

Assessing Systemic Risk and Structural Vulnerability in the EU & Global Banking Sector through Network Analysis

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Section 1: Introduction

In this study, we examine the banking system's structural vulnerabilities using a network analysis, focusing on the exposure of EU banks to systemic risks at a country level during and after the 2007/8 financial crisis. We advocate for an approach that acknowledges the systemic complexity of economic networks to enhance economic theory. By introducing specific ratios, we assess country-level vulnerabilities, employing network analysis to illuminate mutual interdependencies and less visible connections. This network perspective underscores the importance of proactively monitoring systemic linkages for regulators and policymakers, highlighting network analysis's role in identifying potential systemic threats. Allen and Babus's (2007) work is instrumental in this context, offering tools for understanding financial externalities and the cascading effects of financial linkages. Our analysis confirms the crucial need for comprehensive surveillance of both direct and indirect financial linkages to safeguard the stability of the entire financial system, illustrating how efforts to secure individual institutions might inadvertently affect the broader network.

Section 2: systemic risk through cross border exposure

, Haldane (2009), among others, has shown that the interconnectedness of the financial market potentially increases the probability of contagion of financial distress across the network. The interconnectedness of financial institutions as a significant agent of systemic risk has been highlighted repeatedly in the study thus far. Some of the research before the financial crisis of 2007/8 and after that shows that one of the primary concerns of network models is these externalities resulting from counterparty risk; a significant amount of this research has provided a framework for addressing this concern. The role of cross-border capital outflows can ultimately affect credit, diversify risk, or transmit shocks to the domestic economy, with adverse consequences for the financial sector and the real economy. Data suggests that, on average, countries that were net importers of capital before a recession experienced a sharper decline in their stock of money than those that were net exporters of capital. Secondly, the prevalence of cross-border finance and the impact on domestic credit, especially in our sample banks, shows that this can exceed and exceed that implied by domestic monetary conditions.

We will see how this particular scenario was the case with most banks. Our methodology applies a measure called the Herfindahl Index. This value is mainly used for determining the concentration level and was initially used for checking monopolization, where it is in breach of the law, against market shares for businesses. Then, we review how much of the banking activity depends on cross-border activity for these banks. Using matrices to represent the vulnerabilities of banks concerning their foreign lending (see (Gai and Kapadia 2010), (Nier et al. 2007), and regulators (Hellwig, 1995), and Haldane (2009)). To assess contagion risk in the banking system, studies based on network models have been used mainly in two categories of financial networks (see (Allen & Gale, 2000), (Freixas et al., 2000), (Gai et al., 2011), (Caballero & Simsek, 2013), (Alvarez & Barlevy, 2014), (Elliott et al., 2014) or input-out network (See Jovanovic(1987), (Long & Plosser, 1983), Durlauf (1993), (Acemoglu et al., 2013), (Bigio & LaO, 2013))

Central banks and regulators have used network model studies to measure contagion risk in the banking system; the pioneering works of (Elsinger et al., 2006) and Upper (2011) are solid examples of this approach. Several studies apply network analysis to the Bank for International Settlements (BIS) consolidated banking statistics with the same approach of this research ((McGuire & Tarashev, 2008) (Rönqvist & Sarlin, 2014) (McGuire & Tarashev, 2006), (Hattori & Suda, 2007), (Espinosa-Vega & Solé, 2010) Okuma, (2012) as well as to a report published by Deutsche Bank Research (Weistroffer & Möbert,2010) or another report which was published by Fitch Rating (Murray & Rawcliffe, 2010). By contrast, von (2010) looks at the BIS locational banking statistics to identify essential banking centers, and Kavonius, 2009), in turn, uses the euro area flow of funds data to identify sectors and channels through which local shocks may propagate through the financial system cross-border. Identifying systemic risks using disaggregated data, including maturity and currency mismatches, banks' assets, and liabilities, were used by central banks and regulators. In this study, we recompile the aggregate bilateral cross-border exposures into the interlinkage of selected countries' banks to identify sectorial interlinkages. The aggregate cross-border exposures, published by BIS, are statistics that record consolidated banking individual data and banking transactions and resulting claims held by each country's banks.

Section 3: Systemic risk and vulnerability of the banking sector

The current financial crisis reveals new dimensions of systemic risk in banking. This crisis has shown how interconnected the financial world has become and how a shock from a region can propagate very quickly, impacting financial stability worldwide. History has shown once again

the fragility of the banking sector. Banking financial contagion spreads faster than other sectors, and negative externalities have much more potent effects. One of the most feared events in banking is the alarm of systemic risk.

Identifying systemic risk using disaggregated data is often used at central banks and supervisory agencies. These disaggregated data include information on the composition of banks' assets and liabilities, maturity and currency mismatches, and other balance sheet and income metrics. These analyses attempt to capture systemic risks stemming from common exposures, interbank linkages, funding concentrations, and other factors affecting income, liquidity, and capital adequacy conditions. (Examples of such quantitative approaches are (Gabrieli et al., 2014) and (Boss et al., 2006) (Alessandri, et al. 2009) for Austria and the UK, respectively.

Several studies show that the systemic risk in the banking sector is significantly more significant than in all other sectors of the economy. (See (Bühler and Prokopczuk 2010), (Laeven, Ratnovski and Tong, ,2014). (Bühler and Prokopczuk, 2010) In their article “Systemic risk; Is the banking sector special?” they empirically investigate the degree of systemic risk versus other industry sectors. Their study compares the degree of systemic risk in the banking sector with other economic sectors and examines the systemic risk during the financial crisis of 2007-8. The study shows that systemic risk in the banking sector is significantly more significant than in all other sectors of the economy. Moreover, the degree of systemic risk for the banking sector is higher under adverse market conditions. Finally, they document a substantial increase in systemic risk during the financial crisis.

Section 4: Data

To quantify systemic risk, data on banks' total assets at the country level, the GDP of the countries, and total banking system exposure to the rest of the world, Herfindahl indices were analyzed every quarter from 2005 till the end of March 2014. We implement the empirical study through the quarterly data of consolidated exposures from the Bank for International Settlements (BIS) and value for GDP among selected countries (from OECD statistics. The *OECD National Accounts Statistics* database includes annual and quarterly data of a wide range of areas from 1955, such as gross domestic product)¹. To explore an analytical tool, the

¹ OECD iLibrary is the online library of the Organisation for Economic Cooperation and Development (OECD) featuring its books, papers and statistics and is the gateway to OECD's analysis and data. It replaced Source OECD in July 2010. OECD iLibrary also contains content published by the International Energy Agency (IEA), the Nuclear Energy Agency (NEA),

selected countries' banks' exposures were analyzed in light of the countries' total banks' assets (mainly from the European Central Bank and Federal Reserve Economic Data), the total exposure, and the country's GDP, also collated every quarter.

Section 5: Analysing Models

The relationship between i banks and j banks could be shown in a directed weighted graph in network modeling.

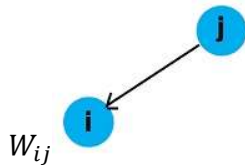


Figure 1: Weighted Graph

Source: author's figure

There is a link between i and j , which means j is exposed to i but not necessarily in the opposite direction. Also, this is a weighted link, meaning there is an important (or not important) link between i and j .

Vulnerability measures at country-level (country level)

The risk of looking at the data in an absolute manner to evaluate the structural vulnerabilities of banks in global comparison could be mitigated by considering the relative data terms to have a more comprehensive picture. To assess the structural vulnerabilities of banks in an international comparison, it makes sense to look at the data in absolute and relative terms. At the country level, we deem essential at least three ratios;

1. The potential impact of the banking sector problems on economic activity is measured by the 'relative size of the banking sector,' i.e., the size of the banking industry relative to GDP. The greater the size of the banking sector relative to GDP, the more severe the problems would affect economic activity or – in case banks need to be supported by the government – could increase public debt.

2. Overall exposure of banks to foreign borrowers – the ‘foreign lending ratio’ is another metric. This metric captures the vulnerability of the national banking sector to cross-country spill-over effects. It is calculated by taking foreign exposure over total bank assets (i.e., domestic and foreign exposure). A large ratio implies that write-downs on foreign exposure may substantially impact the stability of the national banking system.
3. The third metric is the ‘borrower concentration ratio,’ i.e., the diversification of banks’ foreign exposure across other countries. To this end, we apply the Herfindahl Index – usually a standard market concentration measure – to measure the concentration of a country’s top ten borrowers. This ratio is relevant for analyzing banks’ vulnerability to first-round contagion effects. For a banking sector highly exposed to a single or very few other countries, contagion risk may be more substantial than for a well-diversified country in its foreign lending exposure.
4. To calculate the fourth metric, ‘Concentration Index,’ we apply the Herfindahl index to measure GDP share for the financial institutions in the country i , us the size of the banks’ sector in the country i .

Equation 1:

$$\text{ize of the banking sector} = S_b = \frac{\text{size of banks sector in country } i}{\text{size of the economy of country } i}$$

Equation 2:

$$\text{Foreign lending ratio} = L_r = \frac{\text{total foreign exposures of banks sector in country } i}{\text{size of banks sector in country } i}$$

Equation 3:

$$\text{Borrower concentration ratio } C_r = \sum_{i=1}^n \left(\frac{x_i}{X}\right)^2$$

Where:

$$n = \text{total number of countries which country } i\text{'s banks are exposed to}$$

$$X_i = \text{total exposure of country } i\text{'s banks}$$

$$X = \sum_{i=1}^n X_i = \text{total exposures of the country } i\text{'s banks to all other countries}$$

Equation 4:

Concentration Index
= Total banks assets of country i + HI * GDP of country i

The HI is the Herfindahl Index –usually an expected market concentration- which is obtained by summing the squares of the market shares of all the *credit institutions*, CIs in the banking sector of each country and calculated with the following formula:

$$HI = \sum_{i=1}^n \left(\frac{X_i}{X}\right)^2$$

Where:

n = total number of credit institutions in the country

X_i = total assets of CI_i

$X = \sum_{i=1}^n X_i$ = total assets of all CI_s of the country

Section 6: Structural Vulnerability

Modern financial systems and the banking network cover a large number of institutions, markets, and agents and are exposed to a variety of potential sources of vulnerability (Johnston et al., 2000):

1. A first type of vulnerability is associated with the non-diversified risks on and off the balance sheets of individual institutions.
2. A second type of vulnerability concerns the financial system's vulnerability as a whole-systemic vulnerability.
3. A financial system can be considered vulnerable to a crisis where it cannot readily absorb shock.

Assessing potential vulnerabilities in the banking network requires examining a range of factors, including the balance sheet position, the degree of development of the banking network where risks can be managed, and types of incentive structures. See (Johnston et al., 2000), who highlight systematically considering incentive structures as already approached in the investigative science field. In our developed model, we shed light on the relative size of the banking sector, traditional hubs of banking networks and their changes over time, the foreign lending ratio of banks, borrower concentration ratio, economic exposure to cross-border lending, and country's position, in-degree concentration index, Herfindahl Index and exposure concentration index.

The importance of the banking industry in the whole economy is reflected in the relative size of the banking sector (see Figures 3, 5, and 7). There are a few traditional hubs, such as Swiss Banks and British Banks, at the top of the list, but also Irish banks- where the financial sector is relatively new and grew strongly between the 1990s and 2008- take the fourth position in 2014, reducing the relative size since 2006 where they had the first position. The interesting point is that the US, which hosts the most important financial hub worldwide, was at the bottom of the list before and after the financial crisis in 2006, 2007, and 2014 due to its sizeable economic capacity and its market-based financial system in which bank financing assumes a minor role. The foreign lending ratio shows how much the banking sector of a particular country depends on cross-border activities (see Figures 2, 3, and 4). 2014 Figures indicate that 40% of Swiss banks' activities depend on cross-border transactions, followed by Dutch and Swedish banks with 33%. In particular, the combination structure of a limited house market, trade openness, and competitiveness in national banks results in a high ratio for cross-border interaction. Geographical proximity and cultural distance to other major countries or regions play an essential role, too. For instance, Canada's exposures vis-à-vis the US increased to 36% in 2014 from 30% in 2007 Q4. (See Figures 13 and 14).

In Switzerland, it is mainly the two large banks (UBS AG and Credit Suisse AG) with international investment banking operations responsible for relatively high foreign exposures. All this is reflected in the ranking according to the foreign lending ratio, led by Swiss, Dutch, Swedish, and French banks, with ratios between 29% and 40% (see Figure 4). The list is followed by the most prominent European countries: France, Spain, Germany, and the UK. Finally, this measure ranks Italian, Irish, and Greek Banks as the lowest. The borrower concentration ratio identifies those countries that have concentrated their foreign lending activities on specific regions or countries – often their neighboring countries (see Figures 8 and 9). At the top of the list of 2014-Q1 are Ireland and Canada, of which Ireland is exposed primarily to the UK in over 80% of its total foreign exposure, followed by Canada, which is exposed mainly by the US in over 72% of its total foreign exposure, Swiss banks at the next level are exposed to the US primarily as well with over 48% of their foreign exposure. The list is followed by Australia, which lends heavily to New Zealand (over 40% of its foreign lending), and Japanese Banks, which are exposed heavily to the US (over 40% of their foreign lending). To illustrate the countries more vulnerable in more than one measure, we display the ratios in a matrix combining the size of the banking sector with the foreign lending ratio for 2014- Q1 and compare this with the financial crisis time 2007- Q4. (See Figures 10 and 11). The figure

for 2014 identifies Switzerland, Sweden, and the Netherlands as having relatively high exposure and a high foreign lending ratio (Figure 10), and Belgium has improved in this regard since 2007 (Figure 11).

Meanwhile, the status of Ireland, which was an outlier due to the relative size of its banking sector in 2007, was then improved in 2014. Looking at the development of these ratios over time can help trace the vulnerabilities and identify the hotspots in any period. The in-degree concentration index 2014 displays important insight as the USA, UK, and Germany hold over 70% of the network exposures. (Figure 13). Comparing the in-degree concentration index with 2007-Q4 (Figure 14) shows the same group having over 70% of the network exposure. However, the UK has a more critical role. For better illustration, for the first three countries (US et al.), a detailed in-degree concentration index was shown for 2014-Q1 compared to 2007-Q4, the financial crisis period (Figures 12,13,14,16,17,18 and 19). Figures 13 and 14 show that in 2014-Q1, 36% of American Banks' foreign exposures came from Canadian Banks. Alternatively, Canadian banks' exposure has increased since 2007, and they were heavily exposed to American banks. In the case of British Banks, the situation is even worse; 68% of British banks' foreign exposures come from Irish banks. Irish Banks increased this ratio from 29% in 2007-Q4 to 68% to stay heavily exposed to British Banks. (Figures 16,17). German Bank's in-degree concentration index indicates that the Italian Bank's share increased from 40% in 2007-Q4 to 57% in 2014-Q1. (Figures 18, 19).

I was comparing the shares of the five largest credit institutions in total assets between the end of 2013 and the end of 2007, which shows that in big EU countries, banks got more extensive over that period. The ratio increased for Italy from 33 to 40, the UK from 41 to 44, Germany from 22 to 31, Spain from 41 to 56, and France from 52 to 46 (Figures 20 and 21).

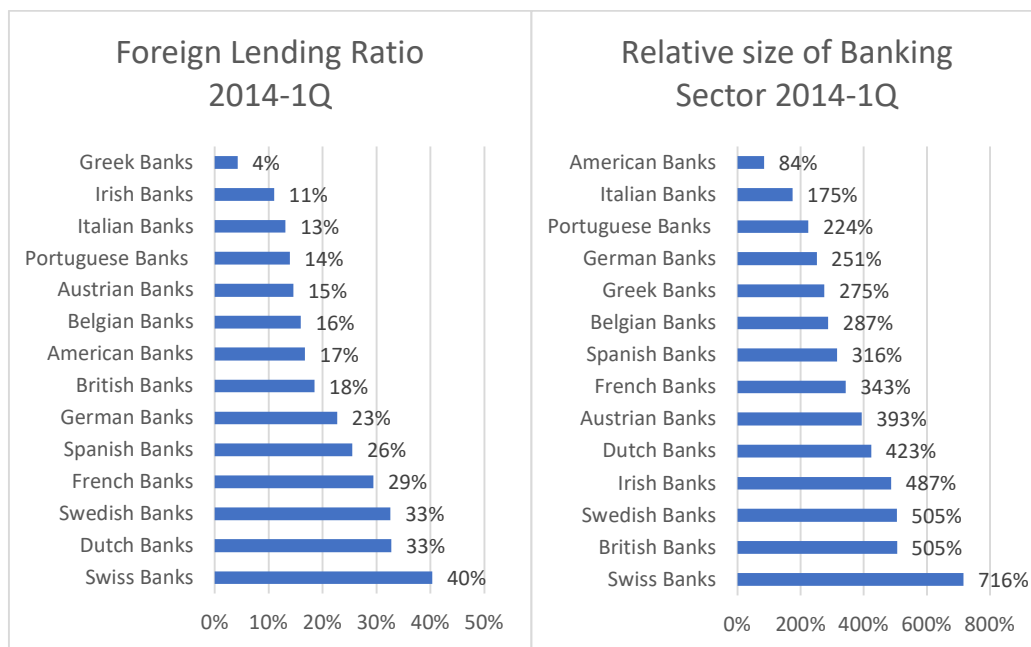


Figure 21: Foreign Lending Ratio 2014

Figure 3 Relative size of the banking sector 2014

Source: author's figure

Figure 2 indicates which banks lend to foreign entities the most, and the Swiss banks lead with a 40% lending ratio. On the other hand, Greek banks are rated the lowest for their 4% ratio in the post-crisis era Q1 2014.

Figure 3 illustrates the banks that dwarf their domestic economies the most. The period in which this is displayed is similar to Figure 6, and one can see the similarities between a high foreign lending ratio and the relative size of the banking sector compared to the domestic economy. Swiss banks offer a case in point with a GDP of 716%.

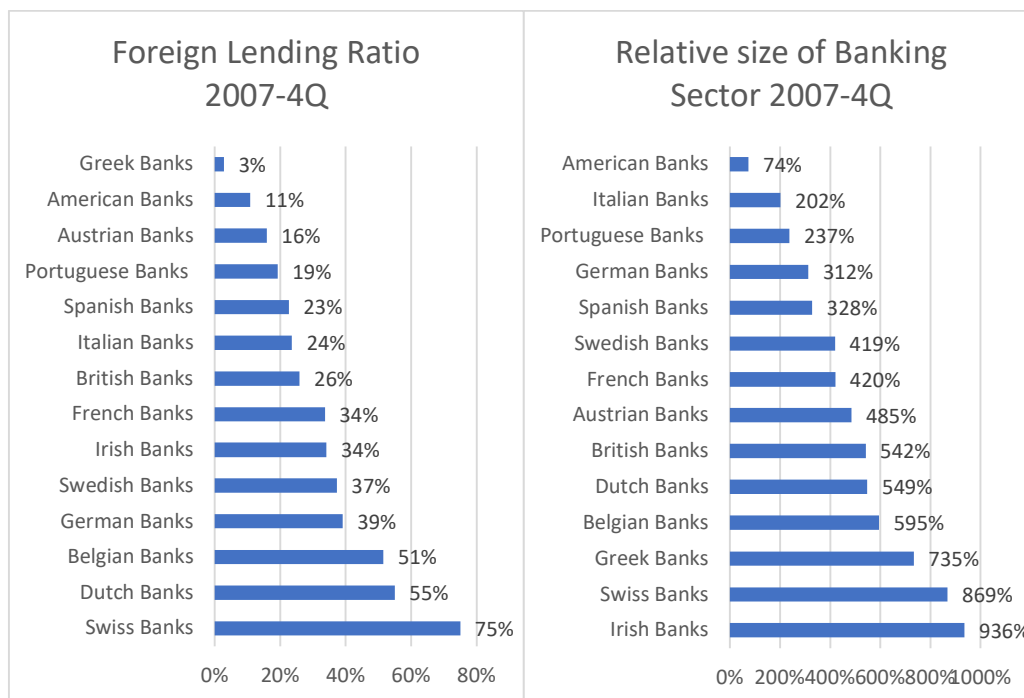
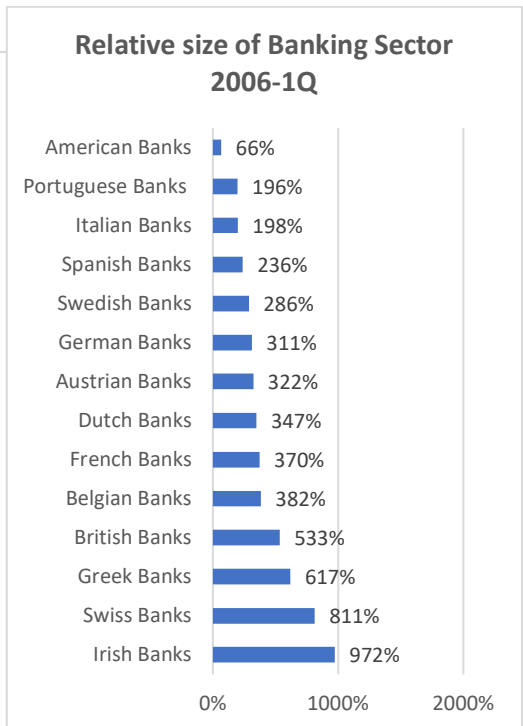
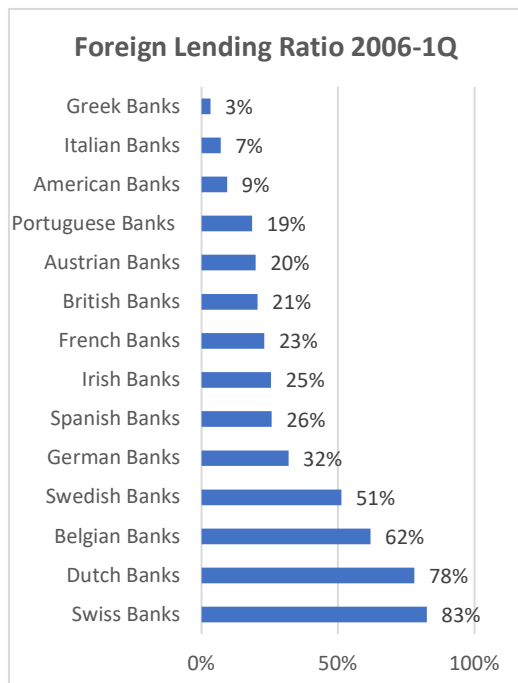


Figure 4: Foreign Lending Ratio 2007

Source: author's figure

Figure 5: Relative size of banking sector 2007

Similarly, Figures 4 and 5 show the overall reduction in these indicators post-crisis. The Q1 2007 value for British banks was recorded at 26% for the foreign lending ratio and 542% for the banking sector relative size, which were reduced to 18% and 505%, respectively.



7

Figure 6: Foreign Lending Ratio 2006

Figure 7 Relative size of banking sector 2006

Source: author's figure

Furthermore, Figures 6 and 7 present a perspective prior to the incidents of 2007. These pre-crisis figures show the trend was that interconnectivity was still yet to increase to crisis-causing levels, and that can be seen again with British Banks's foreign lending ratio of 21% (later 26%) and 533% for banking sector relative size (later 542%)

The low-yielding Swiss currency is also to be noted as accounting for a high percentage of foreign ratio lending. At the same time, Greek banks, on the other hand, are low scorers due to tumultuous events in that country's economy.

The interconnected nature of global banks in Figure 6 means that nations with favorable conditions and financial legacies, like the Irish, Swiss, and UK banks, have the most extensive banking systems.

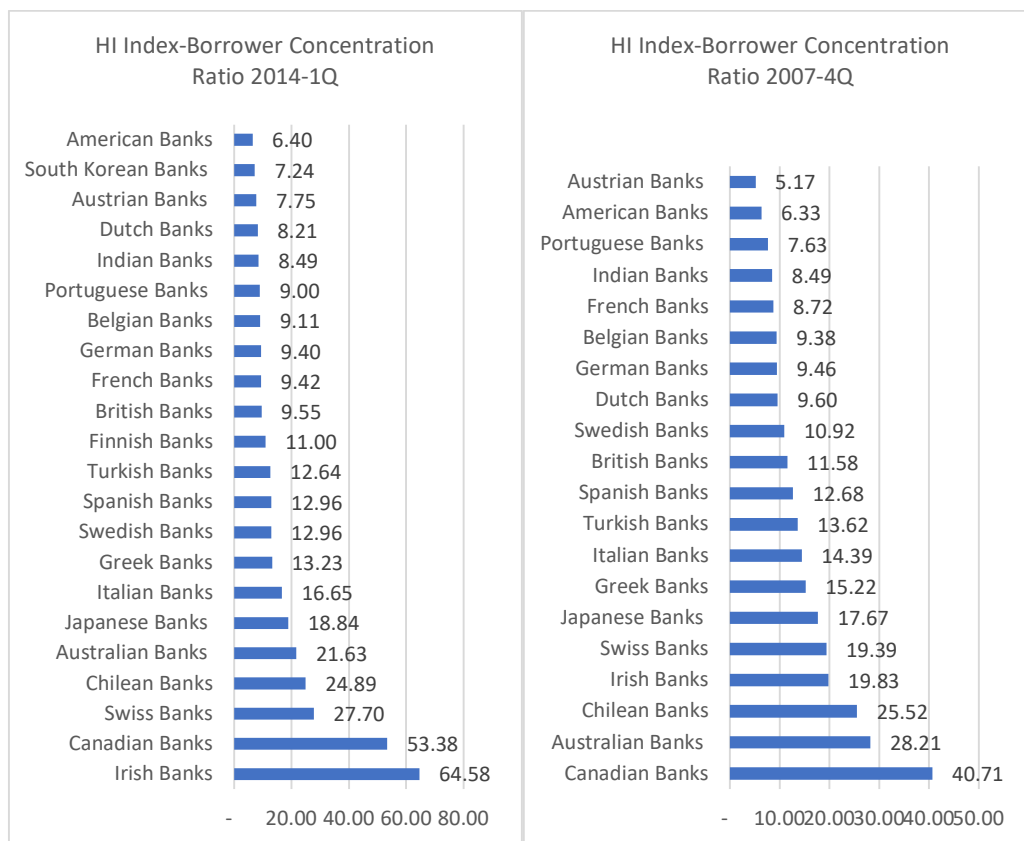


Figure 8 HI index Borrower Concentration Ratio 2014
Source: author's figure

Figure 9 HI index Borrower Concentration Ratio 2007

Figures 8 and 9 comprehensively analyze two critical periods for the financial sector. 2007 Q4 (Figure 9) was the immediate after-effect of the crisis. However, by 2014 Q1, recovery had set to some degree. The HI-index of borrower concentration shows the diversity of borrowers, and for significant economies affected by the crisis, there is a needed reduction in borrower concentration ratios. This could occur due to more diverse borrowers or a smaller lending capacity.

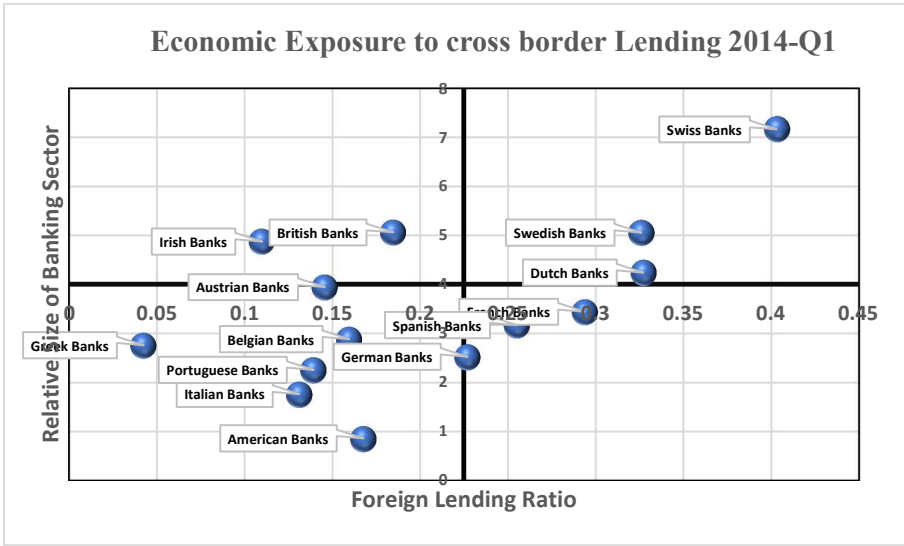


Figure 10: Economic Exposure to Cross-Border Lending 2014

Source: author's figure

Non-performing loan yields in domestic markets are one of the reasons for foreign lending and the resultant growth in the banking sector size. Figure 10 shows the 2014 Q1 comparative illustration of the Banking Sector Size against the Foreign Lending Ratio. High scores on both parameters are a recipe for systemic risk because the economy is exposed, a potential trigger point.

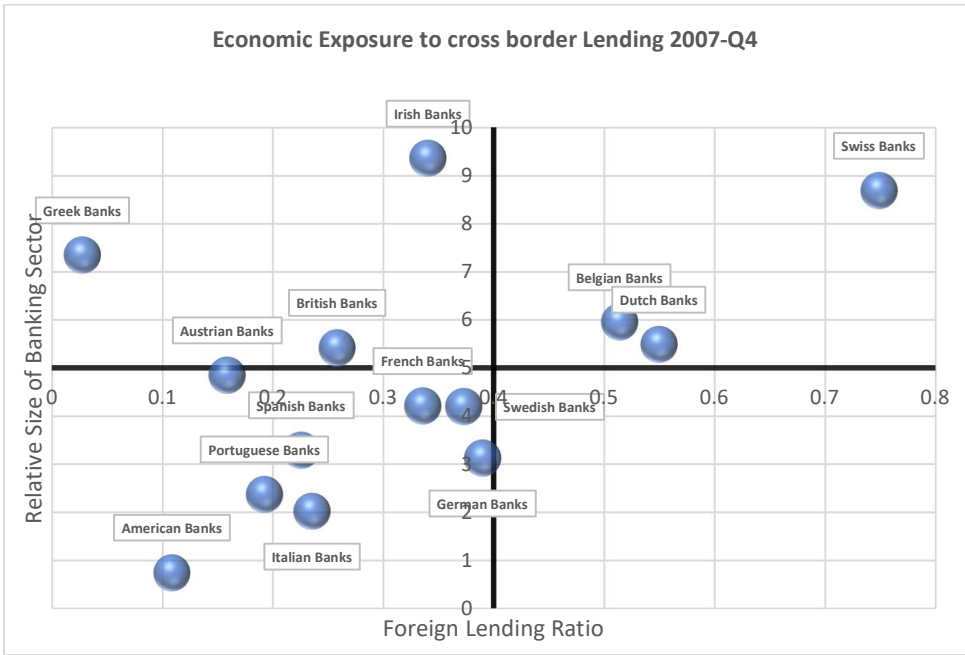


Figure 11: Economic Exposure to Cross-Border Lending 2007

Source: author's figure

Post-crisis (Figure 10), the values obtained are much lower than the pre-crisis level, as shown in Figure 12. Here, we see Irish banks with a foreign lending ratio above 9, compared to below 5 in 2014.

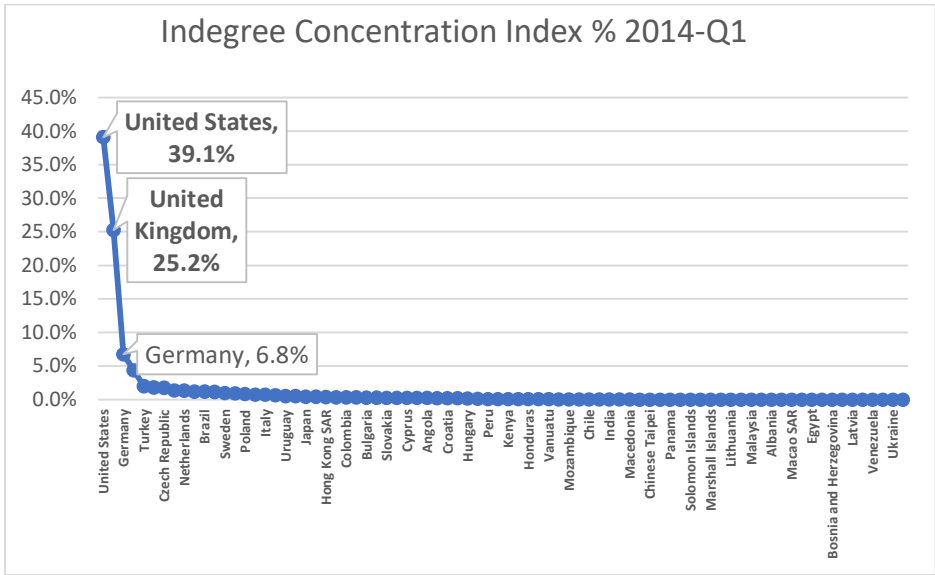


Figure 12: Exposure Concentration Index 2014
Source: author's figure

In the graph, the US and UK have the highest indegree concentration index measuring the kind of bilateral relationships that exist in the links between financial institutions.

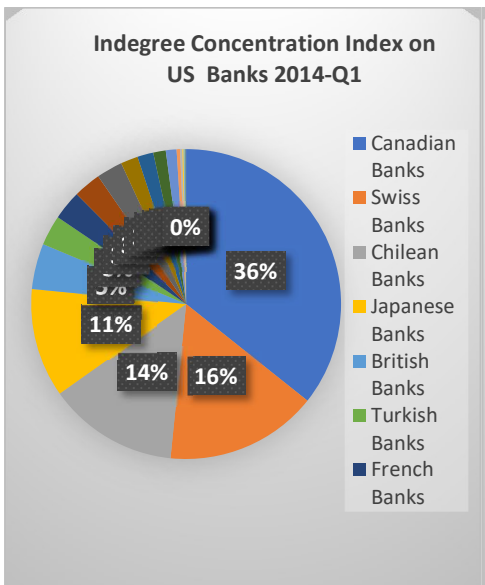


Figure 13: Concentration Index on US Banks 2014
Source: author's figure

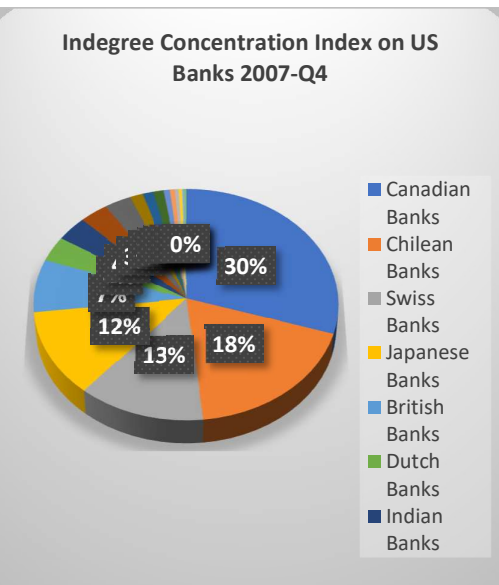


Figure 14: Concentration Index on US Banks 2007

US banks can provide inbound links for these economies, with Canadian banks exhibiting the largest share at 36%. However, there was a reduction in the total amount from 2007 to 2014, where Canada again had the largest market share with a lower 30%.

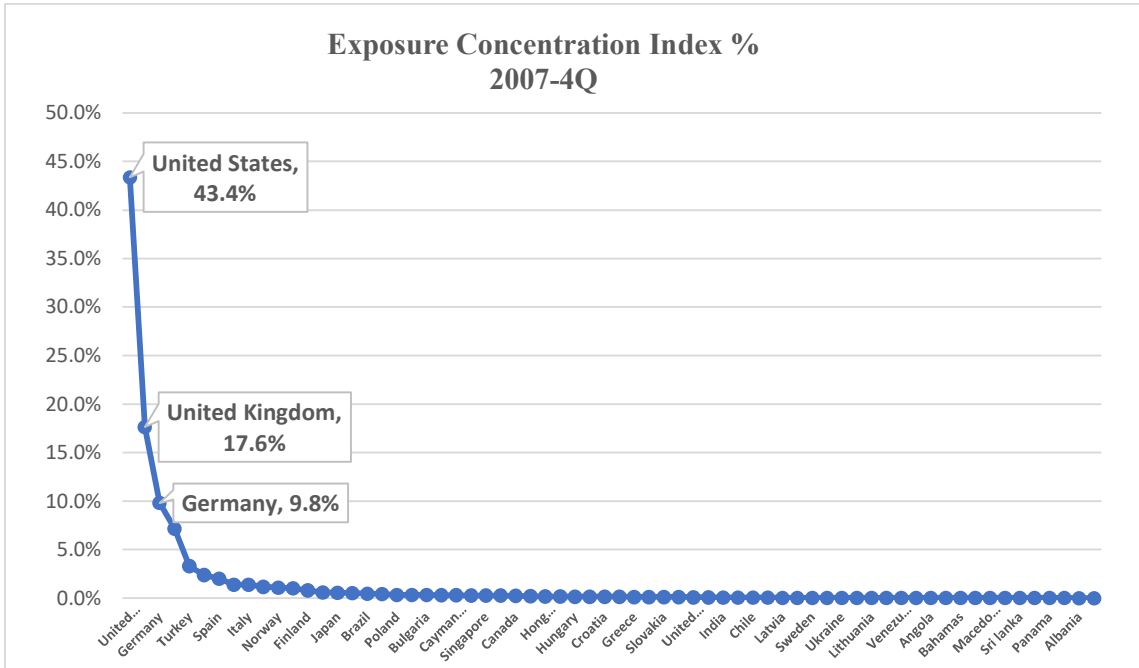


Figure 15: Exposure Concentration Index 2007
Source: author's figure

Inadvertently, after the crisis, the exposure concentration index shows that US banks have a higher exposure concentration.

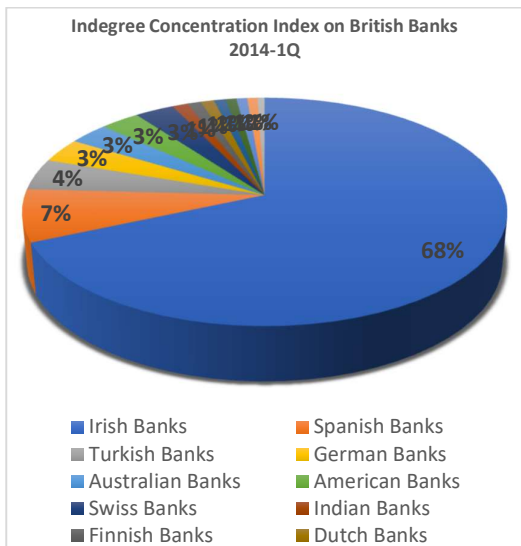


Figure 16 Concentration Index on British Banks 2014
Source: author's figure

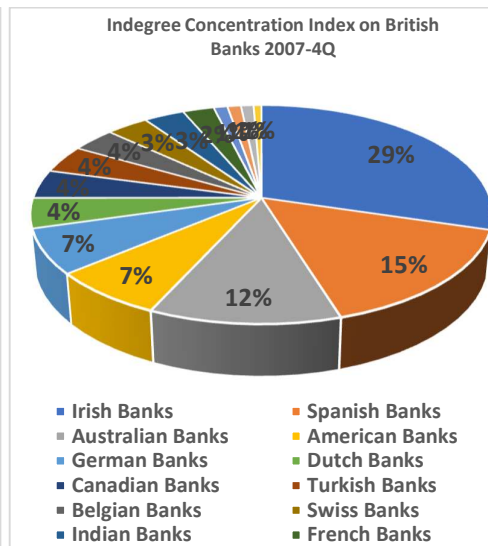


Figure 17: Concentration Index on British Banks 2007-4Q

On the other hand, British banks have a concentration in degree to various economies, with Irish banks at 29% share; however, post-crisis, UK banks have a larger share of Irish banks, although, for every other economy, shares are reduced drastically.

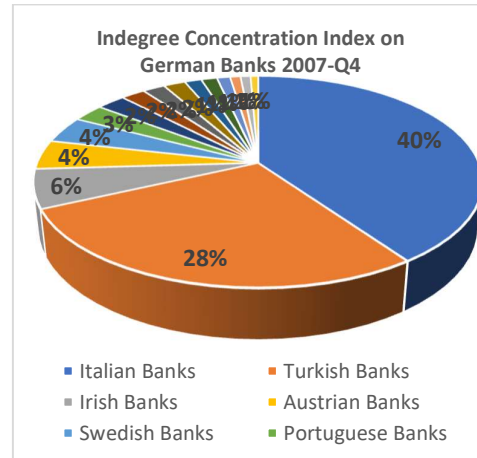
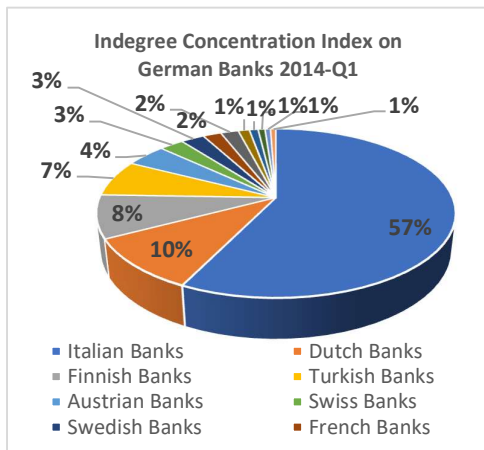


Figure 18: Concentration Index on German Banks 2014 Q1
Source: author's figure

Figure 19 Concentration Index on German Banks 2007 Q4

Big German banks have significant shares in the Italian banks, while post-crisis (2014 Q1), this reduces for most banks, such as Turkish banks, having shares go down from 28% to 7%.



Figure 20: Shares of the 5 Largest CIs in total Assets 2013

Figure 21: Shares of the 5 Largest CIs in total Assets 2007

Source: author's figure

The largest Credit Institutions' (CIs) assets give a structural indication of the Banking system, with Greece and Estonia scoring highly in both periods (before and after the crisis).

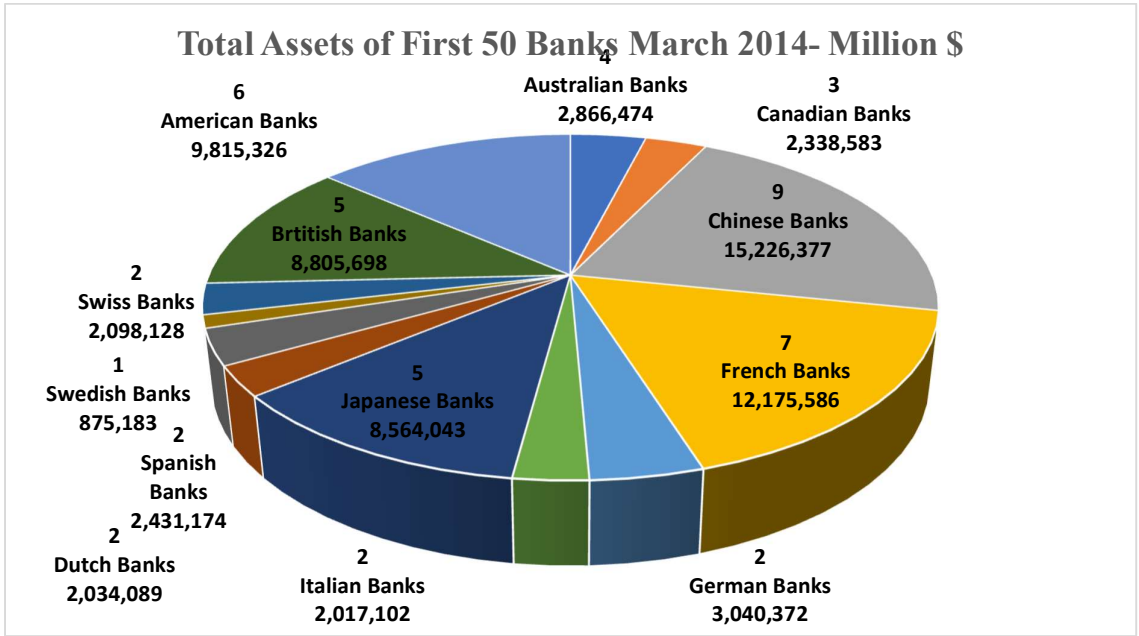


Figure 22 Total Assets of Top 50 Global Banks March 2014

Source: author's figure

Chinese and French banks can cover close to \$30 Trillion of the global share among the top 50 banks.

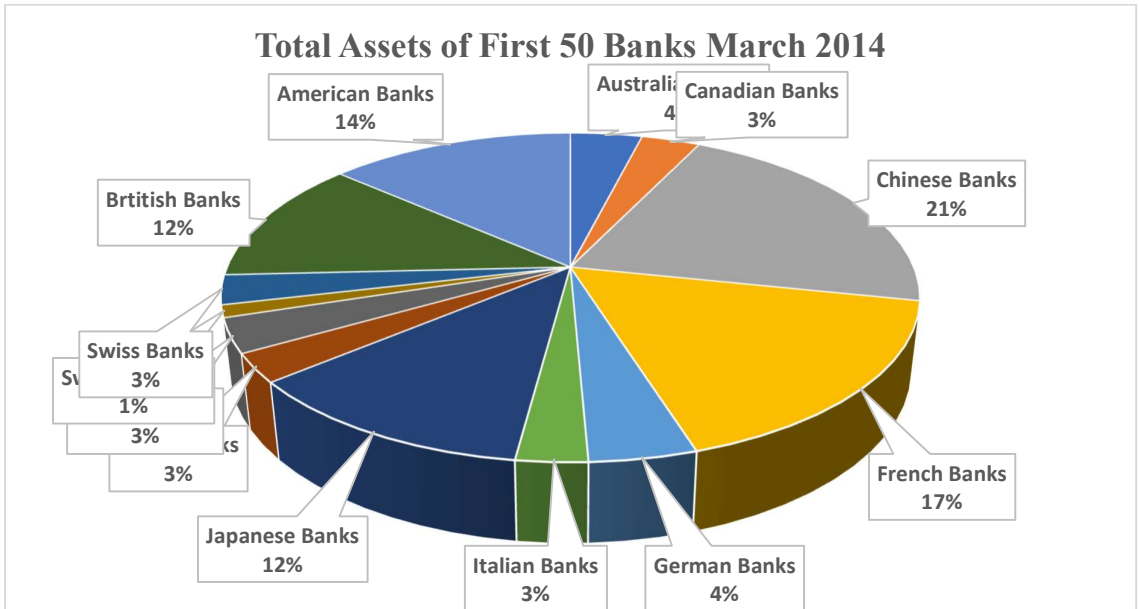


Figure 23: Total Assets of First 50 Banks March 2014 %

Source: author's figure

The global reach and diversity offered by French banks, coupled with the size of the Chinese economy, allow for this domination by both countries, making a combined 38% share.

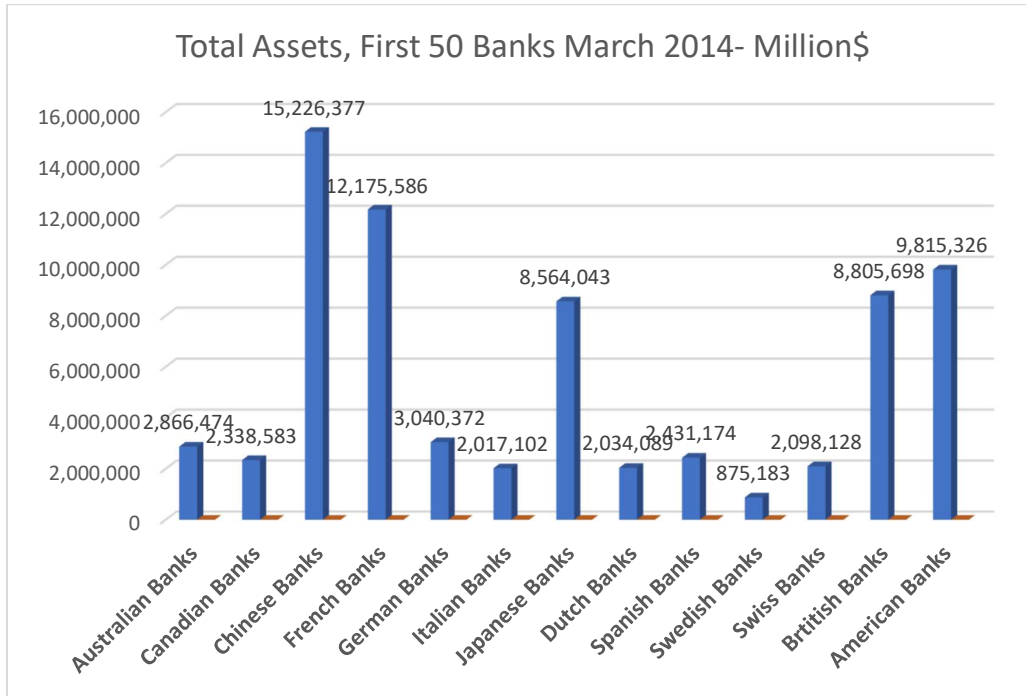


Figure 24: Total Assets of First 50 Banks March 2014 \$ Millions

Source: author's figure

The Chinese banks have a huge market due to the population size, with over \$15 trillion.

French, US, British, and Japanese banks come close behind, and the global participation of this country bank makes them market leaders.

Section 7: Conclusion

This article emphasizes the interconnected nature of banking networks and their impact on systemic risk. It highlights key findings on cross-border activities and the relative resilience of the US banking system compared to those in Europe. The conclusion suggests areas for further research, such as enhancing global banking system risk monitoring and linking banking sector risk to macroeconomic performance. It underlines the importance of understanding the complex interdependencies within the banking sector to mitigate systemic vulnerabilities effectively. The article contributes to the existing literature by providing some insights within a framework that explains how the structure of the banking network and interdependencies between banks at the country's level could contribute to the systemic risk of the network. We study bilateral exposure cascades in a network setting and in-degree concentration index over selected networks. To obtain a realistic representation of interbank exposures relative to critical variables, we exploit a unique dataset of bilateral exposures of banks at the country level, balance sheet data of the banks, and economic data ending up with a concentration index. Research data was able to consolidate the following key findings:

- (i) European banks with the most exposures were also those with the highest cross-border activities, and the highest interactions (out-degree) were about US banks
- (ii) Despite the size of participation and interlinkage from US banks, the US economy was least 'burdened' in comparison to other more prominent players in Switzerland, Germany, and the UK, using the relative banking size index
- (iii) The growth in cross-border activities in the largest banks was also traceable in the period leading to the financial crisis 07/08
- (iv) Relatively more minor nations such as Irish, Italian, and Swedish banks were able to interact with more prominent players by conducting mainly cross-border transactions

Based on the above analysis, we can suggest that several areas for further work could help strengthen banking network vulnerability assessments:

1. Economic exposure to cross-border lending could be used as guidelines by global regulators, such as the European Central Bank, for monitoring banking system risk.
2. Incorporating explicit assessment of the in-degree concentration index to evaluate banking network vulnerabilities.
3. Elevating attention to an audit of incentive structures in assessing banking network vulnerability. An understanding of incentive structures under which the banking structure operates is likely to be a critical determinant of the robustness and potential vulnerability of the banking network.
4. Developing methodologies for linking risk exposures with macroeconomic performance. It would be desirable to research how banking sector risk can be linked to macroeconomic performance, and thereby, a flagging mechanism can be in place not just for the banking system but the whole economic activity.

These results can help better connect global surveillance with country-level specificities. The data also shows that banks' exposure to the current hotspots seems limited if measured against total bank assets. This does not rule out contagion risk due to relatively large exposures of individual banks or non-bank financial institutions. After all, market perceptions of debt sustainability remain an essential factor that may affect the banking sector's stability. The main benefit of this approach is highlighting the inconsistencies between banks' connectivity about

the country's GDP and cross-border activity. The interconnected global picture, in contrast with the individual banks' countries' economies, analyzed in a multi-tier method, displays the obvious vulnerabilities missed by either a micro-only (See (Bhansali et al., 2008)) or macro-only (Adrian & Brunnermeier, 2008) (or flat *macro-* plus *micro-*) investigative approach. For instance, the study analyzed the banking status of different EU countries and provided more significant insights into banking sectors at the country level. As an example, it was indicated that economic exposure to cross-border lending in 2014 shows Swiss Banks still have a high degree of the relative size of the banking sector and foreign lending ratio together, almost unchanged compared to 2007-Q4, followed by Swedish banks and Dutch banks. However, in 2007-Q4, Belgian and Dutch Banks had second and third positions accordingly. The US, UK, and Germany achieved over 70% of the network exposures, as the in-degree concentration index in 2014 indicates. The same group gained over 70% of the network exposures in 2007-Q4; however, the UK generally acquired a more critical role in 2014.

References

1. Allen, F., & Babus, A. (2007). *Networks in finance*. Wharton Financial Institutions Center, Philadelphia, PA.
2. Gai, P., & Kapadia, S. (2010). Contagion in financial networks. *Proceedings of the Royal Society A*, 466(2120), 2401-2423.
3. Nier, E., Yang, J., Yorulmazer, T., & Alentorn, A. (2007). Network models and financial stability. *Journal of Economic Dynamics and Control*, 31(6), 2033-2060.
4. Hellwig, M. (1995). Systemic aspects of risk management in banking and finance. *Swiss Journal of Economics and Statistics*, 131(4), 723-737.
5. Haldane, A.G. (2009). Rethinking the financial network. Speech delivered at the Financial Student Association, Amsterdam.
6. Allen, F., & Gale, D. (2000). Financial contagion. *Journal of Political Economy*, 108(1), 1-33.
7. Freixas, X., Parigi, B.M., & Rochet, J.C. (2000). Systemic risk, interbank relations, and liquidity provision by the central bank. *Journal of Money, Credit and Banking*, 32(3), 611-638.
8. Gai, P., Haldane, A., & Kapadia, S. (2011). Complexity, concentration and contagion. *Journal of Monetary Economics*, 58(5), 453-470.
9. Caballero, R.J., & Simsek, A. (2013). Fire sales in a model of complexity. *The Journal of Finance*, 68(6), 2549-2587.

10. Alvarez, F., & Barlevy, G. (2014). Mandatory disclosure and financial contagion. Federal Reserve Bank of Chicago, Working Paper, 2014-03.
11. Elliott, M., Golub, B., & Jackson, M.O. (2014). Financial networks and contagion. *American Economic Review*, 104(10), 3115-3153.
12. Elsinger, H., Lehar, A., & Summer, M. (2006). Risk assessment for banking systems. *Management Science*, 52(9), 1301-1314.
13. Upper, C. (2011). Simulation methods to assess the danger of contagion in interbank markets. *Journal of Financial Stability*, 7(3), 111-125.
14. McGuire, P., & Tarashev, N. (2008). Bank health and lending to emerging markets. *BIS Quarterly Review*, December.
15. Rönnqvist, S., & Sarlin, P. (2014). Bank networks from text: Interrelations, centrality and determinants. *Quantitative Finance*, 14(9), 1613-1636.
16. Hattori, M., & Suda, Y. (2007). Developments in a cross-border bank exposure network. *BIS Working Papers*, No. 222.
17. Espinosa-Vega, M.A., & Solé, J. (2010). Cross-border financial surveillance: A network perspective. *IMF Working Papers*, 10/105.
18. Okuma, R. (2012). Network analysis of the financial system: An application to the Japanese interbank market. *Journal of Economic Interaction and Coordination*, 7(2), 145-162.
19. Weistroffer, C., & Möbert, J. (2010). Global banking sector: Current issues. *Deutsche Bank Research*, Frankfurt.
20. Murray, J., & Rawcliffe, P. (2010). Contagion and the global banking crisis. *Fitch Ratings*, Special Report.