Quantile Connectedness and Risk Transmission in the Global Banking Market: Lessons for Financial Policy and Risk Management

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Abstract

We analyze the connectedness between 96 banks from 25 countries between January 02, 2006, and December 29, 2023. We use a Quantile Autoregression Vector (QVAR) model to estimate the bank stock markets network. Our results reveal that banking markets are closely interconnected across the time and quantiles of the distribution of volatility, especially for extreme quantiles. We identify the markets and banks that offer significant advantages to diversifying risk, and those that transmit the largest spillovers and induce financial contagion within the network in different scenarios. Global Systematically Important Banks (G-SIBs) are the most connected banks in moderate or low volatility scenarios, and the least connected in high-risk scenarios. US and Japanese banks are the main transmitters of shocks in high-volatility quantiles, while banks from emerging countries provide diversification benefits in moderate and low risk scenarios. These results have important implications for investment decision-making and financial stability policies design.

Keywords: banking, spillovers, connectedness, network, risk.
JEL codes: C32, G11, G15, G21.

Declarations of interest: none.

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1. Introduction

The banking market plays a systemically relevant role in channeling funds between the various economic actors within an economy. However, the growing globalization process of world financial markets has driven greater interdependence between banks in various countries, facilitating the shocks transmission and limiting opportunities for risk diversification within the industry, particularly in high financial tensions and crisis scenarios. Given this, there is no doubt policymakers and financial regulators must monitor with special emphasis the global banking system and the links that each bank has developed with other banks inside and outside a country, with the purpose of designing policies aimed at controlling the risks that threaten financial stability. Investors may even see their investment decisions within the industry altered if they do not know or evaluate the risk transmission channels in different scenarios.

The literature on connectedness in the global banking market has experienced important empirical advances and provided a better understanding about the mechanisms of financial contagion within this industry. Despite this, there are two important knowledge gaps that have not yet been explored, and which are addressed in our study. First, studies in this area have focused on analyzing mean-conditional banking connectedness. This type of analysis would reflect the behavior of the global banking network only in scenarios of relative normality, ignoring the structure and risk transmission mechanisms in crisis scenarios or deep financial tensions. In this sense, the Global Financial Crisis of 2008 and the Sovereign Debt Crisis in Central Europe during 2011 left important lessons. The episodes of high volatility that characterized world markets during these periods showed the fragility of the banking systems of various countries, mainly developed ones, and how some of less systemic relevance spread shocks to others with greater importance. Evidently, this simple example suggests that the banking markets global network becomes strained in scenarios of greater uncertainty, intensifying financial contagion and closing spaces for the diversification of banking portfolios. For this reason, we use the quantile connectedness approach proposed by Ando et al. (2022), who adapt the traditional spillover measures of Diebold and Yilmaz (2012, 2014) through a Quantile Autoregression Vector (QVAR) model. Using this methodology, we can evaluate the behavior of the global banking network in different risk scenarios (represented by different quantiles of the distribution of the realized volatility of banking stock prices), accurately identifying in each of them the markets or commercial banks more and less exposed to the shock's transmission. Second, the investigations that have studied quantile connectedness in the banking market are very scarce and recent, and have made their analyzes using aggregate sectoral indices or small samples of commercial banks that do not allow extrapolating the systematic relevance of a country or bank within the global network and in each possible scenario. For this reason, we use a sample of 96 commercial banks from 25 markets, both developed and emerging, and which include banks qualified as Global Systematically Important Banks (G-SIBs) by the Financial Stability Board (2023). The representativeness of the sample of banks allows us to make a more appropriate description of the global banking system in different scenarios, identifying opportunities for risk diversification in those markets or banks less exposed to the shocks transmission, as well as potential threats to financial stability emanating from those markets or banks most relevant in the risks contagion. It is evident that this description has important

implications both for investment decisions within the banking market and for the design of regulations that promote the stability of financial systems, and that are naturally capable of adapting to different market conditions.

In light of these motivations, we study the connectedness for a system composed of 96 commercial banks from 25 countries, both developed and emerging. The sample is made up of the most representative commercial banks and markets globally, including those that the Financial Stability Board (2023) classifies as Global Systematically Important Banks (G-SIBs). The study period expands from January 2, 2006, to December 29, 2023, a period of time that allows us to study the global banking network during important periods of financial stress such as the Global Financial Crisis, the Sovereign Debt Crisis in Central Europe, the Covid-19 Pandemic and the recent war conflicts in Ukraine and Palestine. From the methodological point of view, we use the quantile connectedness approach formulated by Ando et al. (2022) to estimate spillovers in different quantiles of the realized volatility distribution of commercial banks and markets depending on whether the analysis is performed at banks-level or countries-level, respectively. In the latter case, we use the realized volatility of an equally-weighted portfolio composed of banks belonging to a specific country. In this way, we can capture and compare heterogeneity at the bank-level that is not observed in the aggregate country view and evaluate the systematic relevance of the connectedness of each market and commercial bank within the global banking network for different volatility scenarios.

The banking literature is undoubtedly extensive in many aspects. However, the strand that has focused on the study of the links between the various banking markets is somewhat scarcer, more recent, and strongly focused on developed markets, which evidently are very relevant within the global banking network. An important part of these investigations has highlighted that the vulnerability of banks is associated to geographical proximity and the financial integration process that various countries such as European ones have experienced, facts that have stimulated connectedness between them and facilitated the risks transmission (Singh et al., 2015; Pino et al., 2018; Shahzad et al., 2018; Skouralis, 2021).

More recent investigations, basing their analyzes on banking sector indices from various countries or small samples of commercial banks, has incorporated the connectedness approach introduced by Diebold and Yilmaz (2012, 2014) to quantify the spillovers intensity and shocks transmission paths within the banking industry. For example, Apostolakis et al. (2022) used the methodological framework of Diebold and Yilmaz (2012) through TVP-VAR model to analyze the G7 banking markets. Using sector indices, the authors showed that the G7 markets, particularly France, Germany and Italy, are closely linked to each other, and warn that the US banking market is vulnerable to shocks from European markets. On the other hand, Tabak et al. (2022) analyzed 35 banking indices from various countries, both developed and emerging. Their findings revealed that the geographical proximity between banking markets is a key factor for the transmission of higher intensity shocks, particularly in times of crisis. Other investigations have contributed to significant progress in this line by using information at the level of commercial banks, which naturally has a greater degree of heterogeneity than that based on sectoral indices. In this sense, Wang et al. (2018) carried out a study for 14 Chinese banks using the approach of Diebold and Yilmaz (2009, 2012). Their results revealed Chinese private banks are closely interconnected, while state-owned banks play lower role in shock transmission and banking network connectedness. In another

research, Arreola et al. (2020) studied 26 commercial banks from developed and emerging countries in America. Despite high connectedness between region's banks, their results showed Latin American markets offer important advantages for risk diversification in banking portfolios. In the case of European countries, the most recent evidence shows a strong interconnection of their banking markets, mainly in Central Europe, so there are few possibilities for risk diversification and a greater probability of financial contagion within the region (Brownlees et al., 2021; Borri and Di Giorgio, 2022). The work of Demirer et al. (2018) provide one of the most detailed descriptions of the global banking network. The authors adapted the methodology of Diebold and Yilmaz (2012, 2014) to LASSO-VAR model to analyze the connectedness between 95 large banks worldwide. Their findings demonstrated the geographical nature of the shocks transmission, and how crisis periods intensify banking spillovers, mainly between countries. Recently, Muñoz et al. (2024) combined dynamic factor models and the LASSO-VAR approach of Demirer et al. (2018) to extract idiosyncratic volatility and estimate connections among 205 commercial banks, including G-SIBs. Their findings demonstrated that the system reached a total spillover of 72.77%, which was reduced to an idiosyncratic spillover of 45.54% after removing the unobservable systemic component that affected the connectedness. This result revealed that banks can transmit abnormal shocks beyond the systemic channel, and banks in Canada, Sweden, Australia, Italy, Spain and the United States were identified as the main shocks transmitters within the global network. Undoubtedly, these investigations have made important contributions to the banking connectedness literature. However, all of them have focused on mean-conditional banking connectedness. This simple fact implies that the contribution to interdependence within the global network, whether of a commercial bank or a specific market, can change for other scenarios than those considered normal.

This is why the most recent investigations have focused on studying the behavior of the banking network in extreme scenarios, particularly in times of crisis or strong financial tensions. Shahzad et al. (2019) analyzed the return connectedness for 18 major European banks using the cross-quatilogram approach proposed by Han et al. (2016). Their findings demonstrated European banking markets exhibit an asymmetric response to shocks, being more vulnerable in bearish scenarios. Deev and Lyócsa (2020), using also the cross-quatilogram approach, corroborate this conclusion in a broader study applied to European financial institutions such as banks and insurance companies. The authors add that these institutions are closely interconnected, even in calm scenarios associated with higher return quantiles. In the same line, Qian et al. (2022) analyzed the return connectedness of 30 Chinese financial institutions, including banks and various insurance and securities companies. Their findings confirmed the links between these financial institutions are asymmetric across different quantiles of returns, and particularly in bearish scenarios, in which banks are more susceptible to the shock transmission. More recent studies have incorporated the quantile connectedness methodology proposed by Ando et al. (2022) to evaluate banking interdependence in different scenarios. Chen et al. (2023) analyzed 92 Chinese financial institutions, including 58 traditional institutions (banks, insurance, real estate, and securities companies) and 34 FinTech firms. The authors demonstrated the connectedness asymmetry between these institutions, and the greater intensity of spillovers in extreme quantiles, scenarios in which banks are characterized by being one of the main net shocks receivers of the Chinese financial system. Jin (2024) provides a more specific

analysis by studying only the 15 Chinese Systemically Important Banks (C-SIBs). His results highlight the asymmetric interconnection of banks between different quantiles, and their greater vulnerability in extreme scenarios, which evidently urge policymakers to establish financial regulations adapted to these scenarios. Hoque et al. (2024) found similar results for the US financial sector.

Despite the important contributions of these works, most of them have focused on mean-conditional connectedness and have used sectoral indices or a limited sample of banks to model interactions within the banking industry. Obviously, this does not allow for a complete description of the banking connectedness worldwide nor for evaluating the links in scenarios other than the average or relatively normal. There is no doubt that knowing the behavior and structure of a representative global banking network in various scenarios can be a tool of interest for investors and policymakers, both to guide investment decision-making and to design financial policies adapted to these scenarios, mainly for those of greater vulnerability.

Our research considers these limitations and provides a set of three important results. First, banking markets are closely interconnected globally, and their linkages are time-varying and differ across different quantiles of the realized volatility distribution of bank stock prices. The total spillovers for the system composed of 25 countries were 95.91%, 64.39% and 89.47% at the 95%, 50% and 5% quantiles of the realized volatility distribution, respectively. At the level of the 96 commercial banks, these records were 98.92%, 87.43% and 96.17% for the same quantiles. The periods of financial stress associated with the Global Financial Crisis, European Sovereign Debt Crisis and the Covid-19 Pandemic were characterized by a more stressed banking network and more intense spillovers. Particularly, during the Covid-19 Pandemic, the spillovers intensity was higher and more homogeneous throughout all quantiles of the realized volatility distribution.

Second, we identify the most relevant markets and banks for the transmission of shocks within the network for 95%, 50% and 5% quantiles of realized volatility. These actors are in the central part of the banking network, have greater connections with the rest of the system and transmit the most intense spillovers within the network. The banking markets of Belgium, the United Kingdom, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, and to a lesser extent the markets of Austria and Switzerland act as the main net transmitters of the global banking network across the time and different quantiles. At the level of commercial banks, US banks stand out as relevant actors for the propagation of shocks through the different quantiles of volatility as well as G-SIBs in low and moderate risk scenarios.

Third, for the 95%, 50%, and 5% quantiles of the realized volatility distribution, we also precisely identify markets and banks located on the periphery of the global network, which are characterized by being less sensitive to shocks coming from the rest of the system and for offering better and more precise risk diversification opportunities. In general terms, the banking markets of China, New Zealand, South Korea, Brazil, Australia, India, Russia, and to a lesser extent the markets of Japan, Ireland and Norway are the least connected and transmit the lower spillovers within the global network. At the level of individual banks, the configuration is more heterogeneous than that provided at the country-level, since there are commercial banks that are very relevant for the shocks transmission, but they are established in countries less connected to the global network, and vice versa. Some G-SIB banks provide

important advantages for risk diversification in high-volatility scenarios, while banks from emerging countries provide them in low and moderate volatility scenarios.

The rest of the paper is structured as follows. Section 2 presents our data, while Section 3 details our methodological approach. Section 4 shows our main results, and finally, Section 5 contains the conclusions and implications of this research.

2. Data

Bank stock prices are expressed in US dollars and were obtained from the Bloomberg database. The sample expands from January 2, 2006 to December 29, 2023 and is made up of 96 commercial banks, which represent 25 countries, both developed and emerging. The selection of the sample considers two essential criteria. First, the sample of banks must be representative of the industry globally. To do this, we select the largest and most representative banks from various countries, including banks classified by the Financial Stability Board (2023) as Global Systematically Important Banks (G-SIBs)[5]. Banks with incomplete stock price records were eliminated from the sample. For this reason, some European countries, such as Austria, Belgium, Denmark, Finland, the Netherlands, Norway, and Russia, are represented only by the largest bank, ranked among the world's 100 largest banks by market capitalization (S&P Global Market Intelligence, 2023). Second, the sample must be expanded over a long period of time. The selected sample of banks expands daily over 18 years. This length of time offers us the possibility of analyzing the global banking network across various quantiles and during important periods of financial stress such as the Global Financial Crisis, the Sovereign Debt Crisis in Europe, the Covid-19 Pandemic and the recent geopolitical conflicts in Europe and the Middle East.

The empirical connectedness analysis in the global banking market is based on the realized volatility of banking stock prices. Following Garman and Klass (1980), the daily realized volatility for a stock can be determined by:

$$\hat{\sigma}_{it}^2 = 0.511(H_{it} - L_{it})^2 - 0.019[(C_{it} - O_{it})(H_{it} + L_{it} - 2 - O_{it}) - 2(H_{it} - O_{it})(L_{it} - O_{it})] - 0.383(C_{it} - L_{it})^2, \quad (1)$$

where H_{it}, L_{it}, O_{it} and C_{it} are the logarithms of daily high, low, opening and closing prices for bank stock i on day t. For the aggregate country-level analysis, we use the realized volatility for an equally-weighted portfolio composed of banks belonging to a specific country. It is important to mention that the use of this volatility measure is efficient for high-frequency data and mitigates the influence of time differences for the markets located in other zones.

Table 1 reports the statistical description of the realized volatility of the banking industry at country-level. The European banking markets present the highest figures in the sample, undoubtedly influenced by the strong financial tensions occurred during the Global Financial Crisis and, particularly, the Sovereign Debt Crisis in Europe. The banking markets of Austria (1.76%), Belgium (1.84%), France (1.62%), Germany (1.77%), the Netherlands

[5] China Construction Bank, Bank of Communications, Agricultural Bank of China and Groupe BPCE were also not considered due to lack of data. Credit Suisse Group was not considered as it was acquired by UBS Group AG in June 2023.

(1.75%), Greece (3.32%) and Ireland (2.17%) have the highest realized volatility records. Asian and American markets have a more limited risk level. From a statistical point of view, the rejection of the ADF test indicates that all realized volatility time series are stationary processes, which is an important property for the estimation of the QVAR model. At the commercial bank-level, all volatility series are also stationary processes, although the risk patterns are more heterogeneous than the aggregate records at the country-level (further details see Appendix A1).

Table 1. Descriptive statistics for banking stock volatility.

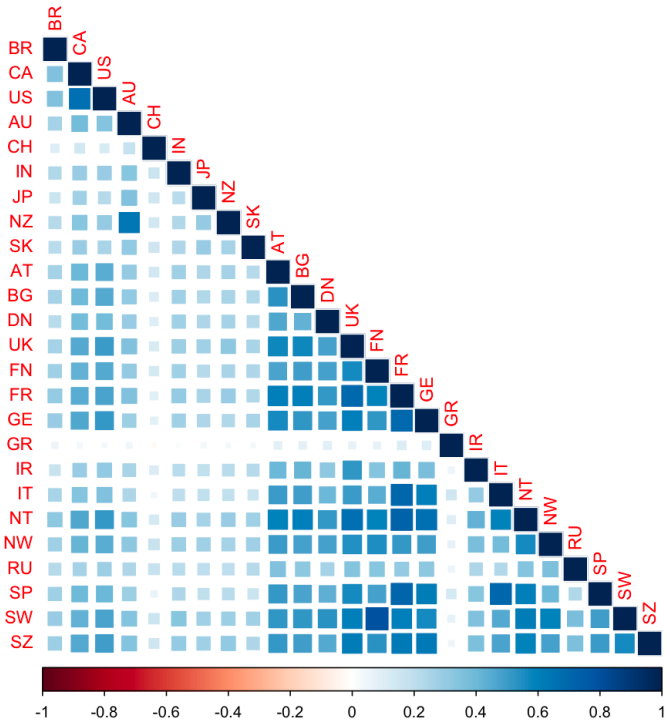
ID code	Country	Banks	Mean	Std. Dev.	ADF test
America					
BR	Brazil	3	1.48	1.53	-9.07***
CA	Canada	8	0.74	0.98	-8.57***
US	United States	18	1.41	1.89	-7.16***
Asia Pacific and Oceania					
AU	Australia	7	0.95	1.05	-8.77***
CH	China	7	1.09	1.27	-9.59***
IN	India	6	1.23	1.39	-8.46***
JP	Japan	7	1.26	1.35	-9.40***
NZ	New Zealand	2	1.09	1.12	-9.03***
SK	South Korea	3	1.06	1.19	-8.81***
Europe					
AT	Austria	1	1.76	2.02	-8.24***
BG	Belgium	1	1.84	2.42	-9.00***
DN	Denmark	1	1.38	1.49	-9.02***
FN	Finland	1	1.37	1.55	-8.71***
FR	France	3	1.62	1.79	-8.22***
GE	Germany	2	1.77	1.92	-7.63***
GR	Greece	1	3.32	4.65	-11.24***
IR	Ireland	3	2.17	2.97	-9.19***
IT	Italy	5	1.46	1.53	-9.37***
NT	Netherlands	1	1.75	2.22	-8.10***
NW	Norway	1	1.38	1.68	-7.22***
RU	Russia	1	1.66	2.27	-9.49***
SP	Spain	4	1.40	1.44	-10.09***
SW	Sweden	4	1.15	1.30	-8.34***
SZ	Switzerland	1	1.51	1.82	-7.58***
UK	United Kingdom	5	1.37	1.72	-8.33***

Notes: Statistics are in percentage points. Data correspond to the realized volatility for an equally-weighted portfolio for each country. The sampled period extends from January 2, 2006, to December 29, 2023. ADF corresponds to the Augmented Dickey-Fuller unit root test. This test only considers the random walk specification. Superscripts ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Source: Authors.

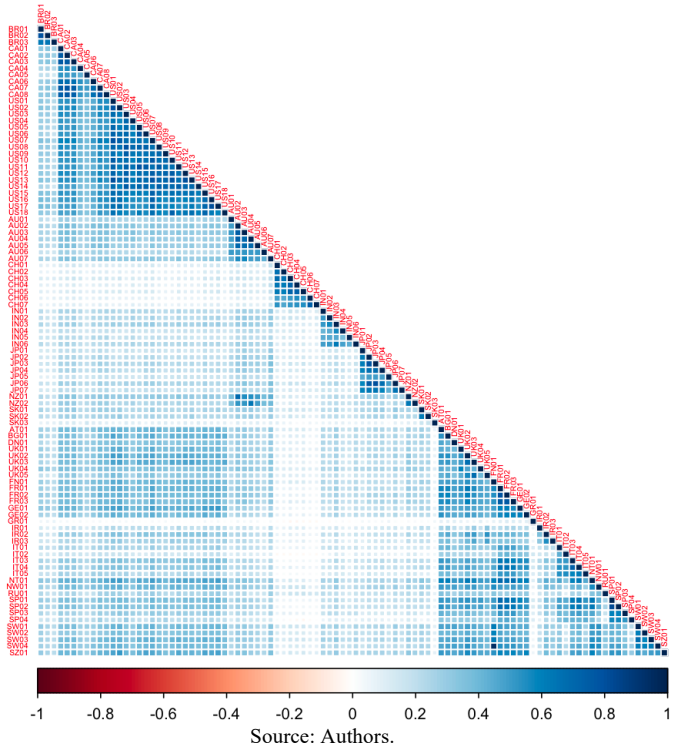
Figure 1 presents the Pearson correlations between the different banking markets. Both at country-level (Figure 1a) and at commercial bank-level (Figure 1b), a positive and significant dependency between banking markets is observed, which facilitates the risk transmission and reduces the possibilities of diversification within the banking industry. The strong country-level correlation is mainly observed between European banking markets, while banks in Greece and China present a lower dependence. At the commercial bank-level, Figure 1b depicts a similar correlational picture.

Figure 1. Unconditional correlations matrix for banking stock volatility.

(a) At country-level



(b) At bank-level



Source: Authors.

3. Methodology

In order to assess the interconnectedness between banking markets at country and individual bank-level, we employ the quantile connectedness method introduced by Ando et al. (2022). This approach builds upon the conventional framework proposed by Diebold and Yilmaz (2012, 2014), but incorporates a quantile vector autoregression model indicated in the following baseline structure:

$$\boldsymbol{y}_t = \boldsymbol{\mu}(\tau) + \sum_{j=1}^{p} \boldsymbol{\Phi}_j(\tau)\boldsymbol{y}_{t-j} + \boldsymbol{u}_t(\tau), \tag{2}$$

where $\boldsymbol{y}_t$ and $\boldsymbol{y}_{t-j}$ are $k \times 1$ dimensional vectors that contain the endogenous variables in t and $t-j$, respectively. In addition, the quantile of interest $\tau \in [0,1]$, p is the autoregression order of the QVAR model, $\boldsymbol{\mu}(\tau)$ is a $k \times 1$ dimensional conditional mean vector, $\boldsymbol{\Phi}_j(\tau)$ is a $k \times k$ matrix that contains the coefficients of the QVAR system while $\boldsymbol{u}_t(\tau)$ is a $k \times 1$ dimensional vector with a variance–covariance matrix of dimension $k \times k$, denoted by $\boldsymbol{\Sigma}(\tau)$.

To describe the equation-by-equation quantile approach of the VAR system, we detail the single equation of (2) as:

$$y_{st} = \boldsymbol{\Phi}_s'(\tau)\boldsymbol{z}_t + u_{st}(\tau), \tag{3}$$

where $s = 1,2,\dots,k$ and $\boldsymbol{z}_t$ indicates the $(kp+1) \times 1$ vector of all regressors including the intercept. The vector $\boldsymbol{\Phi}_s$ contains the corresponding autoregressive coefficients at τth-quantile and, naturally, the residuals $\boldsymbol{u}_{st}(\tau)$ adhere to the conditional quantile restriction $Q_t(u_{st}(\tau)|\boldsymbol{z}_t) = 0$, where Q_t indicates the τ conditional quantile function of y_{st}.

According to Koenker and Hallock (2001), the autoregressive coefficients for a specific quantile τ can be estimate by solving the problem:

$$\min_{\boldsymbol{\Phi}_s(\tau)} \sum_{t=1}^{T} (\tau - \boldsymbol{I}[y_{st} \leq \boldsymbol{\Phi}_s'(\tau)\boldsymbol{z}_t])(y_{st} - \boldsymbol{\Phi}_s'(\tau)\boldsymbol{z}_t), \tag{4}$$

where $\boldsymbol{I}[\cdot]$ is the indicative function taking the value of 1 when $y_{st} \leq \boldsymbol{\Phi}_s'(\tau)\boldsymbol{z}_t$ and 0 otherwise, and T is the number of observations in the sample.

To derive the connectedness measures of Diebold and Yilmaz (2012, 2014) through Wold's Theorem within the QVAR framework, we can re-write the Equation (2) as an infinite moving average representation $QVMA(\infty)$ as follows:

$$\boldsymbol{y}_t = \boldsymbol{\mu}(\tau) + \sum_{i=0}^{\infty} \boldsymbol{\psi}_i(\tau)\boldsymbol{u}_{t-i}, \tag{5}$$

where the $k \times k$ dimensional coefficients matrix, denoted by $\boldsymbol{\psi}_i(\tau)$, is defined as:

$$\boldsymbol{\psi}_i(\tau) = \begin{cases} 0 & , i < 0 \\ \boldsymbol{I}_k & , i = 0 \\ \boldsymbol{\Phi}_1\boldsymbol{\psi}_{i-1}(\tau) + \boldsymbol{\Phi}_2\boldsymbol{\psi}_{i-2}(\tau) + \cdots + \boldsymbol{\Phi}_p\boldsymbol{\psi}_{i-p}(\tau) & , i > 0 \end{cases} \tag{6}$$

According to Diebold and Yilmaz (2012), the moving average representation is relevant to understand system dynamics and connectedness statistics. To achieve order-invariant variance decompositions of the QVAR system, these connectedness measures employ the methodological framework proposed by Koop et al. (1996) and Pesaran and Shin (1998), hereinafter KPPS. Therefore, for $H = 1,2, \ldots$, we denote the KPPS H-step-ahead forecast error variance decomposition as:

$$\theta_{ij}^{g}(H) = \frac{\Sigma(\tau)_{ii}^{-1} \sum_{h=0}^{H-1} \left(\boldsymbol{e}_i' \boldsymbol{\psi}_h(\tau) \boldsymbol{\Sigma}(\tau) \boldsymbol{e}_j\right)^2}{\sum_{h=0}^{H-1} \left(\boldsymbol{e}_i' \boldsymbol{\psi}_h(\tau) \boldsymbol{\Sigma}(\tau) \boldsymbol{\psi}_h(\tau)' \boldsymbol{e}_i\right)}, \tag{7}$$

where $\Sigma(\tau)_{ii}$ is the standard deviation of the error of the i-th equation in the quantile τ, and $\boldsymbol{e}_i$ is a selection vector with value one at the i-th element and zero otherwise. As the sum of the elements of each row in Equation (7) is not equal to 1 $\left(\sum_{j=1}^{k} \theta_{ij}^{g}(H) \neq 1\right)$, in order to get a unit sum of each row of the variance decomposition matrix, the following normalization must be done for each entry:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{k} \theta_{ij}^{g}(H)}, \tag{8}$$

where by construction $\sum_{j=1}^{k} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{k} \tilde{\theta}_{ij}^{g}(H) = k$. Equation (8) thus constitutes a natural measure of the pairwise directional spillover from variable j to variable i. Next, the total directional spillover received by variable i from all other variables j is:

$$S_{i\leftarrow\circ}^{g}(H) = \sum_{\substack{j=1 \\ j\neq i}}^{k} \tilde{\theta}_{ij}^{g}(H), \tag{9}$$

Similarly, the total directional spillover transmitted by variable i to other variables j is:

$$S_{\circ\leftarrow i}^{g}(H) = \sum_{\substack{j=1 \\ j\neq i}}^{k} \tilde{\theta}_{ji}^{g}(H). \tag{10}$$

The net spillover from variable i to the remaining variables j is:

$$S_{i}^{g}(H) = S_{\circ\leftarrow i}^{g}(H) - S_{i\leftarrow\circ}^{g}(H). \tag{11}$$

This measure of net connectedness shows the dynamics between the shocks transmitted and received by a market within the QVAR system. Finally, using the KPSS variance decomposition, the adjusted total spillover or system-wide connectedness of Chatziantoniou and Gabauer (2021) and Gabauer (2021) which ranges between $[0,1]$, can be represented by:

$$S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i\neq j}}^{k} \tilde{\theta}_{ij}^{g}(H)}{k-1}. \tag{12}$$

This spillover measure quantifies the contribution of the shocks of the k variables to the forecast error variance (Diebold and Yilmaz, 2009). Usually, this measure is used as a

proxy for market risk, therefore, in our case, a higher $S^g(H)$ shows a higher degree of interconnectedness between the markets (or banks) in the QVAR system.

4. Empirical results

4.1. Describing the quantile interconnectedness in the global banking market

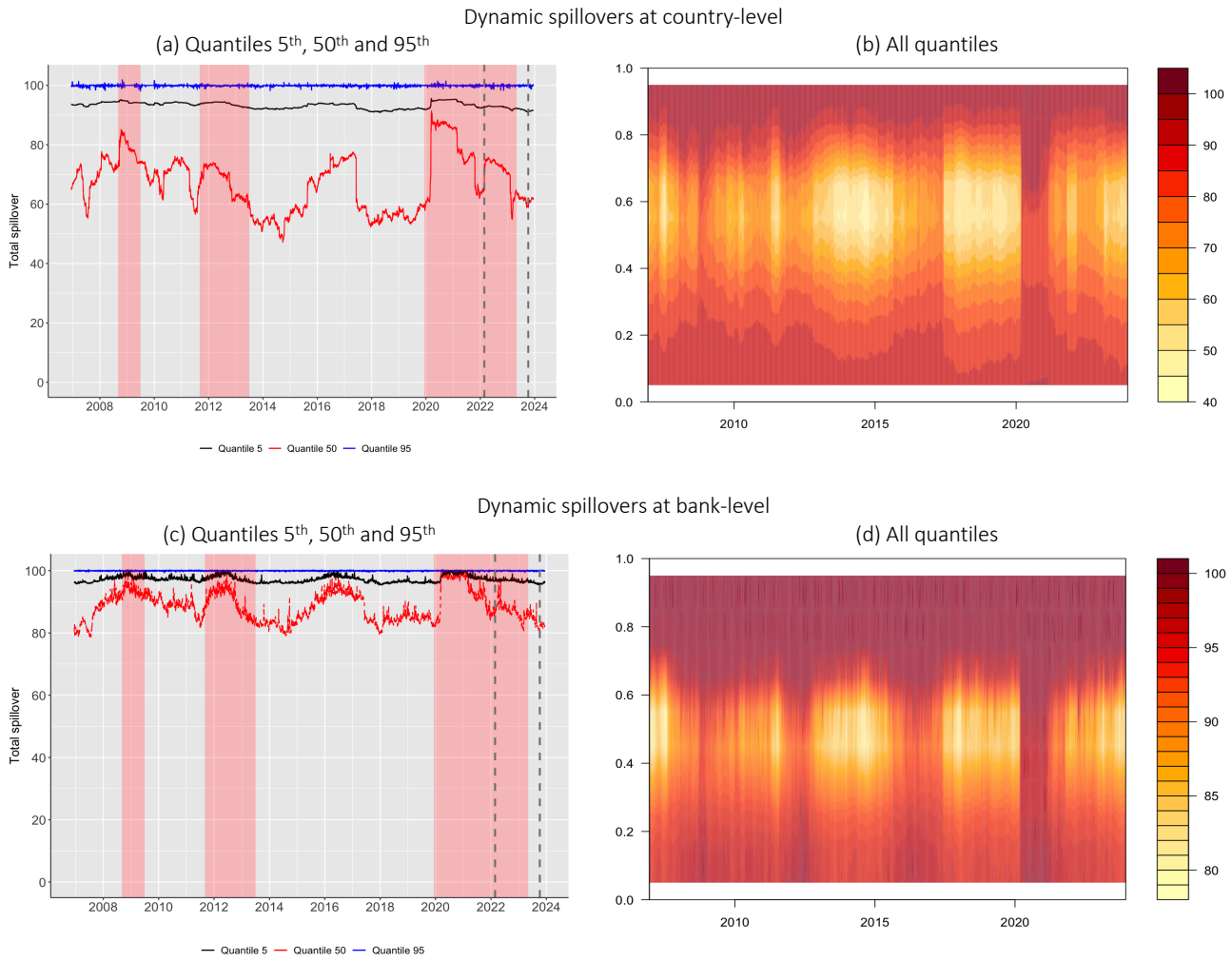
Here we present the results of the quantile connectedness method proposed by Ando et al. (2022). For the estimation, we used a QVAR(1) model whose order was defined based on the Bayesian Information Criterion (BIC). For all computations we use a 250-days rolling-window, capable of capturing the dynamics of bank volatility linkages over a year, and 20-step-ahead forecast error variance decomposition.

Figure 2 presents bank interconnectedness over time and across the different quantiles of the realized volatility distribution. Figure 2a shows the bank volatility spillovers at level of the 25 countries for 95% (high-volatility), 50% (average-volatility) and 5% (low-volatility) quantiles. We can discuss three important results regarding banking links. First, volatility spillovers vary across the time and different quantiles. This finding supports the volatility connectedness between banking markets change dynamically for different risk levels, modifying in each scenario the shock transmission mechanisms and the diversification possibilities of banking portfolios. Second, the extreme quantiles associated with episodes of high-volatility (95% quantile) and low-volatility (5% quantile) exhibit a certain degree of symmetry between themselves, where the spillovers that range between 100% and 92%, respectively. This suggests that in extreme volatility scenarios, mainly in the highest quantiles of the realized volatility distribution, the global banking network experience shocks of greater intensity that increase the channels of financial contagion as well as the markets vulnerability. Third, scenarios associated with quantiles close to the mean (50% quantile), and defined as scenarios of relative normality, exhibit spillovers that are around 70%. The result of this scenario corroborates the findings of Demirer et al. (2018), and shows even that normal scenarios, interconnectedness within the banking market is high. Figure 2c, constructed at the level of the 96 commercial banks, shows the realized volatility spillovers for the 95% (high-volatility), 50% (average-volatility) and 5% (low-volatility) quantiles. The empirical findings are somewhat similar to those indicated by Figure 2a, although with higher intensity spillovers. The 95%, 50% and 5% quantiles show spillovers that border 100%, 90% and 97%, respectively. Therefore, this configuration at bank-level not only describes more intense spillovers than those observed at country-level but also a lower degree of asymmetry in the transmission of shocks along the different quantiles of the realized volatility distribution.

Figures 2b and 2d show the intensity of volatility spillovers at the country and commercial bank levels, respectively. Common aspects are observed in both figures. First, periods of strong financial and economic tensions such as the Global Financial Crisis, the Sovereign Debt Crisis in Europe and the Covid-19 Pandemic generated a significant increase in the magnitude of spillovers, a fact naturally increased the spread of risks within banking industry. Of these episodes, the Covid-19 Pandemic had the most profound effects in that it

not only increased the spillovers intensity, but also its spread was transversal throughout the different quantiles of realized volatility. Second, recent war conflicts such as the Russian Invasion of Ukraine and the War between Israel and Palestine had dissimilar impacts on the global banking market. Only the Russian Invasion of Ukraine generated a significant increase of around 10% in the spillovers associated to 50% quantile, which is undoubtedly related to the financial sanctions on Russia and the exclusion of its main banks from the Society for Worldwide Interbank Financial Telecommunication (SWIFT).

Figure 2. Banking spillovers across different quantiles.



Note: Spillovers were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. Global Financial Crisis considers the period between September 01, 2008 and June 30, 2009; the European Government Debt Crisis considers the period between September 03, 2011 and June 30, 2013; and the Covid-19 Pandemic considers the period between December 09, 2019 and May 05, 2023. The segmented gray line indicates the beginning of the Russian Invasion of Ukraine (February 24, 2022) and the Israel-Palestine War (October 7, 2023). Source: Authors.

4.2. Network analysis

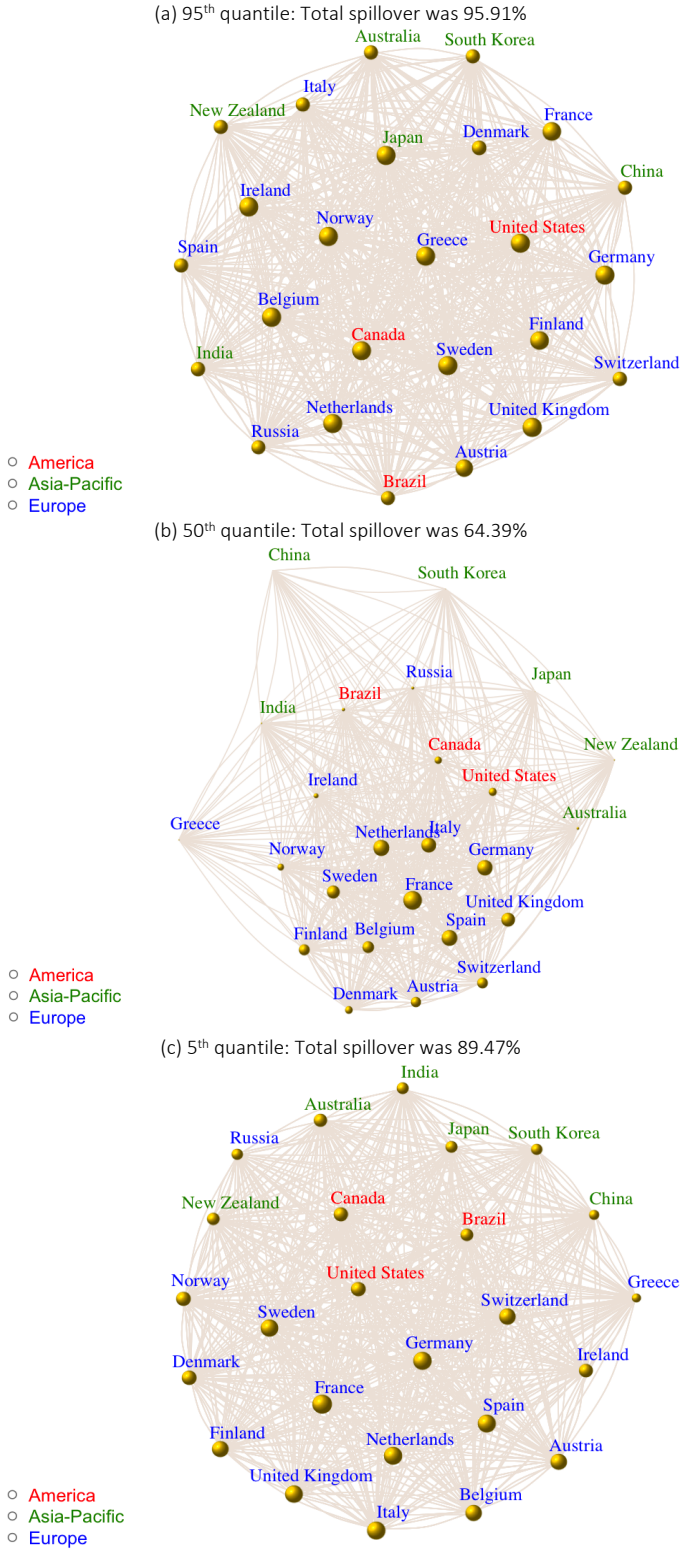
In this section we develop a network analysis to describe the structure and connectedness channels of the global banking market both at the level of countries and commercial banks. Figure 3 presents the banking networks at the level of the 25 countries for 95%, 50% and 5% quantiles.

Figure 3a shows the banking network for the high-volatility scenario (95% quantile). In this context, the full system total spillover was 95.91%. Undoubtedly, in a scenario of high-volatility and uncertainty, banking markets are closely interconnected in a dense and stressed global network, characterized by higher intensity spillovers. Such a scenario creates a space conducive to the transmission of financial risks within the banking market, and naturally eliminates spaces to diversify risk. Although practically all markets transmit shocks of similar magnitude in this scenario, the European and North American markets have a somewhat more centralized position within the network that makes them the most relevant actors in the spread of risks in the banking industry. Banking markets in New Zealand, Australia, India, Brazil, China and South Korea are less connected to the global network, which allows them to be somewhat less vulnerable to financial contagion in a context of high volatility.

Figure 3b presents the network for 50% quantile, which is associated with a scenario of relative normality. In this case, the total spillover of the system comprised by 25 banking markets was 64.39%. This result confirms the asymmetric behavior exhibited by banking connectedness across different levels or quantiles of volatility. The weakening of spillovers for quantiles close to the average fosters a context facilitates the control of financial contagion, mainly from the European markets, which are in the central areas of the global network and transmit the largest shocks within the system. On the other hand, the Asia-Pacific and American markets, which are in the peripheral areas of the banking network, would provide important benefits to diversify the risk of banking portfolios. The lower linkage of the Russian banking market in relation to other European countries may be influenced by the exclusion of its main banks from the SWIFT system established as a consequence of the Russian invasion of Ukraine.

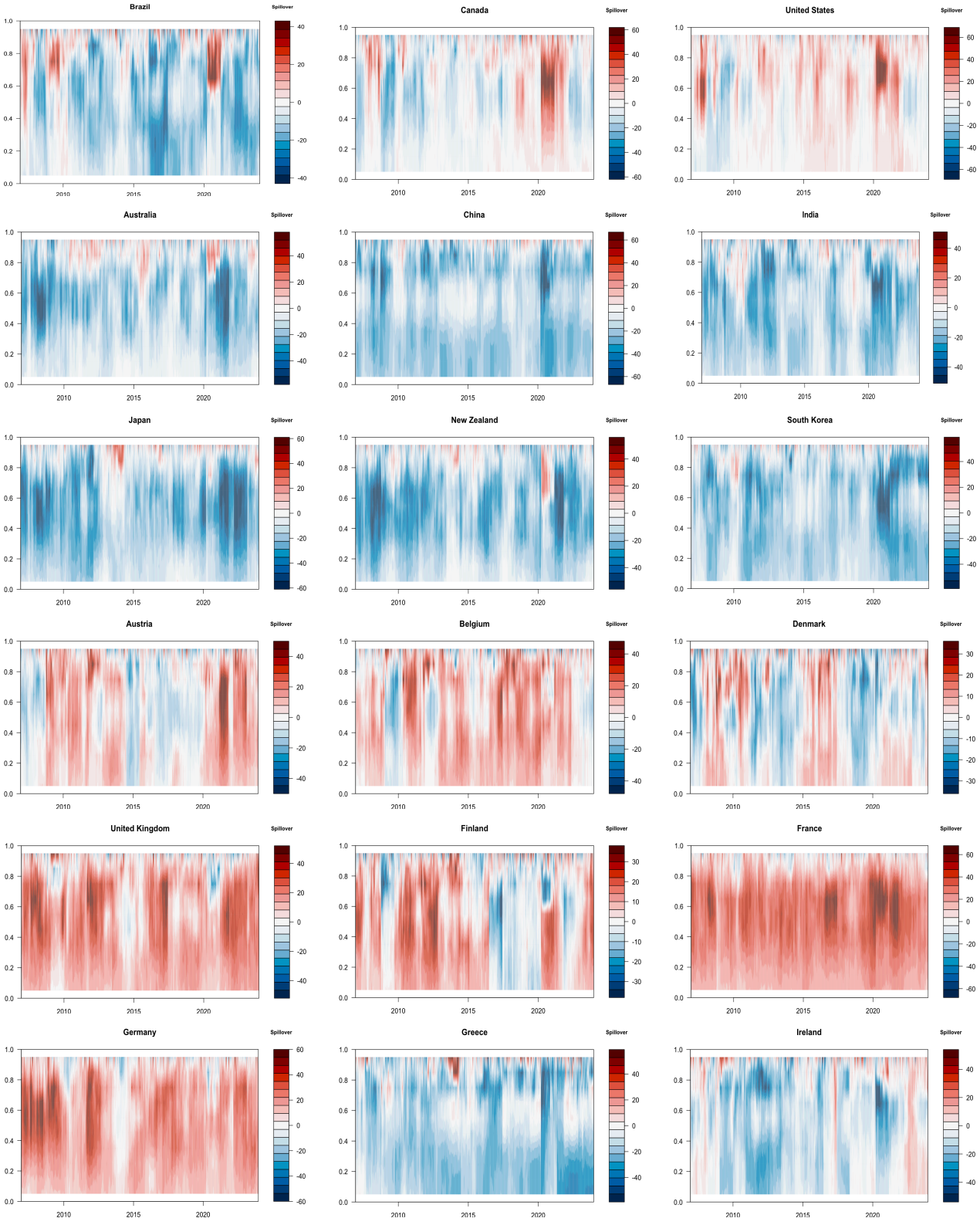
Figure 3c presents the banking network for 5% quantile, in which case the total spillover was 89.47%. The network configuration is very similar to that indicated in Figure 3a, which confirms the symmetry and greater intensity of banking shocks in extreme scenarios. Strengthening links in low-risk scenarios leads banking markets to deepen their commercial relationships and their degree of financial integration, facts that increase the banking vulnerability to the transmission of shocks, mainly from European markets, which are the main transmitters of spillovers.

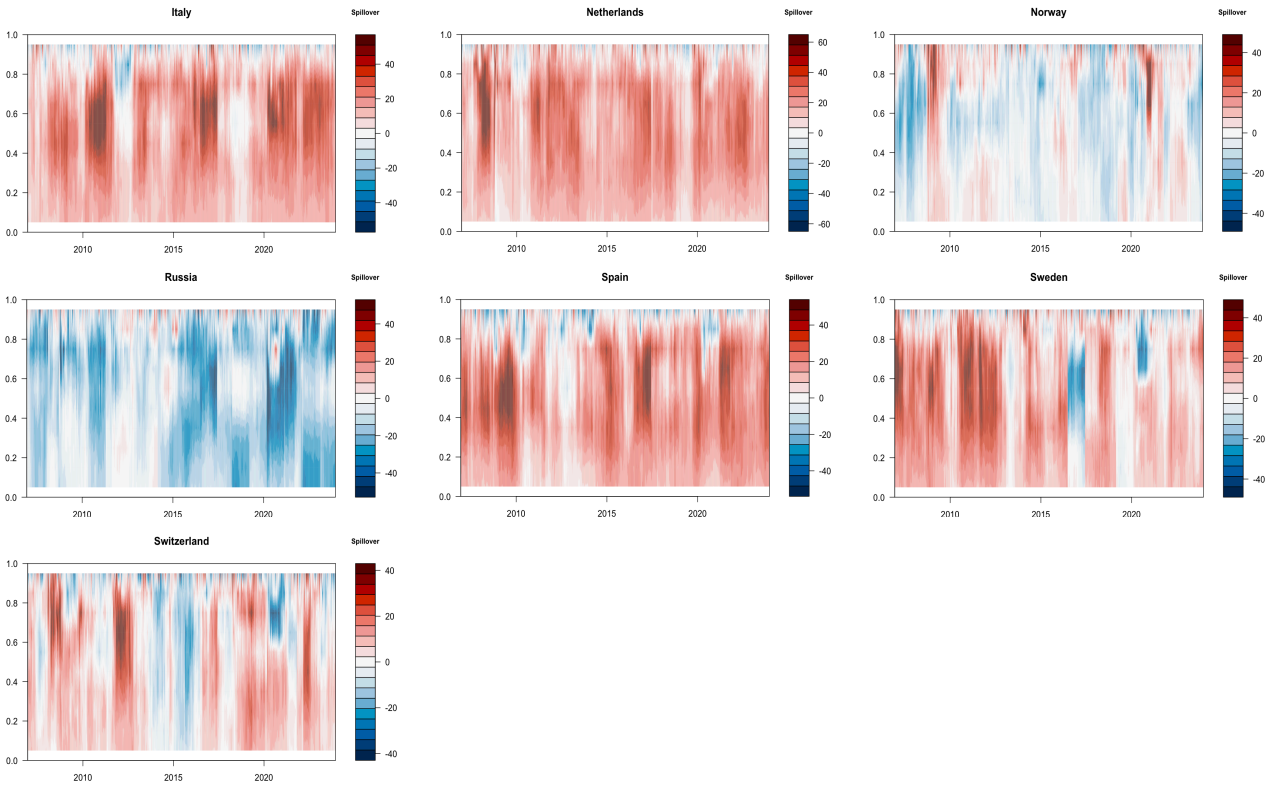
Figure 3. Spillover network across different quantiles: country-level.



Note: Spillover networks were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. Source: Authors.

Figure 4. Net spillovers for banking markets across different quantiles.



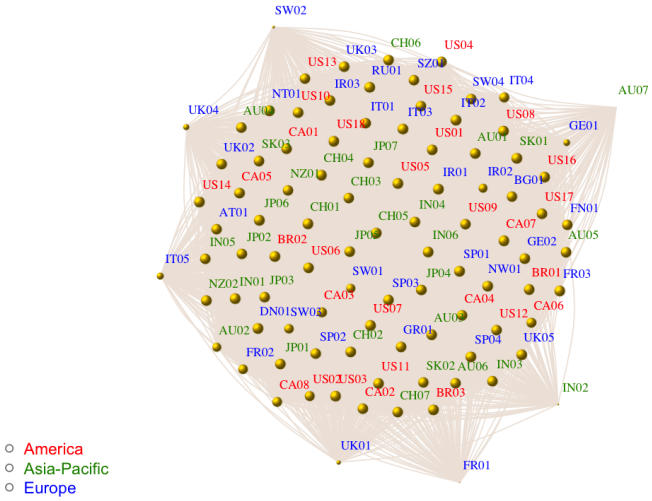


Note: Spillovers were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. Source: Authors.

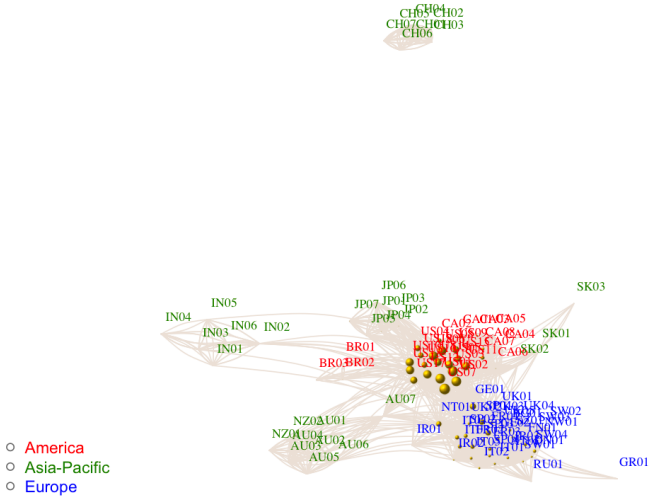
Figure 4 shows the net spillover for the 25 banking markets over time and for all quantiles of the realized volatility distribution. Three key aspects stand out for discussion. First, across the different quantiles of volatility, European markets have been characterized by their systemic relevance within the global banking network. The banking markets of Belgium, the United Kingdom, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, and to a lesser extent the markets of Austria and Switzerland act as the main net shock transmitters of the network (Singh et al., 2015; Apostolakis et al., 2022). These findings confirm the need to supervise the European banking system on a permanent basis and to establish financial regulations capable of controlling the spread of shocks that threaten the stability of the system regardless of the risk scenarios. Second, the banking markets of Brazil, Australia, China, India, Japan, New Zealand, South Korea, Greece, and to a lesser extent those of Ireland and Russia make up the set of main net shock receivers across time and the different quantiles of volatility. Despite this, Figure 4 also reveals that these markets are characterized by receiving and transmitting the smallest spillovers within the network. This fact suggests that these markets develop a lower connectedness degree compared to other markets such as European markets, and therefore, they would be less vulnerable to shocks and would offer greater space for international diversification. Third, the banking markets of Canada and the United States have a mixed behavior, which becomes a net transmitter during episodes of systemic relevance such as the Global Financial Crisis and the recent Covid-19 Pandemic.

Figure 5. Spillover network across different quantiles: bank-level.

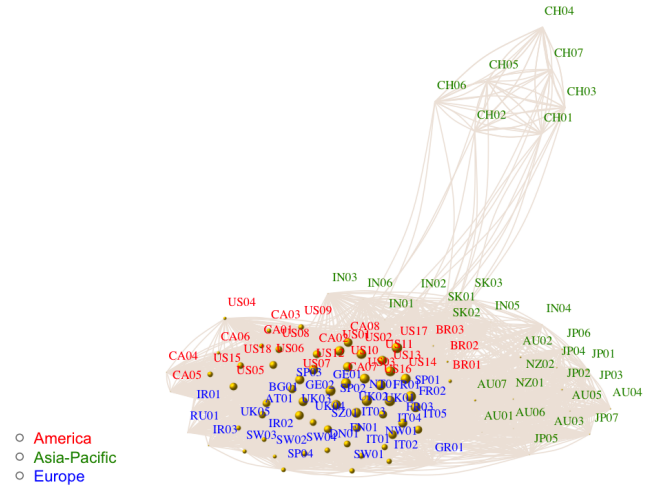
(a) 95th quantile: Total spillover was 98.92%



(b) 50th quantile: Total spillover was 87.43%



(c) 5th quantile: Total spillover was 96.17%



Note: Spillover networks were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. Source: Authors.

Figure 5 presents the networks at commercial bank-level for the 95%, 50% and 5% quantiles. In each risk scenario, the total spillover indices were greater than those obtained at country-level (Figure 3), mainly in the 50% quantile. Figure 5a presents the banking network for 95% quantile, a system where the total spillover reached 98.92%. The denser structure of the banking network describes the greater intensity of the transmitted shocks as well as a high number of connections that amplify the risk contagion channels. Only a few banks in the United Kingdom, France, Italy, Sweden and India located in the outer areas of the network would be the least vulnerable and would provide benefits to diversify risk in scenarios of high uncertainty. Figure 5b displays the banking network associated with the 50% quantile. In this scenario, the total spillover was 87.43%, a record higher than the 64.39% of the country-level network described for the same quantile (Figure 3b). Two interesting aspects arise from this case merit a more detailed discussion. First, the connectedness structure follows regional patterns as suggested by Demirer et al. (2018) and Muñoz et al. (2024). On the one hand, the positions of North American and European banks are clearly established as specific groups that develop links both within and between countries in the region, a fact that facilitates financial contagion within and between them (Shahzad et al., 2019). On the other hand, Asia-Pacific banks have closer ties within each country and therefore, risk diversification would generate greater advantages only in international portfolios (Qian et al., 2022; Chen et al., 2023). The most obvious example is Chinese banks, which are disconnected from banks in other countries (Jin, 2024). Second, the role of North American banks in the network at bank-level is much more preponderant than that established in the network at country-level. Figure 3b described a secondary contribution of these markets on connectedness and shock transmission after the predominant role of European markets. However, the impact of commercial banks in the United States and Canada is the most important, mainly from the G-SIBs banks established in these countries. This fact highlights the importance and greater precision of analysis at the bank-level both for the design of investment strategies and for the formulation of banking regulations. Finally, Figure 5c shows the banking network for commercial banks at 5% quantile. In this low-risk scenario, the system spillover was 96.17%, and the connectedness patterns are clearly regional. In this context, it is interesting how Chinese banks develop links with banks in other countries, in addition to internal ones, as a way of deep of commercial transactions in quiet scenarios.

4.3. More and less vulnerable markets and banks in the global network

Previous sections clearly showed the structure of the global banking network changes dynamically across time and quantiles of the realized volatility distribution of banking stock prices. This suggests, on the one hand, that shock transmission mechanisms intensify in different scenarios and markets (or banks) through which financial tensions spread with greater speed and strength, while on the other hand, the weakening of interconnectedness between markets (or banks) in certain quantiles open space for risk diversification strategies in the global banking markets. Therefore, identifying the markets or banks more or less exposed to the shocks transmission within the global network is crucial to develop financial regulations or portfolio decisions adapted to different scenarios.

To establish the degree of connectedness of each market or bank within the global network in 95%, 50%, and 5% quantiles, and thereby identify the more or less connected markets or banks, we use the centrality degree (Samitas et al., 2022; Karim et al., 2022; Chuliá et al., 2023). The centrality degree measures the number of links that each node (market or bank) has within a network, and therefore, quantifies the number of times that a market or bank interacts with other actors considering the transmitted and received spillovers. A lower (higher) centrality degree indicates a more peripheral (central) position of the specific market or bank within the global network. Naturally, a lower centrality degree implies less exposure to volatility shocks and therefore, a lower level of vulnerability of the market or bank.

Table 2 presents the 12 most connected banking markets, and therefore, most relevant for the shock transmission in the different quantiles of interest. In each panel the markets are presented according to their centrality degree (decreasing order). Next, we analyze three important results. First, in each quantile of interest, banking markets are characterized by being net transmitters of shocks and developing a number of connections greater than the full system average centrality. These 12 markets show an average centrality degree of 180, 146 and 168 for the 95%, 50% and 5% quantiles, respectively, records higher to the 170, 105 and 153 average links of the entire system at the same quantiles. Only for the intermediate 50% quantile we observed a greater range of centrality fluctuation (between 112 and 146 connections), which would reflect a less dense structure of the banking network. Second, the markets most connected to the global network are similar across different quantiles of the realized volatility distribution. Belgium, the United Kingdom, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, and to a lesser extent Austria and Switzerland, make up the most important set of banking markets for the risks propagation within the global network. After the high systemic importance of these European markets, banking industries of the United States and Canada play a secondary role in the shocks transmission. Third, banking markets of Japan, Greece, Norway and Ireland are actors highly linked and facilitate financial contagion only in high-risk scenarios (95% quantile). Undoubtedly, this description suggests financial regulations aimed at mitigating shocks and attenuating threats to the banking stability of a country can be adapted to different risk scenarios, although it is evident that in all of them the systemically relevant role of European banking markets must be recognized.

Table 3 presents the 20 commercial banks most connected to the global network according to the centrality degree (decreasing order) and the different quantiles under study. Most of them act as net shock transmitters within the network at commercial bank-level, mainly for the 50% and 5% quantiles. We observe greater heterogeneity around the markets represented compared to what is indicated in Table 2. The incidence of Japanese banks is only relevant in high-risk scenarios. However, the greater presence of US commercial banks within the set of most connected banks through the different quantiles is without a doubt the fact that stands out the most. Along with them, diverse commercial banks from Austria, the Netherlands, Japan, France, Germany, Spain and the United Kingdom are important actors for the shocks transmission, mainly those categorized as G-SIBs. The systematic presence of G-SIBs is relevant on the higher amount of links as well as the shocks transmission between banks in scenarios of moderate-volatility (50% quantile) and low-volatility (5% quantile). In this sense, American banks (JPMorgan Chase & Co., Bank of America Corp., Citigroup Inc.,

Wells Fargo & Company), French (BNP Paribas, Morgan Stanley SA, Societe Generale SA), German (Deutsche Bank AG.), Dutch (ING Groep N.V.) and Spanish (Banco Santander S.A.) stand out as the most relevant G-SIBs in these scenarios. In summary, the identification of specific banks as the main drivers of financial contagion within the global network is crucial to determine the vulnerability degree of the system and define the way in which financial regulators must supervise the banking industry using these shocks propagation routes as policy tool. Appendices A2, A3 and A4 present the spillover and centrality statistics of all banks for the different quantiles.

Table 2. Top-12 more-connected markets in the banking network.

Country	ID code	Spillover to others	Spillover from others	Net Spillover	Centrality
		Panel A. 95th quantile			
United Kingdom	UK	100.0	95.7	4.3	182
Japan	JP	98.4	95.8	2.6	181
Belgium	BG	99.8	95.7	4.1	181
Germany	GE	97.5	95.9	1.7	181
Greece	GR	98.6	95.7	3.0	181
Norway	NW	97.2	95.9	1.3	181
Sweden	SW	97.8	95.8	1.9	181
United States	US	99.6	95.7	3.9	180
Netherlands	NT	99.9	95.8	4.2	180
Canada	CA	96.4	95.9	0.5	179
France	FR	96.6	95.9	0.7	179
Ireland	IR	100.7	95.6	5.1	179
	Average	**98.6**	**95.8**	**2.8**	**180**
	Min	**96.4**	**95.6**	**0.5**	**179**
	Max	**100.7**	**95.9**	**5.1**	**182**
		Panel B. 50th quantile			
France	FR	122.9	82.4	40.5	181
Netherlands	NT	108.7	80.1	28.6	165
Spain	SP	106.5	79.7	26.7	162
Germany	GE	105.2	78.8	26.3	159
Italy	IT	105.1	79.1	26.0	157
United Kingdom	UK	99.3	78.3	21.1	150
Sweden	SW	91.9	76.5	15.4	144
Belgium	BG	84.1	75.5	8.6	137
Finland	FN	81.2	74.0	7.2	130
Switzerland	SZ	79.0	73.2	5.8	127
Austria	AT	74.9	71.8	3.1	123
United States	US	70.1	67.7	2.4	112
	Average	**94.1**	**76.4**	**17.6**	**146**
	Min	**70.1**	**67.7**	**2.4**	**112**
	Max	**122.9**	**82.4**	**40.5**	**181**
		Panel C. 5th quantile			
France	FR	112.9	91.9	21.0	177
Germany	GE	106.1	91.3	14.8	174
Italy	IT	107.1	91.4	15.7	172
Netherlands	NT	106.5	91.4	15.0	172
Spain	SP	106.4	91.4	15.0	172
Sweden	SW	102.7	91.0	11.7	171
United Kingdom	UK	106.1	91.4	14.7	170
Finland	FN	96.9	90.5	6.4	164
Switzerland	SZ	96.9	90.6	6.3	164
Belgium	BG	98.5	90.8	7.8	163
Austria	AT	96.5	90.5	6.1	158
Canada	CA	88.9	89.7	-0.8	155
	Average	**102.1**	**91.0**	**11.1**	**168**
	Min	**88.9**	**89.7**	**-0.8**	**155**
	Max	**112.9**	**91.9**	**21.0**	**177**

Notes: Spillover networks were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. At the country-level, the total system spillovers were 95.91%, 64.39% and 89.47% for quantiles 95%, 50% and 5%, respectively. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The means of the centrality measure were 170, 105 and 153 for quantiles 95%, 50% and 5%, respectively. Source: Authors.

Table 3. Top-20 more-connected banks in the global network.

Country	Bank	ID code	Spillover to others	Spillover from others	Net Spillover	Centrality
		Panel A. 95th quantile				
Austria	Erste Group Bank AG	AT01	96.6	98.9	-2.4	188
South Korea	Shinhan Financial Group Co Ltd	SK02	96.6	99.0	-2.4	187
United States	Fifth Third Bancorp	US05	100.9	98.9	2.0	186
United States	Huntington Bancshares Inc	US06	102.0	98.9	3.1	186
United States	JPMorgan Chase & Co (*)	US07	101.8	98.9	2.9	186
United States	Regions Financial Corp	US11	99.6	98.9	0.7	186
United States	The Bank of New York Mellon (*)	US15	97.8	99.0	-1.2	186
China	Ping An Bank Co Ltd	CH02	104.4	98.8	5.6	186
China	China Minsheng Banking Corp Ltd	CH04	101.0	98.9	2.1	186
Japan	Chiba Bank Ltd	JP01	97.1	98.9	-1.8	186
Japan	Sumitomo Mitsui Trust Holdings Inc	JP04	99.9	98.9	1.0	186
Japan	Shinsei Bank Ltd	JP05	100.4	98.9	1.5	186
Japan	Mizuho Financial Group Inc (*)	JP06	101.5	98.9	2.6	186
Greece	Attica Bank S.A.	GR01	101.3	98.9	2.4	186
Ireland	Permanent TSB Group Holdings PLC	IR01	99.8	98.9	0.8	186
Italy	Banca Mediolanum SpA	IT01	97.6	98.9	-1.4	186
Spain	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	98.6	98.9	-0.4	186
Sweden	Nordea Bank Abp	SW04	98.0	98.9	-1.0	186
United Kingdom	NatWest Group PLC	UK05	100.6	98.9	1.7	186
Brazil	Banco do Brasil SA	BR03	97.0	99.0	-1.9	185
		Panel B. 50th quantile				
United States	JPMorgan Chase & Co (*)	US07	126.1	91.9	34.2	125
United States	Bank of America Corporation (*)	US01	122.9	91.6	31.3	111
United States	Citigroup Inc	US02	117.7	91.1	26.6	111
United States	Comerica Inc	US03	123.8	91.5	32.4	109
Netherland	ING Groep N.V. (*)	NT01	122.2	91.2	31.0	107
Germany	Deutsche Bank AG (*)	GE01	107.5	90.7	16.9	106
Spain	Banco Santander S.A. (*)	SP01	123.2	91.4	31.8	102
United States	Wells Fargo & Company (*)	US13	118.7	91.3	27.4	101
France	BNP Paribas SA (*)	FR01	123.7	91.9	31.8	98
United States	U.S. Bancorp	US12	120.9	91.5	29.4	97
United States	Huntington Bancshares Inc	US06	118.3	91.1	27.2	96
United States	KeyCorp	US08	119.9	91.6	28.3	96
United States	Morgan Stanley (*)	US17	114.8	91.2	23.6	94
France	Societe Generale SA (*)	FR02	122.3	91.4	31.0	94
United States	PNC Financial Services Group Inc	US10	118.7	91.4	27.3	90
Italy	Intesa Sanpaolo S.p.A.	IT04	116.8	89.9	26.9	89
United States	Fifth Third Bancorp	US05	116.9	91.0	25.8	88
United States	Regions Financial Corp	US11	117.2	91.2	26.0	88
Spain	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	115.3	91.0	24.2	88
United States	Zions Bancorp NA	US14	115.3	90.9	24.3	86
		Panel C. 5th quantile				
Germany	Deutsche Bank AG (*)	GE01	108.2	96.8	11.4	139
Netherland	ING Groep N.V. (*)	NT01	111.1	96.8	14.4	136
France	BNP Paribas SA (*)	FR01	112.6	97.0	15.7	135
Spain	Banco Santander S.A. (*)	SP01	111.6	96.9	14.8	135
United Kingdom	Barclays PLC (*)	UK02	104.6	96.7	7.9	132
United States	Morgan Stanley (*)	US17	111.6	96.8	14.8	129
France	Societe Generale SA (*)	FR02	109.8	96.9	12.9	129
Canada	The Toronto-Dominion Bank (*)	CA07	104.0	96.4	7.6	128
Spain	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	108.8	96.8	12.1	128
United States	Goldman Sachs Group Inc (*)	US16	107.4	96.6	10.8	123
United States	Citigroup Inc (*)	US02	110.1	96.6	13.5	122
Germany	Commerzbank AG	GE02	104.2	96.5	7.7	122
United Kingdom	Lloyds Banking Group	UK03	102.3	96.4	5.8	121
Spain	Bankinter SA	SP03	104.0	96.6	7.4	120
France	Credit Agricole S.A. (*)	FR03	107.9	96.7	11.1	119
United Kingdom	HSBC Holdings (*)	UK01	99.5	96.5	3.0	119
Canada	Royal Bank of Canada (*)	CA08	102.6	96.4	6.2	118
United States	Bank of America Corporation (*)	US01	112.1	96.7	15.4	118
United States	Comerica Inc	US03	110.6	96.7	13.9	118
United States	JPMorgan Chase & Co (*)	US07	112.0	96.8	15.2	116

Notes: Spillover networks were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. At the bank-level, the total system spillovers were 98.92%, 87.43% and 96.17% for quantiles 95%, 50% and 5%, respectively. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The means of the centrality measure were 178, 57 and 83 for quantiles 95%, 50% and 5%, respectively. (*) Classified as Global Systemically Important Banks (G-SIBs) by the Financial Stability Board (2023). Source: Authors.

Table 4 shows the 12 least connected banking markets, and therefore, less vulnerable to the shocks transmission across different quantiles of interest. In each panel the markets are presented according to their centrality degree (increasing order). Throughout the quantiles, the banking markets of China, New Zealand, South Korea, Brazil, Australia, India, Russia, and to a lesser extent the markets of Japan, Ireland and Norway, are the least connected to the global network at country-level. Almost all of these markets are net shock receivers and transmit spillovers lower than the average of the entire system in each scenario, mainly in the 50% quantile. Even the average centrality degree for these 12 least connected markets in each quantile is below the system average, registering 159, 64, and 139 links in the 95%, 50%, and 5% quantiles, respectively. It is evident the lower levels of connectedness and intensity of spillovers provide these markets a lower vulnerability to shocks transmitted in the global banking system and make them important alternatives to diversify stock portfolios in this sector. Furthermore, the greater resilience of these markets facilitates the effectiveness of financial regulations aimed at mitigating shocks that threaten the financial stability. On the other hand, the banking markets of Italy, Spain, Switzerland, Denmark and Austria exhibit lower interconnectedness only in high-volatility scenarios (95% quantile), although somewhat higher than the linkages of the less vulnerable markets previously identified. This suggests that its potential benefit on portfolio diversification as well as its contribution to cushioning the effects of financial contagion in the banking industry are specifically linked to high-risk scenarios.

Table 5 presents the 20 commercial banks least connected to the global network according to centrality degree (increasing order) and for the different quantiles. Naturally, these banks are characterized by having lower levels of interconnectedness with the rest of the system, as well as transmitting and receiving the lowest spillovers within the network. We observe two specific facts that deserve to be discussed. First, in high-volatility scenarios (95% quantile), most of the banks least connected to the global network come from developed countries, and of them, 9 are classified as G-SIBs (BNP Paribas SA, HSBC Holdings, Standard Chartered PLC, Deutsche Bank AG, Royal Bank of Canada, Societe Generale SA, Citigroup Inc, Barclays PLC, Sumitomo Mitsui Financial Group Inc.). This contrasts with the 3 G-SIBs most connected to the network in the same quantile indicated in Table 3 (JPMorgan Chase & Co., The Bank of New York Mellon, Mizuho Financial Group Inc.). This fact corroborates the view that G-SIBs have global systemic importance in terms of capital adequacy, loss absorption capacity and supervision needs, which leads regulators to establish policies aimed at strengthening their financial position to face of crisis or high-risk scenarios. In these circumstances, various G-SIBs would offer greater guarantees about their operational functioning as well as important advantages to diversify banking portfolios in scenarios of high volatility and uncertainty in the markets. Second, in low-risk scenarios, the less connected banks configuration is concentrated in emerging market institutions. On the one hand, in a moderate-volatility scenario (50% quantile), Brazilian banks (Banco do Brasil SA, Banco Bradesco SA, Itau Unibanco Holding SA), South Korean banks (Jeju Bank, Industrial Bank of Korea, Shinhan Financial Group Co Ltd) and mainly Indians (IndusInd Bank Ltd., Kotak Mahindra Bank Ltd., State Bank of India, HDFC Bank Ltd., Axis Bank Ltd., ICICI Bank Ltd.) are the least vulnerable to the shocks transmission within the global network. On the other hand, in low-risk scenarios (5% quantile), the Chinese banks facilitate risk diversification because they are less connected within the global banking system.

Undoubtedly, this description helps investors establish more diversified and effective investment strategies within the banking industry. Appendices A2, A3 and A4 present the spillover and centrality statistics of all banks for the 95%, 50% and 5% quantiles, respectively.

Table 4. Top-12 less-connected markets in the banking network.

Country	ID code	Spillover to others	Spillover from others	Net Spillover	Centrality
		Panel A. 95th quantile			
China	CH	92.9	96.0	-3.0	157
New Zealand	NZ	92.3	96.1	-3.7	157
South Korea	SK	92.0	96.1	-4.1	157
Italy	IT	93.8	96.0	-2.1	157
Brazil	BR	94.1	96.0	-1.9	158
Australia	AU	93.7	96.0	-2.4	158
India	IN	91.6	96.1	-4.5	158
Russia	RU	92.3	96.1	-3.8	158
Spain	SP	90.5	96.2	-5.7	158
Switzerland	SZ	93.3	96.0	-2.7	158
Denmark	DN	95.5	95.9	-0.3	159
Austria	AT	96.3	95.9	0.3	174
	Average	**93.2**	**96.0**	**-2.8**	**159**
	Min	**90.5**	**95.9**	**-5.7**	**157**
	Max	**96.3**	**96.2**	**0.3**	**174**
		Panel B. 50th quantile			
China	CH	16.0	31.8	-15.8	26
Greece	GR	24.0	38.8	-14.9	39
South Korea	SK	22.9	43.3	-20.4	41
India	IN	28.4	46.6	-18.1	53
Japan	JP	23.3	54.7	-31.4	54
Brazil	BR	34.8	47.9	-13.0	62
New Zealand	NZ	30.5	59.4	-29.0	62
Russia	RU	33.5	49.5	-16.1	62
Ireland	IR	45.7	56.7	-11.0	79
Australia	AU	39.6	64.4	-24.8	82
Norway	NW	59.8	66.3	-6.5	100
Canada	CA	60.1	65.3	-5.2	103
	Average	**34.9**	**52.1**	**-17.2**	**64**
	Min	**16.0**	**31.8**	**-31.4**	**26**
	Max	**60.1**	**66.3**	**-5.2**	**103**
		Panel C. 5th quantile			
Greece	GR	60.8	84.7	-23.9	119
China	CH	61.4	85.4	-24.0	125
Russia	RU	73.3	87.3	-14.0	133
India	IN	76.9	88.1	-11.2	134
South Korea	SK	71.4	87.3	-15.9	134
Japan	JP	74.8	87.9	-13.1	137
Brazil	BR	78.2	88.2	-10.0	142
New Zealand	NZ	78.2	88.5	-10.3	142
Australia	AU	82.3	89.1	-6.8	145
Ireland	IR	81.2	88.7	-7.5	149
United States	US	90.7	89.9	0.8	154
Norway	NW	89.6	89.8	-0.1	155
	Average	**76.6**	**87.9**	**-11.3**	**139**
	Min	**60.8**	**84.7**	**-24.0**	**119**
	Max	**90.7**	**89.9**	**0.8**	**155**

Notes: Spillover networks were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. At the country-level, the total system spillovers were 95.91%, 64.39% and 89.47% for quantiles 95%, 50% and 5%, respectively. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The means of the centrality measure were 170, 105 and 153 for quantiles 95%, 50% and 5%, respectively. Source: Authors.

Table 5. Top-20 less-connected banks in the global network.

Country	Bank	ID code	Spillover to others	Spillover from others	Net Spillover	Centrality
		Panel A. 95th quantile				
Australia	Macquarie Group Ltd	AU07	91.1	99.0	-7.9	88
France	BNP Paribas SA (*)	FR01	93.5	99.0	-5.5	104
India	HDFC Bank Ltd	IN02	93.8	99.0	-5.2	107
Sweden	Svenska Handelsbanken AB	SW02	94.2	99.0	-4.8	119
United Kingdom	HSBC Holdings (*)	UK01	94.4	99.0	-4.6	132
United Kingdom	Standard Chartered PLC (*)	UK04	94.8	99.0	-4.2	144
Germany	Deutsche Bank AG (*)	GE01	94.8	99.0	-4.2	151
Italy	Mediobanca Banca di Credito Finanziario	IT05	94.8	99.0	-4.1	151
Ireland	Bank of Ireland Group PLC	IR02	95.5	99.0	-3.5	170
Australia	Australia & New Zealand Banking Group	AU02	95.6	98.9	-3.4	172
Sweden	Skandinaviska Enskilda Banken AB	SW01	95.8	98.9	-3.2	174
Sweden	Swedbank AB	SW03	95.8	99.0	-3.2	175
Canada	Canadian Imperial Bank of Commerce	CA03	96.0	98.9	-2.9	176
Canada	Royal Bank of Canada (*)	CA08	95.8	99.0	-3.2	176
France	Societe Generale SA (*)	FR02	95.9	99.0	-3.1	176
Canada	National Bank of Canada	CA06	95.9	99.0	-3.1	179
Italy	Intesa Sanpaolo S.p.A.	IT04	96.2	99.0	-2.7	179
United States	Citigroup Inc (*)	US02	96.1	98.9	-2.9	180
United Kingdom	Barclays PLC (*)	UK02	97.1	98.9	-1.9	180
Japan	Sumitomo Mitsui Financial Group Inc (*)	JP03	101.5	98.9	2.6	181
		Panel B. 50th quantile				
South Korea	Jeju Bank	SK03	52.7	76.9	-24.1	5
Greece	Attica Bank S.A.	GR01	53.1	75.4	-22.3	5
India	IndusInd Bank Ltd	IN05	57.0	83.2	-26.1	15
India	Kotak Mahindra Bank Ltd	IN01	61.4	84.3	-22.9	17
India	State Bank of India	IN04	60.0	83.8	-23.8	17
South Korea	Industrial Bank of Korea	SK01	55.6	83.9	-28.3	17
Ireland	Permanent TSB Group Holdings PLC	IR01	57.6	80.8	-23.2	18
Brazil	Banco do Brasil SA	BR03	65.2	84.6	-19.4	19
Russia	Sberbank of Russia PJSC	RU01	62.1	81.7	-19.6	19
Australia	Bank of Queensland Ltd	AU01	59.9	84.6	-24.7	21
India	HDFC Bank Ltd	IN02	60.9	85.1	-24.2	23
India	Axis Bank Ltd	IN06	65.2	84.3	-19.1	23
Australia	Bendigo & Adelaide Bank Ltd	AU06	60.4	84.1	-23.6	25
India	ICICI Bank Ltd	IN03	63.5	84.4	-20.9	25
South Korea	Shinhan Financial Group Co Ltd	SK02	56.0	85.4	-29.5	25
New Zealand	Australia & New Zealand Banking Group	NZ01	66.1	87.2	-21.1	26
New Zealand	Westpac Banking Corp	NZ02	65.0	86.4	-21.4	27
Brazil	Banco Bradesco SA	BR02	75.4	85.1	-9.7	28
Japan	Shinsei Bank Ltd	JP05	63.3	84.2	-20.9	28
Brazil	Itau Unibanco Holding SA	BR01	74.1	86.0	-11.9	30
		Panel C. 5th quantile				
China	Industrial and Commercial Bank of China (*)	CH07	76.9	94.9	-18.0	16
China	Bank of China (*)	CH06	75.6	94.8	-19.1	19
China	China Minsheng Banking Corp Ltd	CH04	80.4	95.0	-14.5	21
China	Shanghai Pudong Development Bank Co	CH03	82.2	95.1	-12.9	23
China	Huaxia Bank Co Ltd	CH05	82.8	95.2	-12.4	23
China	Ping An Bank Co Ltd	CH02	84.5	95.2	-10.7	24
China	China Merchants Bank Co Ltd	CH01	86.1	95.3	-9.2	25
India	State Bank of India	IN04	85.0	95.6	-10.6	42
India	ICICI Bank Ltd	IN03	87.3	95.6	-8.3	43
Japan	Shinsei Bank Ltd	JP05	84.6	95.6	-11.0	44
Japan	Resona Holdings Inc	JP07	87.5	96.0	-8.4	44
India	IndusInd Bank Ltd	IN05	83.7	95.4	-11.7	46
South Korea	Jeju Bank	SK03	70.1	94.2	-24.1	46
Australia	Westpac Banking Corporation	AU04	89.1	96.2	-7.2	47
India	Axis Bank Ltd	IN06	87.7	95.6	-7.9	47
Russia	Sberbank of Russia PJSC	RU01	83.4	95.3	-11.9	48
Australia	Commonwealth Bank of Australia	AU05	90.1	96.2	-6.1	50
Japan	Mizuho Financial Group Inc (*)	JP06	90.0	96.2	-6.2	50
Greece	Attica Bank S.A.	GR01	70.2	94.2	-23.9	52
Japan	Sumitomo Mitsui Financial Group Inc (*)	JP03	91.8	96.3	-4.6	53

Notes: Spillover networks were computed through QVAR(1). Spillover measures consider a KPPS *20*-step-ahead forecast error variance decomposition and a 250-days rolling-window. At the bank-level, the total system spillovers were 98.92%, 87.43% and 96.17% for quantiles 95%, 50% and 5%, respectively. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The means of the centrality measure were 178, 57 and 83 for quantiles 95%, 50% and 5%, respectively. (*) Classified as Global Systemically Important Banks (G-SIBs) by the Financial Stability Board (2023). Source: Authors.

5. Conclusions and discussion

During recent years, the banking connectedness literature has made important advances for understand the dynamics of the global banking market. However, two aspects that limited the practical and empirical scope of previous literature still had to be reconciled. On the one hand, several studies have focused on mean-conditional connectedness, ignoring the nature and structure of the links between banks in scenarios different to the mean, while other studies based on quantile interconnectedness have used banking sector indices or small samples of commercial banks in which it is not possible to extrapolate the systematic relevance of markets or banks within the global network across different scenarios.

Our research reconciles these knowledge gaps and provides a set of three novel results. First, global banking markets are closely interconnected over time and across different quantiles of the realized volatility distribution of bank stock prices. At country-level, the total spillovers were 95.91%, 64.39% and 89.47% in the 95%, 50% and 5% quantiles, respectively. In addition, the spillovers reached records of 98.92%, 87.43% and 96.17% for the same quantiles of the volatility distribution carried out at the level of the 96 commercial banks. Next, two other aspects emerge from these analyses: i) spillovers increase strongly during periods of crisis and financial stress such as the Global Financial Crisis, the Sovereign Debt Crisis in Europe, and particularly during the Covid-19 Pandemic, in which volatility spillovers increased drastically across all quantiles; and ii) banking spillovers, particularly at commercial bank-level, have evident geographical patterns in which the intense links within the European and North American markets stand out, and the lesser links of some Asian markets, especially the Chinese ones.

Second, we identify in each scenario (quantile) those markets and banks most connected to the global network. These markets are located in the central areas of the network across each quantile of interest and are characterized by being net shock transmitters as well as developing a high number of connections with other markets or banks. As a common aspect across the different quantiles, the banking markets of Belgium, the United Kingdom, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, and to a lesser extent those of Austria and Switzerland make up the set of most important markets for risk transmission within the global network. After them, the banking markets of the United States and Canada play a secondary role on financial contagion. However, this configuration is somewhat more heterogeneous at commercial bank-level. The greater presence of US banks within the set of the most connected banks across the different quantiles stands out in this configuration. Along with them, other commercial banks from Austria, the Netherlands, Japan, France, Germany, Spain and the United Kingdom are relevant for shocks transmission, mainly those categorized as G-SIBs. JPMorgan Chase & Co., Bank of America Corp., Citigroup Inc., Wells Fargo & Company, BNP Paribas, Morgan Stanley SA, Societe Generale SA, Deutsche Bank AG., ING Groep N.V. and Banco Santander S.A., stand out as the most connected G-SIBs in moderate and low volatility scenarios. This description suggests that financial regulations aimed at mitigating shocks and attenuating threats to a country's banking stability can be adapted to different risk scenarios.

Third, the banking markets of China, New Zealand, South Korea, Brazil, Australia, India, Russia, and to a lesser extent the markets of Japan, Ireland and Norway have been identified as the least connected to the global banking system. These markets are located in

the external areas of the network and transmit the lowest spillovers of the entire system in each scenario, mainly in the 50% quantile. At the commercial bank-level, and particularly in moderate and low risk scenarios, the configuration of less connected banks is concentrated in emerging market institutions such as Banco do Brasil SA, Banco Bradesco SA, Itau Unibanco Holding SA, Jeju Bank, Industrial Bank of Korea, Shinhan Financial Group Co Ltd., IndusInd Bank Ltd., Kotak Mahindra Bank Ltd., State Bank of India, HDFC Bank Ltd., Axis Bank Ltd., ICICI Bank Ltd., and some Chinese banks. However, in high-volatility scenarios, most of the banks less connected to the global network come from developed countries, and within them, 9 G-SIBs stand out (BNP Paribas SA, HSBC Holdings, Standard Chartered PLC, Deutsche Bank AG, Royal Bank of Canada, Societe Generale SA, Citigroup Inc, Barclays PLC, Sumitomo Mitsui Financial Group Inc.). These markets, and especially the commercial banks described, provide an important set of alternatives that investors can choose to diversify banking portfolios, and reveal the diversifying potential of G-SIBs in high-risk scenarios as well as their greater systemic relevance on the interconnectedness in scenarios of lower uncertainty.

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Appendix

Appendix A1. Descriptive statistics: stock volatility by banks.

Country	Name	ID	Mean	St. Dev.	Max	ADF Statistic
Panel A. America						
Brazil	Itau Unibanco Holding SA	BR01	1.50	1.52	21.00	-8.55***
	Banco Bradesco SA	BR02	1.53	1.56	19.99	-9.64***
	Banco do Brasil SA	BR03	1.79	1.90	23.79	-10.19***
Canada	Bank of Montreal	CA01	0.86	1.13	17.93	-8.46***
	The Bank of Nova Scotia	CA02	0.85	1.09	14.70	-8.94***
	Canadian Imperial Bank of Commerce	CA03	0.86	1.15	17.28	-7.98***
	Canadian Western Bank	CA04	1.19	1.40	17.67	-8.50***
	Laurentian Bank of Canada	CA05	0.96	1.24	23.61	-9.46***
	National Bank of Canada	CA06	0.87	1.18	18.34	-8.96***
	The Toronto-Dominion Bank (*)	CA07	0.83	1.06	16.45	-9.13***
	Royal Bank of Canada (*)	CA08	0.84	1.07	14.44	-9.32***
United States	Bank of America Corporation (*)	US01	1.68	2.48	34.21	-6.83***
	Citigroup Inc (*)	US02	1.72	2.65	49.47	-8.09***
	Comerica Inc	US03	1.72	2.15	32.39	-7.76***
	First Horizon Corporation	US04	1.68	2.38	44.11	-8.85***
	Fifth Third Bancorp	US05	1.82	2.91	57.32	-7.28***
	Huntington Bancshares Inc	US06	1.85	2.91	40.60	-6.08***
	JPMorgan Chase & Co (*)	US07	1.39	1.87	23.23	-7.47***
	KeyCorp	US08	1.82	2.57	43.34	-7.80***
	M&T Bank Corp	US09	1.38	1.70	22.39	-7.77***
	PNC Financial Services Group Inc	US10	1.41	1.99	53.44	-7.28***
	Regions Financial Corp	US11	1.92	2.73	52.88	-7.52***
	U.S. Bancorp	US12	1.29	1.76	20.57	-6.59***
	Wells Fargo & Company (*)	US13	1.48	2.10	28.34	-6.49***
	Zions Bancorp NA	US14	1.88	2.43	29.74	-7.36***
	The Bank of New York Mellon (*)	US15	1.38	1.82	31.69	-8.13***
	Goldman Sachs Group Inc (*)	US16	1.42	1.71	23.48	-8.15***
	Morgan Stanley (*)	US17	1.70	2.41	62.59	-7.95***
	State Street Corp (*)	US18	1.58	2.40	89.25	-8.44***
Panel B. Asia Pacific and Oceania						
Australia	Bank of Queensland Ltd	AU01	1.23	1.30	13.90	-9.53***
	Australia & New Zealand Banking Group Ltd	AU02	1.08	1.22	13.65	-9.15***
	National Australia Bank Limited	AU03	1.08	1.21	16.00	-8.67***
	Westpac Banking Corporation	AU04	1.07	1.16	12.57	-9.04***
	Commonwealth Bank of Australia	AU05	0.98	1.07	12.45	-9.24***
	Bendigo & Adelaide Bank Ltd	AU06	1.23	1.38	25.52	-9.77***
	Macquarie Group Ltd	AU07	1.40	1.69	32.07	-8.28***
China	China Merchants Bank Co Ltd	CH01	1.42	1.56	10.55	-10.22***
	Ping An Bank Co Ltd	CH02	1.54	1.76	10.57	-10.49***
	Shanghai Pudong Development Bank Co Ltd	CH03	1.29	1.61	10.56	-9.71***
	China Minsheng Banking Corp Ltd	CH04	1.18	1.50	10.53	-11.12***
	Huaxia Bank Co Ltd	CH05	1.30	1.68	23.48	-10.28***
	Bank of China (*)	CH06	0.97	1.27	11.63	-9.52***
	Industrial and Commercial Bank of China Ltd (*)	CH07	0.98	1.22	10.75	-10.43***
India	Kotak Mahindra Bank Ltd	IN01	1.53	1.76	23.63	-8.89***
	HDFC Bank Ltd	IN02	1.18	1.32	15.10	-9.10***
	ICICI Bank Ltd	IN03	1.62	1.78	22.13	-8.48***
	State Bank of India	IN04	1.56	1.60	24.44	-11.00***
	IndusInd Bank Ltd	IN05	1.83	2.19	36.93	-9.68***
	Axis Bank Ltd	IN06	1.68	1.83	32.73	-9.21***
Japan	Chiba Bank Ltd	JP01	1.39	1.44	18.11	-9.96***
	Mitsubishi UFJ Financial Group Inc (*)	JP02	1.41	1.50	16.86	-9.81***
	Sumitomo Mitsui Financial Group Inc (*)	JP03	1.38	1.56	16.38	-8.86***
	Sumitomo Mitsui Trust Holdings Inc	JP04	1.50	1.66	17.05	-9.80***
	Shinsei Bank Ltd	JP05	1.69	1.88	20.59	-9.86***
	Mizuho Financial Group Inc (*)	JP06	1.29	1.57	16.74	-8.77***
	Resona Holdings Inc	JP07	1.46	1.63	17.84	-9.90***
New Zealand	Australia & New Zealand Banking Group Ltd	NZ01	1.16	1.25	15.14	-8.69***
	Westpac Banking Corp	NZ02	1.16	1.17	11.09	-9.76***
South Korea	Industrial Bank of Korea	SK01	1.35	1.54	16.14	-8.75***
	Shinhan Financial Group Co Ltd	SK02	1.34	1.42	16.20	-8.70***
	Jeju Bank	SK03	1.29	2.05	26.74	-8.77***

Panel C. Europe

Austria	Erste Group Bank AG	AT01	1.76	2.02	20.00	-8.24***
Belgium	KBC Group NV	BG01	1.84	2.42	40.48	-9.00***
Denmark	Danske Bank A/S	DN01	1.38	1.49	17.19	-9.02***
Finland	Nordea Bank Abp	FN01	1.37	1.55	18.17	-8.71***
France	BNP Paribas SA (*)	FR01	1.61	1.79	19.12	-8.52***
	Societe Generale SA (*)	FR02	1.83	2.06	23.03	-8.72***
	Credit Agricole S.A. (*)	FR03	1.70	1.88	23.36	-8.23***
Germany	Deutsche Bank AG (*)	GE01	1.73	1.87	22.52	-7.80***
	Commerzbank AG	GE02	2.11	2.31	28.82	-8.28***
Greece	Attica Bank S.A.	GR01	3.32	4.65	54.00	-11.24***
Ireland	Permanent TSB Group Holdings PLC	IR01	3.20	4.89	97.94	-9.35***
	Bank of Ireland Group PLC	IR02	2.53	3.46	79.11	-8.99***
	AIB Group PLC	IR03	2.86	3.84	88.24	-10.27***
Italy	Banca Mediolanum SpA	IT01	1.51	1.53	16.31	-10.31***
	BPER Banca	IT02	1.82	1.98	28.25	-9.71***
	UniCredit SpA	IT03	1.96	2.13	27.17	-8.92***
	Intesa Sanpaolo S.p.A.	IT04	1.63	1.83	26.06	-8.68***
	Mediobanca Banca di Credito Finanziario SpA	IT05	1.46	1.54	23.85	-10.07***
Netherland	ING Groep N.V. (*)	NT01	1.75	2.22	32.14	-8.10***
Norway	DNB Bank ASA	NW01	1.38	1.68	21.11	-7.22***
Russia	Sberbank of Russia PJSC	RU01	1.66	2.27	61.64	-9.49***
Spain	Banco Santander S.A. (*)	SP01	1.53	1.62	22.17	-9.37***
	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	1.51	1.60	19.91	-9.46***
	Bankinter SA	SP03	1.56	1.56	18.15	-10.07***
	Banco de Sabadell SA	SP04	1.59	1.77	21.99	-11.34***
Sweden	Skandinaviska Enskilda Banken AB	SW01	1.36	1.60	18.55	-8.54***
	Svenska Handelsbanken AB	SW02	1.14	1.21	11.07	-8.58***
	Swedbank AB	SW03	1.41	1.75	20.54	-7.91***
	Nordea Bank Abp	SW04	1.27	1.43	14.92	-9.16***
Switzerland	UBS Group AG (*)	SZ01	1.51	1.82	27.70	-7.58***
United Kingdom	HSBC Holdings (*)	UK01	1.11	1.28	20.80	-8.37***
	Barclays PLC (*)	UK02	1.77	2.31	54.95	-8.73***
	Lloyds Banking Group	UK03	1.67	2.36	41.46	-7.71***
	Standard Chartered PLC (*)	UK04	1.55	1.79	26.24	-9.29***
	NatWest Group PLC	UK05	1.86	2.81	109.57	-9.82***

Note: ADF is the Augmented Dickey-Fuller test. This test only considers the random walk specification. Superscripts ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. (*) Classified as Global Systemically Important Banks (G-SIBs) by the Financial Stability Board (2023). Source: Authors.

Appendix A2. Spillovers and centrality statistics for 95th quantile.

Country	Name	ID	Directional spillover			Centrality
			To others	From others	Net	
Panel A. America						
Brazil	Itau Unibanco Holding SA	BR01	97.2	98.9	-1.7	184
	Banco Bradesco SA	BR02	97.8	98.9	-1.2	183
	Banco do Brasil SA	BR03	97.0	99.0	-1.9	185
Canada	Bank of Montreal	CA01	100.7	98.9	1.8	183
	The Bank of Nova Scotia	CA02	98.8	98.9	-0.1	184
	Canadian Imperial Bank of Commerce	CA03	96.0	98.9	-2.9	176
	Canadian Western Bank	CA04	100.6	98.9	1.7	185
	Laurentian Bank of Canada	CA05	101.7	98.9	2.8	183
	National Bank of Canada	CA06	95.9	99.0	-3.1	179
	The Toronto-Dominion Bank (*)	CA07	99.6	98.9	0.7	183
	Royal Bank of Canada (*)	CA08	95.8	99.0	-3.2	176
United States	Bank of America Corporation (*)	US01	102.3	98.9	3.4	184
	Citigroup Inc (*)	US02	96.1	98.9	-2.9	180
	Comerica Inc	US03	102.5	98.9	3.6	183
	First Horizon Corporation	US04	102.3	98.9	3.5	183
	Fifth Third Bancorp	US05	100.9	98.9	2.0	186
	Huntington Bancshares Inc	US06	102.0	98.9	3.1	186
	JPMorgan Chase & Co (*)	US07	101.8	98.9	2.9	186
	KeyCorp	US08	99.3	98.9	0.4	182
	M&T Bank Corp	US09	102.4	98.9	3.5	185
	PNC Financial Services Group Inc	US10	101.0	98.9	2.1	184
	Regions Financial Corp	US11	99.6	98.9	0.7	186
	U.S. Bancorp	US12	99.4	98.9	0.5	184
	Wells Fargo & Company (*)	US13	99.8	98.9	0.8	185
	Zions Bancorp NA	US14	100.6	98.9	1.7	185
	The Bank of New York Mellon (*)	US15	97.8	99.0	-1.2	186
	Goldman Sachs Group Inc (*)	US16	101.4	98.9	2.6	182
	Morgan Stanley (*)	US17	98.5	98.9	-0.4	184
	State Street Corp (*)	US18	99.0	98.9	0.1	185
	Regional average		**99.6**	**98.9**	**0.7**	**183**
Panel B. Asia Pacific and Oceania						
Australia	Bank of Queensland Ltd	AU01	98.5	98.9	-0.4	182
	Australia & New Zealand Banking Group Ltd	AU02	95.6	98.9	-3.4	172
	National Australia Bank Limited	AU03	97.1	98.9	-1.8	185
	Westpac Banking Corporation	AU04	100.3	98.9	1.4	185
	Commonwealth Bank of Australia	AU05	100.4	98.9	1.5	184
	Bendigo & Adelaide Bank Ltd	AU06	98.5	98.9	-0.4	185
	Macquarie Group Ltd	AU07	91.1	99.0	-7.9	88
China	China Merchants Bank Co Ltd	CH01	102.6	98.9	3.7	182
	Ping An Bank Co Ltd	CH02	104.4	98.8	5.6	186
	Shanghai Pudong Development Bank Co Ltd	CH03	105.6	98.9	6.7	184
	China Minsheng Banking Corp Ltd	CH04	101.0	98.9	2.1	186
	Huaxia Bank Co Ltd	CH05	101.8	98.9	2.9	184
	Bank of China (*)	CH06	107.6	98.8	8.8	182
	Industrial and Commercial Bank of China Ltd (*)	CH07	107.1	98.8	8.3	185
India	Kotak Mahindra Bank Ltd	IN01	97.6	99.0	-1.4	185
	HDFC Bank Ltd	IN02	93.8	99.0	-5.2	107
	ICICI Bank Ltd	IN03	99.2	98.9	0.3	182
	State Bank of India	IN04	97.6	98.9	-1.4	184
	IndusInd Bank Ltd	IN05	100.7	98.9	1.8	183
	Axis Bank Ltd	IN06	101.1	98.9	2.2	182
Japan	Chiba Bank Ltd	JP01	97.1	98.9	-1.8	186
	Mitsubishi UFJ Financial Group Inc (*)	JP02	102.5	98.9	3.6	183
	Sumitomo Mitsui Financial Group Inc (*)	JP03	101.5	98.9	2.6	181
	Sumitomo Mitsui Trust Holdings Inc	JP04	99.9	98.9	1.0	186
	Shinsei Bank Ltd	JP05	100.4	98.9	1.5	186
	Mizuho Financial Group Inc (*)	JP06	101.5	98.9	2.6	186
	Resona Holdings Inc	JP07	102.1	98.9	3.1	184
New Zealand	Australia & New Zealand Banking Group Ltd	NZ01	96.4	99.0	-2.6	181
	Westpac Banking Corp	NZ02	99.8	98.9	0.9	185
South Korea	Industrial Bank of Korea	SK01	96.9	99.0	-2.0	184
	Shinhan Financial Group Co Ltd	SK02	96.6	99.0	-2.4	187
	Jeju Bank	SK03	102.6	98.9	3.7	185
	Regional average		**100.0**	**98.9**	**1.1**	**178**

Panel C. Europe

Austria	Erste Group Bank AG	AT01	96.6	98.9	-2.4	188
Belgium	KBC Group NV	BG01	96.1	99.0	-2.8	181
Denmark	Danske Bank A/S	DN01	100.3	98.9	1.4	184
Finland	Nordea Bank Abp	FN01	96.1	98.9	-2.9	182
France	BNP Paribas SA (*)	FR01	93.5	99.0	-5.5	104
	Societe Generale SA (*)	FR02	95.9	99.0	-3.1	176
	Credit Agricole S.A. (*)	FR03	97.6	98.9	-1.4	183
Germany	Deutsche Bank AG (*)	GE01	94.8	99.0	-4.2	151
	Commerzbank AG	GE02	100.6	98.9	1.7	185
Greece	Attica Bank S.A.	GR01	101.3	98.9	2.4	186
Ireland	Permanent TSB Group Holdings PLC	IR01	99.8	98.9	0.8	186
	Bank of Ireland Group PLC	IR02	95.5	99.0	-3.5	170
	AIB Group PLC	IR03	98.8	98.9	-0.1	183
Italy	Banca Mediolanum SpA	IT01	97.6	98.9	-1.4	186
	BPER Banca	IT02	101.0	98.9	2.1	183
	UniCredit SpA	IT03	97.6	98.9	-1.3	184
	Intesa Sanpaolo S.p.A.	IT04	96.2	99.0	-2.7	179
	Mediobanca Banca di Credito Finanziario SpA	IT05	94.8	99.0	-4.1	151
Netherland	ING Groep N.V. (*)	NT01	97.2	98.9	-1.8	182
Norway	DNB Bank ASA	NW01	98.0	98.9	-0.9	182
Russia	Sberbank of Russia PJSC	RU01	98.4	98.9	-0.5	185
Spain	Banco Santander S.A. (*)	SP01	97.2	99.0	-1.7	185
	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	98.6	98.9	-0.4	186
	Bankinter SA	SP03	97.9	99.0	-1.1	185
	Banco de Sabadell SA	SP04	100.5	98.9	1.6	184
Sweden	Skandinaviska Enskilda Banken AB	SW01	95.8	98.9	-3.2	174
	Svenska Handelsbanken AB	SW02	94.2	99.0	-4.8	119
	Swedbank AB	SW03	95.8	99.0	-3.2	175
	Nordea Bank Abp	SW04	98.0	98.9	-1.0	186
Switzerland	UBS Group AG (*)	SZ01	97.3	99.0	-1.6	185
United Kingdom	HSBC Holdings (*)	UK01	94.4	99.0	-4.6	132
	Barclays PLC (*)	UK02	97.1	98.9	-1.9	180
	Lloyds Banking Group	UK03	100.2	98.9	1.3	182
	Standard Chartered PLC (*)	UK04	94.8	99.0	-4.2	144
	NatWest Group PLC	UK05	100.6	98.9	1.7	186
	Regional average		**97.4**	**98.9**	**-1.5**	**174**
	Full sample average		**98.9**	**98.9**	**0.0**	**178**

Note: Spillover effects computed from QVAR(1) and consider a KPPS 20-step-ahead forecast error variance decomposition. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. (*) Classified as Global Systemically Important Banks (G-SIBs) by the Financial Stability Board (2023). Source: Authors.

Appendix A3. Spillovers and centrality statistics for 50th quantile.

Country	Name	ID	Directional spillover			Centrality
			To others	From others	Net	
Panel A. America						
Brazil	Itau Unibanco Holding SA	BR01	74.1	86.0	-11.9	30
	Banco Bradesco SA	BR02	75.4	85.1	-9.7	28
	Banco do Brasil SA	BR03	65.2	84.6	-19.4	19
Canada	Bank of Montreal	CA01	92.7	87.6	5.1	56
	The Bank of Nova Scotia	CA02	93.9	88.4	5.5	63
	Canadian Imperial Bank of Commerce	CA03	87.4	87.2	0.2	47
	Canadian Western Bank	CA04	68.2	84.8	-16.6	35
	Laurentian Bank of Canada	CA05	65.2	82.5	-17.2	32
	National Bank of Canada	CA06	78.2	86.6	-8.4	45
	The Toronto-Dominion Bank (*)	CA07	94.4	88.0	6.4	61
	Royal Bank of Canada (*)	CA08	89.0	88.6	0.4	54
United States	Bank of America Corporation (*)	US01	122.9	91.6	31.3	111
	Citigroup Inc (*)	US02	117.7	91.1	26.6	111
	Comerica Inc	US03	123.8	91.5	32.4	109
	First Horizon Corporation	US04	105.8	88.5	17.4	73
	Fifth Third Bancorp	US05	116.9	91.0	25.8	88
	Huntington Bancshares Inc	US06	118.3	91.1	27.2	96
	JPMorgan Chase & Co (*)	US07	126.1	91.9	34.2	125
	KeyCorp	US08	119.9	91.6	28.3	96
	M&T Bank Corp	US09	111.6	90.5	21.1	80
	PNC Financial Services Group Inc	US10	118.7	91.4	27.3	90
	Regions Financial Corp	US11	117.2	91.2	26.0	88
	U.S. Bancorp	US12	120.9	91.5	29.4	97
	Wells Fargo & Company (*)	US13	118.7	91.3	27.4	101
	Zions Bancorp NA	US14	115.3	90.9	24.3	86
	The Bank of New York Mellon (*)	US15	105.3	90.2	15.2	79
	Goldman Sachs Group Inc (*)	US16	106.7	90.4	16.3	74
	Morgan Stanley (*)	US17	114.8	91.2	23.6	94
	State Street Corp (*)	US18	103.8	89.7	14.1	77
	Regional average		**102.4**	**89.2**	**13.2**	**74**
Panel B. Asia Pacific and Oceania						
Australia	Bank of Queensland Ltd	AU01	59.9	84.6	-24.7	21
	Australia & New Zealand Banking Group Ltd	AU02	75.4	88.0	-12.6	37
	National Australia Bank Limited	AU03	71.9	87.2	-15.3	31
	Westpac Banking Corporation	AU04	76.8	87.9	-11.1	37
	Commonwealth Bank of Australia	AU05	68.5	86.9	-18.3	31
	Bendigo & Adelaide Bank Ltd	AU06	60.4	84.1	-23.6	25
	Macquarie Group Ltd	AU07	64.9	87.5	-22.6	43
China	China Merchants Bank Co Ltd	CH01	70.8	84.7	-14.0	42
	Ping An Bank Co Ltd	CH02	70.6	83.8	-13.1	40
	Shanghai Pudong Development Bank Co Ltd	CH03	70.7	83.9	-13.3	46
	China Minsheng Banking Corp Ltd	CH04	72.1	83.2	-11.1	47
	Huaxia Bank Co Ltd	CH05	71.7	83.8	-12.1	48
	Bank of China (*)	CH06	68.5	81.5	-13.0	38
	Industrial and Commercial Bank of China Ltd (*)	CH07	65.1	81.7	-16.5	37
India	Kotak Mahindra Bank Ltd	IN01	61.4	84.3	-22.9	17
	HDFC Bank Ltd	IN02	60.9	85.1	-24.2	23
	ICICI Bank Ltd	IN03	63.5	84.4	-20.9	25
	State Bank of India	IN04	60.0	83.8	-23.8	17
	IndusInd Bank Ltd	IN05	57.0	83.2	-26.1	15
	Axis Bank Ltd	IN06	65.2	84.3	-19.1	23
Japan	Chiba Bank Ltd	JP01	66.9	87.3	-20.4	36
	Mitsubishi UFJ Financial Group Inc (*)	JP02	74.3	88.4	-14.1	53
	Sumitomo Mitsui Financial Group Inc (*)	JP03	75.5	88.4	-12.9	48
	Sumitomo Mitsui Trust Holdings Inc	JP04	72.9	87.7	-14.9	38
	Shinsei Bank Ltd	JP05	63.3	84.2	-20.9	28
	Mizuho Financial Group Inc (*)	JP06	75.9	87.9	-12.0	41
	Resona Holdings Inc	JP07	68.8	86.7	-17.9	31
New Zealand	Australia & New Zealand Banking Group Ltd	NZ01	66.1	87.2	-21.1	26
	Westpac Banking Corp	NZ02	65.0	86.4	-21.4	27
South Korea	Industrial Bank of Korea	SK01	55.6	83.9	-28.3	17
	Shinhan Financial Group Co Ltd	SK02	56.0	85.4	-29.5	25
	Jeju Bank	SK03	52.7	76.9	-24.1	5
	Regional average		**66.5**	**85.1**	**-18.6**	**32**

Panel C. Europe

Austria	Erste Group Bank AG	AT01	91.8	88.3	3.5	66
Belgium	KBC Group NV	BG01	101.5	89.9	11.6	73
Denmark	Danske Bank A/S	DN01	81.8	86.9	-5.1	55
Finland	Nordea Bank Abp	FN01	98.1	89.5	8.6	79
France	BNP Paribas SA (*)	FR01	123.7	91.9	31.8	98
	Societe Generale SA (*)	FR02	122.3	91.4	31.0	94
	Credit Agricole S.A. (*)	FR03	111.7	90.7	21.0	85
Germany	Deutsche Bank AG (*)	GE01	107.5	90.7	16.9	106
	Commerzbank AG	GE02	102.7	89.4	13.3	77
Greece	Attica Bank S.A.	GR01	53.1	75.4	-22.3	5
Ireland	Permanent TSB Group Holdings PLC	IR01	57.6	80.8	-23.2	18
	Bank of Ireland Group PLC	IR02	79.1	86.7	-7.6	48
	AIB Group PLC	IR03	70.9	83.6	-12.6	33
Italy	Banca Mediolanum SpA	IT01	83.7	88.1	-4.5	58
	BPER Banca	IT02	86.1	87.7	-1.6	55
	UniCredit SpA	IT03	113.3	90.4	22.9	81
	Intesa Sanpaolo S.p.A.	IT04	116.8	89.9	26.9	89
	Mediobanca Banca di Credito Finanziario SpA	IT05	101.0	89.4	11.6	72
Netherland	ING Groep N.V. (*)	NT01	122.2	91.2	31.0	107
Norway	DNB Bank ASA	NW01	80.3	86.5	-6.2	48
Russia	Sberbank of Russia PJSC	RU01	62.1	81.7	-19.6	19
Spain	Banco Santander S.A. (*)	SP01	123.2	91.4	31.8	102
	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	115.3	91.0	24.2	88
	Bankinter SA	SP03	94.3	89.3	4.9	70
	Banco de Sabadell SA	SP04	93.0	88.1	4.9	64
Sweden	Skandinaviska Enskilda Banken AB	SW01	85.7	87.7	-2.0	60
	Svenska Handelsbanken AB	SW02	76.7	87.1	-10.4	44
	Swedbank AB	SW03	85.8	87.4	-1.5	56
	Nordea Bank Abp	SW04	99.0	89.1	9.8	77
Switzerland	UBS Group AG (*)	SZ01	95.3	88.6	6.7	67
United Kingdom	HSBC Holdings (*)	UK01	81.9	88.5	-6.5	59
	Barclays PLC (*)	UK02	105.7	90.1	15.6	75
	Lloyds Banking Group	UK03	96.2	88.5	7.8	76
	Standard Chartered PLC (*)	UK04	83.7	87.8	-4.1	62
	NatWest Group PLC	UK05	93.3	87.9	5.4	69
	Regional average		**94.2**	**88.1**	**6.1**	**67**
	Full sample average		**87.4**	**87.4**	**0.0**	**57**

Note: Spillover effects computed from QVAR(1) and consider a KPPS 20-step-ahead forecast error variance decomposition. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. (*) Classified as Global Systemically Important Banks (G-SIBs) by the Financial Stability Board (2023). Source: Authors.

Appendix A4. Spillovers and centrality statistics for 5th quantile.

Country	Name	ID	Directional spillover			Centrality
			To others	From others	Net	
Panel A. America						
Brazil	Itau Unibanco Holding SA	BR01	95.0	96.0	-1.0	81
	Banco Bradesco SA	BR02	93.2	95.8	-2.6	67
	Banco do Brasil SA	BR03	91.1	95.8	-4.6	65
Canada	Bank of Montreal	CA01	98.8	96.3	2.5	90
	The Bank of Nova Scotia	CA02	102.7	96.4	6.3	112
	Canadian Imperial Bank of Commerce	CA03	97.3	96.2	1.1	84
	Canadian Western Bank	CA04	89.1	96.0	-6.9	56
	Laurentian Bank of Canada	CA05	81.5	95.6	-14.1	57
	National Bank of Canada	CA06	95.1	96.3	-1.1	76
	The Toronto-Dominion Bank (*)	CA07	104.0	96.4	7.6	128
	Royal Bank of Canada (*)	CA08	102.6	96.4	6.2	118
United States	Bank of America Corporation (*)	US01	112.1	96.7	15.4	118
	Citigroup Inc (*)	US02	110.1	96.6	13.5	122
	Comerica Inc	US03	110.6	96.7	13.9	118
	First Horizon Corporation	US04	101.2	96.1	5.1	60
	Fifth Third Bancorp	US05	107.5	96.6	10.9	95
	Huntington Bancshares Inc	US06	107.3	96.6	10.7	97
	JPMorgan Chase & Co (*)	US07	112.0	96.8	15.2	116
	KeyCorp	US08	107.3	96.7	10.5	90
	M&T Bank Corp	US09	105.0	96.6	8.4	81
	PNC Financial Services Group Inc	US10	110.2	96.7	13.4	109
	Regions Financial Corp	US11	108.9	96.8	12.1	109
	U.S. Bancorp	US12	110.0	96.8	13.2	113
	Wells Fargo & Company (*)	US13	109.0	96.7	12.3	113
	Zions Bancorp NA	US14	109.0	96.6	12.4	115
	The Bank of New York Mellon (*)	US15	103.5	96.5	7.0	86
	Goldman Sachs Group Inc (*)	US16	107.4	96.6	10.8	123
	Morgan Stanley (*)	US17	111.6	96.8	14.8	129
	State Street Corp (*)	US18	103.1	96.4	6.7	91
	Regional average		**103.3**	**96.4**	**6.9**	**97**
Panel B. Asia Pacific and Oceania						
Australia	Bank of Queensland Ltd	AU01	83.5	95.9	-12.4	62
	Australia & New Zealand Banking Group Ltd	AU02	91.0	96.4	-5.4	57
	National Australia Bank Limited	AU03	89.2	96.3	-7.1	54
	Westpac Banking Corporation	AU04	89.1	96.2	-7.2	47
	Commonwealth Bank of Australia	AU05	90.1	96.2	-6.1	50
	Bendigo & Adelaide Bank Ltd	AU06	81.0	95.9	-14.9	56
	Macquarie Group Ltd	AU07	88.7	96.4	-7.7	85
China	China Merchants Bank Co Ltd	CH01	86.1	95.3	-9.2	25
	Ping An Bank Co Ltd	CH02	84.5	95.2	-10.7	24
	Shanghai Pudong Development Bank Co Ltd	CH03	82.2	95.1	-12.9	23
	China Minsheng Banking Corp Ltd	CH04	80.4	95.0	-14.5	21
	Huaxia Bank Co Ltd	CH05	82.8	95.2	-12.4	23
	Bank of China (*)	CH06	75.6	94.8	-19.1	19
	Industrial and Commercial Bank of China Ltd (*)	CH07	76.9	94.9	-18.0	16
India	Kotak Mahindra Bank Ltd	IN01	87.4	95.7	-8.3	61
	HDFC Bank Ltd	IN02	88.8	95.8	-6.9	56
	ICICI Bank Ltd	IN03	87.3	95.6	-8.3	43
	State Bank of India	IN04	85.0	95.6	-10.6	42
	IndusInd Bank Ltd	IN05	83.7	95.4	-11.7	46
	Axis Bank Ltd	IN06	87.7	95.6	-7.9	47
Japan	Chiba Bank Ltd	JP01	88.8	96.1	-7.3	57
	Mitsubishi UFJ Financial Group Inc (*)	JP02	90.8	96.3	-5.5	57
	Sumitomo Mitsui Financial Group Inc (*)	JP03	91.8	96.3	-4.6	53
	Sumitomo Mitsui Trust Holdings Inc	JP04	88.7	96.2	-7.5	53
	Shinsei Bank Ltd	JP05	84.6	95.6	-11.0	44
	Mizuho Financial Group Inc (*)	JP06	90.0	96.2	-6.2	50
	Resona Holdings Inc	JP07	87.5	96.0	-8.4	44
New Zealand	Australia & New Zealand Banking Group Ltd	NZ01	88.7	96.4	-7.7	68
	Westpac Banking Corp	NZ02	88.5	96.2	-7.7	62
South Korea	Industrial Bank of Korea	SK01	84.8	95.8	-10.9	67
	Shinhan Financial Group Co Ltd	SK02	85.5	95.9	-10.4	77
	Jeju Bank	SK03	70.1	94.2	-24.1	46
	Regional average		**85.6**	**95.7**	**-10.1**	**48**

Panel C. Europe

Austria	Erste Group Bank AG	AT01	102.3	96.4	5.9	107
Belgium	KBC Group NV	BG01	103.4	96.6	6.7	111
Denmark	Danske Bank A/S	DN01	96.2	96.3	-0.1	92
Finland	Nordea Bank Abp	FN01	101.5	96.5	4.9	99
France	BNP Paribas SA (*)	FR01	112.6	97.0	15.7	135
	Societe Generale SA (*)	FR02	109.8	96.9	12.9	129
	Credit Agricole S.A. (*)	FR03	107.9	96.7	11.1	119
Germany	Deutsche Bank AG (*)	GE01	108.2	96.8	11.4	139
	Commerzbank AG	GE02	104.2	96.5	7.7	122
Greece	Attica Bank S.A.	GR01	70.2	94.2	-23.9	52
Ireland	Permanent TSB Group Holdings PLC	IR01	79.2	95.0	-15.8	56
	Bank of Ireland Group PLC	IR02	95.3	96.3	-1.0	89
	AIB Group PLC	IR03	87.9	95.6	-7.7	64
Italy	Banca Mediolanum SpA	IT01	99.2	96.5	2.7	91
	BPER Banca	IT02	98.1	96.2	1.9	85
	UniCredit SpA	IT03	106.2	96.7	9.5	106
	Intesa Sanpaolo S.p.A.	IT04	106.7	96.6	10.2	112
	Mediobanca Banca di Credito Finanziario SpA	IT05	104.2	96.5	7.7	108
Netherland	ING Groep N.V. (*)	NT01	111.1	96.8	14.4	136
Norway	DNB Bank ASA	NW01	96.0	96.2	-0.2	96
Russia	Sberbank of Russia PJSC	RU01	83.4	95.3	-11.9	48
Spain	Banco Santander S.A. (*)	SP01	111.6	96.9	14.8	135
	Banco Bilbao Vizcaya Argentaria, S.A.	SP02	108.8	96.8	12.1	128
	Bankinter SA	SP03	104.0	96.6	7.4	120
	Banco de Sabadell SA	SP04	98.5	96.2	2.3	82
Sweden	Skandinaviska Enskilda Banken AB	SW01	96.9	96.4	0.5	86
	Svenska Handelsbanken AB	SW02	93.6	96.3	-2.7	81
	Swedbank AB	SW03	95.1	96.2	-1.1	85
	Nordea Bank Abp	SW04	100.4	96.5	3.9	92
Switzerland	UBS Group AG (*)	SZ01	101.1	96.4	4.7	113
United Kingdom	HSBC Holdings (*)	UK01	99.5	96.5	3.0	119
	Barclays PLC (*)	UK02	104.6	96.7	7.9	132
	Lloyds Banking Group	UK03	102.3	96.4	5.8	121
	Standard Chartered PLC (*)	UK04	97.3	96.4	0.9	108
	NatWest Group PLC	UK05	97.8	96.3	1.5	88
	Regional average		**99.9**	**96.4**	**3.5**	**102**
	Full sample average		**96.2**	**96.2**	**0.0**	**83**

Note: Spillover effects computed from QVAR(1) and consider a KPPS 20-step-ahead forecast error variance decomposition. Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. (*) Classified as Global Systemically Important Banks (G-SIBs) by the Financial Stability Board (2023). Source: Authors.