	2167	20939	7557	159	2594		9583	13	15470	27889
159,268	Switzerland	8220	9696	1323	5627	701	68058	60645	854	655	849	10790	29162	13645	2065	7347	3185		271	86465	76823
36,178	Turkey	380	1811	1321	2517	NaN	30847	19018	31083	107	NaN	6313	8390	20782	2	21455	215	6147		37528	24492
761,648	United Kingdom	133427	17012	25875	107694	2312	224666	409259	11866	5382	111414	49770	188909	128906	5246	406941	48872	166389	3090		634309
1,622,337	United States	107814	10760	20742	720340	461	402553	496792	4236	9389	7107	30977	1296100	164675	5038	203576	103150	670629	4819	1080697	

Source: Bank for International Settlements; Bankscope; Authors' calculations.

Table 2. Panel Regression with Country Fixed Effects

Dependent variable: GDP growth rate surprise
Sample: 2005–2012 (annual, 4th quarter)

λ =0.5, ρ=0.5	(1)	(2)	(3)	(4)	(5)	(6)
Crisis	-3.03***	-3.64***	-3.16***	-1.28	-3.08***	-3.67***
	(0.29)	(0.63)	(0.28)	(1.02)	(0.28)	(0.52)
Vul (credit)$_{-1}$	0.02	0.01				
	(0.02)	(0.02)				
Vul(credit)$_{-1}$ *		0.03				
Crisis		(0.03)				
Vul (funding)$_{-1}$			0.05**	0.05**		
			(0.02)	(0.02)		
Vul(funding)$_{-1}$ *				-0.07*		
Crisis				(0.03)		
Capital$_{-1}$					-8.12	-7.77
					(4.98)	(4.96)
Capital$_{-1}$ * Crisis						12.39*
						(7.13)
Exposure$_{-1}$					0.36	0.38
					(0.27)	(0.29)
Exposure$_{-1}$ * Crisis						-0.30
						(0.27)
Observations	140	140	140	140	140	140
R-squared	0.494	0.499	0.513	0.528	0.508	0.521
Country-pairs	20	20	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Dependent variable: Growth rate surprise (Actual GDP growth rate – GDP growth rate forecast) in percentage points
Crisis: 2008–2009
Vul (.): the vulnerability index from the network analysis
Capital: capital/GDP
Exposure: (foreign claims + foreign liabilities)/GDP

Table 3. Robustness: Panel Regression with Country Fixed Effects

Dependent variable: GDP growth rate surprise
Sample: 2005–2012 (annual, 4th quarter)

λ =0.3, ρ=0.3	(1)	(2)	(3)	(4)
Crisis	-3.07***	-3.44***	-3.17***	-2.20***
	(0.29)	(0.54)	(0.28)	(1.02)
Vul (credit)$_{-1}$	0.04	0.03		
	(0.02)	(0.03)		
Vul(credit)$_{-1}$ *		0.03		
Crisis		(0.03)		
Vul (funding)$_{-1}$			0.11***	0.12**
			(0.04)	(0.02)
Vul(funding)$_{-1}$ *				-0.07*
Crisis				(0.03)
Observations	140	140	140	140
R-squared	0.500	0.502	0.519	0.535
Country-pairs	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Dependent variable: Growth rate surprise (Actual GDP growth rate – GDP growth rate forecast) in percentage points
Crisis: 2008–2009
Vul (.): the vulnerability index from the network analysis
Capital: capital/GDP
Exposure: (foreign claims + foreign liabilities)/GDP

Table 4. Robustness: Panel Regression with Random Effects

Dependent variable: GDP growth rate surprise
Sample: 2005–2012 (annual, 4th quarter)

λ =0.5, ρ=0.5	(1)	(2)	(3)	(4)
Crisis	-3.04***	-3.65***	-3.00***	-0.48***
	(0.28)	(0.61)	(0.28)	(0.96)
Vul (credit)$_{-1}$	0.02	0.01		
	(0.01)	(0.02)		
Vul(credit)$_{-1}$ * Crisis		0.03		
		(0.03)		
Vul (funding)$_{-1}$			0.01	0.03*
			(0.01)	(0.01)
Vul(funding)$_{-1}$ * Crisis				-0.09***
				(0.03)
Observations	140	140	140	140
R-squared	0.453	0.458	0.441	0.473
Country-pairs	20	20	20	20

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Dependent variable: Growth rate surprise (Actual GDP growth rate—GDP growth rate forecast) in percentage points
Crisis: 2008–2009
Vul (.): the vulnerability index from the network analysis
Capital: capital/GDP
Exposure: (foreign claims + foreign liabilities)/GDP

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