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Banking across Borders in Luxembourg

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Abstract

This paper examines the role of Luxembourg in the international banking system through the Locational Banking Statistics compiled by the Bank for International Settlements. Across European countries, Luxembourg features the largest cross-border banking positions relative to GDP. Indeed, Luxembourg is a small open economy with an international financial centre, whose banking sector consists mostly of foreign-controlled banks. The cross-border banking positions focus on loans and deposits between banks and notably intragroup positions. The geographical counterparts of cross-border banking positions in Luxembourg are mainly Western European countries (especially the euro area) and North America (notably the United States), whether for claims or liabilities. By order of importance, the main country counterparts are Germany, France, Great Britain, Switzerland, Italy, the United States, the Netherlands and Belgium. Within the international banking network, the importance of cross-border banking positions in Luxembourg resembles that of Belgium, Ireland, Japan and the Netherlands. These countries feature fewer connections than the United States, Germany and France. At the top of the network, Great Britain stands as the leading international banking centre. The structure of the international banking network evolves over time. During periods of financial stress, the density of connections stagnates or diminishes and the network becomes less resilient. This was notably the case during the global financial crisis of 2007-2008 and the European sovereign debt crisis of 2010-2012. Over time, the international banking network became more fragmented with more communities developing. This suggests a regionalisation of cross-border banking flows, as cross-border banking activity becomes more concentrated within specific groups of countries.

Keywords: Cross-border banking positions, BIS Locational Banking Statistics, Network analysis

JEL codes: F30, E50

Contact: gabriele.difilippo@bcl.lu. **Disclaimer:** This paper should not be reported as representing the views of the Banque centrale du Luxembourg or the Eurosystem. The views expressed are those of the author and may not be shared by other research staff or policymakers in the Banque centrale du Luxembourg or the Eurosystem. **Acknowledgements:** For their comments, the author would like to thank Paolo Guarda and Jean-Pierre Schoder. For their administrative support, the author would like to thank Roland Nockels and Romain Weber. Any remaining errors are the sole responsibility of the author.

Table of Contents

Non-Technical Summary

This paper examines the role of Luxembourg in the international banking system using cross-border banking positions in the Locational Banking Statistics compiled by the Bank for International Settlements.

Across European countries, Luxembourg features the largest banking positions relative to GDP, owing to its small size and the importance of its financial centre. Claims and liabilities held by banks resident in Luxembourg are mainly cross-border. This reflects Luxembourg's position as a small open economy, acting as an international financial centre, with mainly foreign-owned banks. Whether on the assets side or on the liabilities side, these cross-border banking positions are mostly loans and deposits between banks, including intragroup banking positions. Although secondary, the non-financial sector remains a relatively important counterpart in cross-border banking positions. This reflects the fact that foreign-controlled banks in Luxembourg provide financial services to support business activity and corporate investments by multinational enterprises outside Luxembourg. Cross-border banking positions in Luxembourg are mainly linked to Western European countries (especially the euro area) and North America (notably the United States), whether for assets or liabilities. By order of importance, the main country counterparts are Germany, France, Great Britain, Switzerland, Italy, the United States, the Netherlands and Belgium.

The analysis of the international banking network shows that Luxembourg's position resembles that of Belgium, Ireland, Japan and the Netherlands when considering the number of connections (or cross-border banking positions). These countries feature fewer connections than the United States, Germany and France. At the top of the network, Great Britain stands as the leading international banking centre. The structure of the international banking network evolves over time. Its evolution follows that of systemic stress in the financial system. In particular, during periods of financial stress, the density of connections stagnates or declines and the international banking network becomes less resilient. This was notably the case during the global financial crisis of 2007-2008 and the European sovereign debt crisis of 2010-2012. Over time, the international banking network has become more fragmented, with more communities composing the network. This suggests a regionalisation of cross-border banking flows, as cross-border banking activity concentrates within specific groups of countries.

Résumé Non Technique

Ce document examine le rôle du Luxembourg dans le système bancaire international en analysant les positions bancaires transfrontalières du Luxembourg, issues des statistiques bancaires de localisation (en anglais, *Locational Banking Statistics*) compilées par la Banque des règlements internationaux.

Par rapport aux autres pays européens, le Luxembourg présente les positions bancaires les plus importantes par rapport au PIB, en raison de sa petite taille et de l'importance de sa place financière. Les positions bancaires détenues par les banques résidentes au Luxembourg sont principalement transfrontalières, que ce soit à l'actif ou au passif. Cela reflète la position du Luxembourg en tant que petite économie ouverte, agissant comme un centre financier international, où le secteur bancaire est essentiellement composé de banques sous contrôle étranger. Que ce soit à l'actif ou au passif, ces positions bancaires transfrontalières regroupent essentiellement des prêts et dépôts entre banques, y compris des positions bancaires intragroupes. Bien que secondaire, le secteur non financier reste une contrepartie relativement importante dans les positions bancaires transfrontalières. Cela reflète le fait que les banques sous contrôle étranger au Luxembourg fournissent des services financiers pour soutenir l'activité commerciale et les investissements d'entreprises multinationales en dehors du Luxembourg. Les positions bancaires transfrontalières au Luxembourg sont principalement liées aux pays d'Europe occidentale (notamment la zone euro) et à l'Amérique du Nord (notamment les États-Unis), que ce soit à l'actif ou au passif. Par ordre d'importance, les principaux pays de contrepartie sont l'Allemagne, la France, la Grande-Bretagne, la Suisse, l'Italie, les États-Unis, les Pays-Bas et la Belgique.

L'analyse du réseau bancaire international montre que la position du Luxembourg ressemble à celle de la Belgique, de l'Irlande, du Japon et des Pays-Bas, lorsque l'on considère le nombre de connexions (ou positions bancaires transfrontalières). Ces pays sont moins connectés que les États-Unis, l'Allemagne et la France. Au sommet du réseau, la Grande-Bretagne constitue le premier centre bancaire international. La structure du réseau bancaire international évolue dans le temps. Son évolution suit celle des tensions systémiques dans le système financier. En particulier, pendant les périodes de tensions financières, la densité des connexions stagne voire diminue et le réseau bancaire international devient moins résilient. Ce fut notamment le cas lors de la crise financière mondiale de 2007-2008 et de la crise de la dette souveraine européenne de 2010-2012. Au fil du temps, le réseau bancaire international est devenu plus fragmenté, avec un plus grand nombre de communautés composant le réseau. Cela suggère une régionalisation des flux bancaires transfrontaliers, dans la mesure où l'activité bancaire transfrontalière se concentre au sein de groupes spécifiques de pays.

1. Introduction

International finance and multinational business operations have traditionally been facilitated by international banks (Cassis (2006)). International banking activity is important in Luxembourg, notably due to the presence of foreign-controlled banks (Moyse *et al*. (2014)). Cross-border activity by resident banks covers a wide variety of operations including private banking, corporate services, depositary and custodian services, wealth management and treasury services. Resident banks can provide financial support in the form of bilateral or syndicated loans to support business activities and corporate investments by financial corporations (notably investment funds) and non-financial groups (including multinational enterprises (MNEs)). In addition, many European banks channel international lending through their base in Luxembourg owing to economies of scale and financial expertise. Most resident subsidiaries hold excess deposits and act as net liquidity provider to their parent bank abroad (Wintersteller (2013)).

Against this background, this paper examines the role of Luxembourg in the international banking system, by analysing cross-border banking positions in the Locational Banking Statistics compiled by the Bank for International Settlements. To understand the role of Luxembourg within the international banking framework, the paper decomposes cross-border positions by instruments, by sector counterpart and by geographical counterpart. The analysis also performs a comparison across European countries. In addition, the paper applies network analysis to understand the evolution of the landscape of cross-border lending. Perhaps one challenge regarding the analysis of the international banking network lies in the readability of the results. Indeed, since a network considers interconnections between countries, big datasets featuring a large number of countries and interconnections can lead to complex network representations. To ease the readability of the results, the paper uses specific network metrics to characterise the evolution of the international banking network over time and the position of Luxembourg within this network.

The remainder of the paper is organised as follows. Section 2 presents the data on international banking statistics. Section 3 describes the main characteristics of banking positions in Luxembourg. Section 4 analyses the international network of cross-border banking positions. Section 5 is the conclusion.

2. Data on international banking statistics

The Bank for International Settlements (BIS) compiles and publishes international banking statistics (IBS) under the auspices of the Committee on the Global Financial System (CGFS) and in cooperation with central banks worldwide which provide the data. The dataset features quarterly gross stocks of international assets and liabilities held by resident banks in a given country *vis-à-vis* other jurisdictions. Data are reported at an aggregated country level rather than at the individual bank level, in order to maintain the confidentiality of the individual banks that report the statistics to their respective central bank. In addition, data are exchange rate-adjusted and labelled in the same currency (in millions of US dollars) across reporting countries. As the IBS uses uniform and consistent statistical concepts of international banking activity across countries, this dataset is often deemed one of the most comprehensive to analyse developments in global banking (Muñoz de la Peña and van Rixtel (2015)).

More specifically, the IBS embeds two datasets. On the one hand, the Consolidated Banking Statistics (CBS) builds banking statistics by the nationality of reporting banks. On the other hand, the Locational Banking Statistics (LBS) produces banking statistics by the residence of reporting institutions, along the lines of the Balance of Payments (BOP) statistics. In other words, the CBS reports the positions of Luxemburgish banks (whatever their country of residence) *vis-à-vis* other jurisdictions, while the LBS reports the positions of banks resident in Luxembourg (whatever the nationality of their group) *vis-à-vis* other jurisdictions.

Compared to the CBS statistics, the LBS database better suits the scope of the analysis which aims to understand the role of Luxembourg within the international banking system. Indeed, the LBS data capture capital flows through the banking sector in international financial markets. On the assets side, it identifies the countries (including non-reporting countries) to which funding is provided by banks located in each reporting country. On the liabilities side, it identifies the countries from which funding is acquired by banks located in each reporting country.

The LBS database covers 42 reporting countries that provide data about their bilateral banking positions (claims and liabilities) by residence of counterparty, which may be in 212 jurisdictions worldwide. At the end of each quarter, reporting countries are required to indicate amounts outstanding for credit exposures of resident banks *vis-à-vis* other countries. The banking positions are thus available on a quarterly frequency.

In terms of coverage, it is estimated that the LBS statistics capture around 95% of all cross-border banking activity.[1] In addition, the LBS database disaggregates the bilateral banking positions into a number of dimensions: by balance sheet positions (claims *versus* liabilities), by currency denomination (Euro, Japanese Yen, Pound Sterling, Swiss Franc, US Dollar, other currencies), by instrument (debt securities *versus* loans and deposits) and by counterparty sector (banks *versus* non-banks). More precisely, the counterparty sector covers banks (including "related office" and "unrelated banks") and non-banks (regrouping "non-financial sector" and "non-bank financial institutions"). "Related office" positions (or inter-office positions) cover banks' positions *vis-à-vis* their affiliates or equivalently intragroup positions between offices of the same banking group. "Unrelated banks" positions (or non-inter-office positions) regroup banks' positions against non-affiliates. Non-bank financial institutions include notably investment funds and special purpose vehicles, while the non-financial sector represents non-financial corporations, general government and households including non-profit institutions serving households (BIS (2019)).[2]

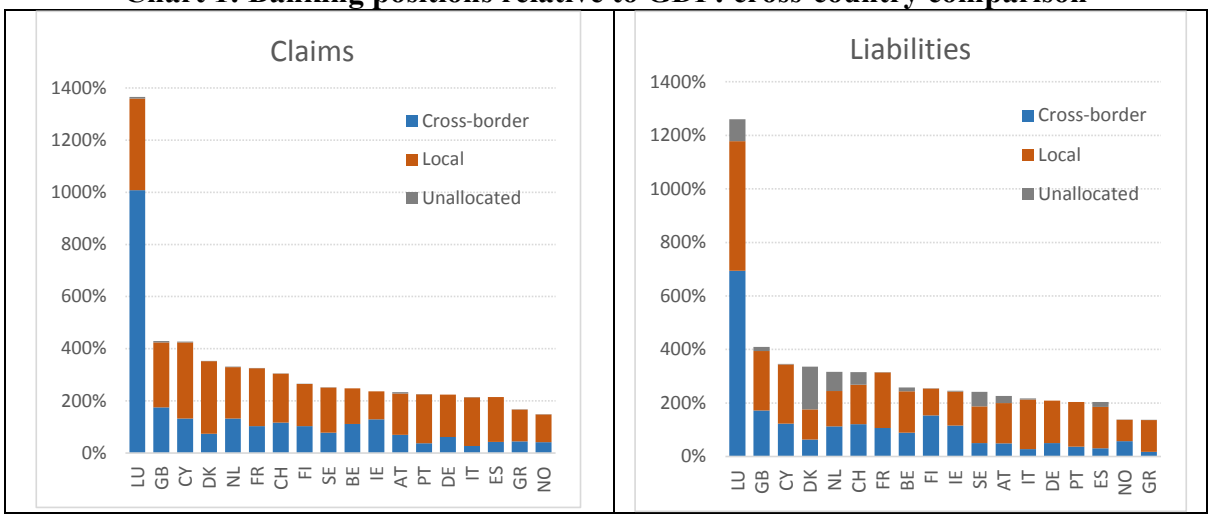
3. Characteristics of banking positions in Luxembourg

3.1 Banking positions relative to GDP: a cross-country comparison

Chart 1 presents claims and liabilities of resident banks relative to GDP for several European countries. The chart distinguishes cross-border and local claims and liabilities.[3]

[1] See https://www.bis.org/statistics/about_banking_stats.htm
[2] See BIS (2019), Table 2.6, "Sector of counterparty" p. 17.
[3] Cross-border positions are between resident banks and non-resident counterparties. Local positions are between resident banks and resident counterparties.

Chart 1: Banking positions relative to GDP: cross-country comparison



Source: BIS Locational Banking Statistics for banking positions, International Monetary Fund for GDP. Units: Percent of GDP, average Q1 2012-Q4 2021

On average over the period Q1 2012-Q4 2021, Luxembourg features the highest banking positions relative to GDP across European countries. This observation holds both for local and cross-border positions. In particular, cross-border claims and liabilities are both much higher in Luxembourg. Thus in Luxembourg, resident banks hold most claims and liabilities against non-resident counterparts, while in other European countries, resident banks hold most claims and liabilities *vis-à-vis* resident counterparts. The large size of cross-border banking positions reflects Luxembourg's position as a small open economy, acting as an international financial centre, with mainly foreign-owned banks.[4]

3.2 Financial instruments composing banking positions

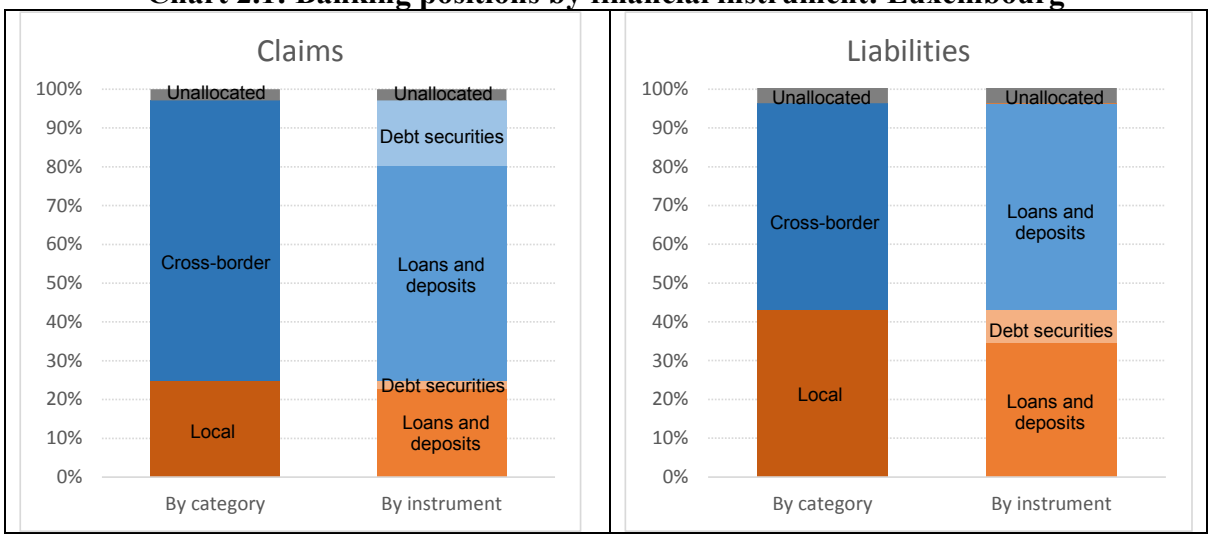
Chart 2.1 breaks down the banking positions in Luxembourg by financial instruments. Loans and deposits account for most claims and liabilities. This observation holds both for cross-border and local positions.

According to BIS (2003),[5] loans should comprise financial assets which are created through the lending of funds by a creditor (lender) to a debtor (borrower) and which are not represented by negotiable securities. Deposits should comprise all claims reflecting evidence of deposit - including non-negotiable certificates of deposit - which are not represented by negotiable securities. Thus, loans and deposits should include interbank borrowings and loans, and inter-office balances.

[4] See appendix A

[5] See https://www.bis.org/publ/bppdf/bispap16.pdf

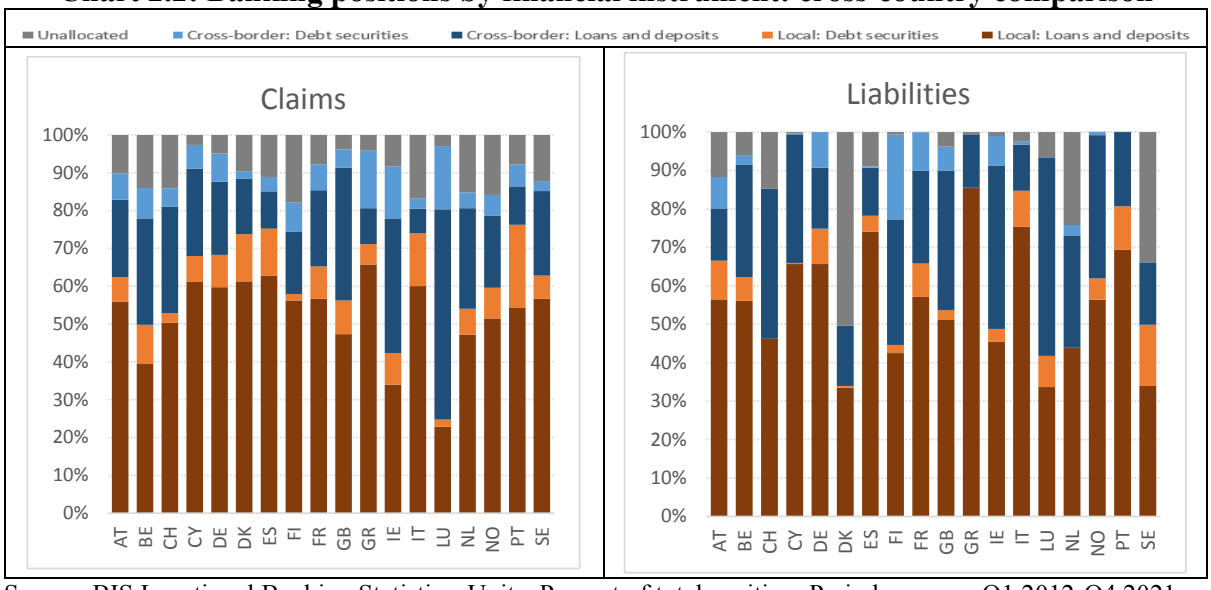
Chart 2.1: Banking positions by financial instrument: Luxembourg



Source: BIS Locational Banking Statistics. Units: Percent of total position. Period: average Q1 2012-Q4 2021.
NB: Missing data or negligible amounts for cross-border debt securities on the liabilities-side.

Chart 2.2 decomposes banking positions by financial instrument across European countries. For most countries, local loans and deposits account for a major share in banking positions, whether for claims or liabilities. Luxembourg stands out because most loans and deposits are cross-border. Hence, while Luxembourg banking activity is mainly driven by the foreign market, banking activity in other European countries is mainly local and focuses more on the domestic market.

Chart 2.2: Banking positions by financial instrument: cross-country comparison

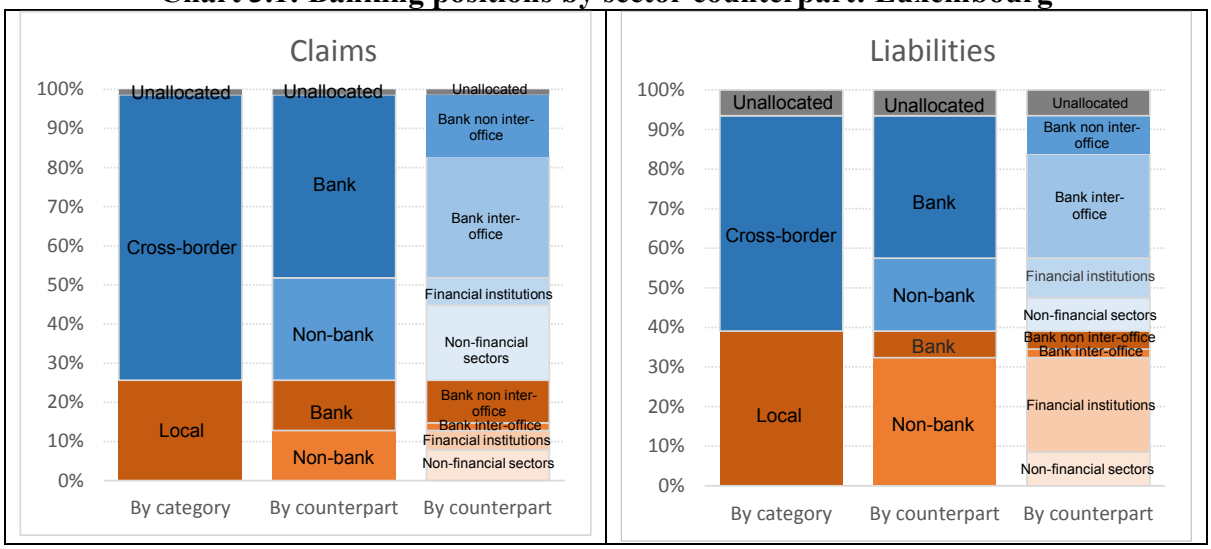


Source: BIS Locational Banking Statistics. Units: Percent of total position. Period: average Q1 2012-Q4 2021

3.3 Sector counterparts of banking positions

Chart 3.1 decomposes claims and liabilities in Luxembourg by sector counterpart.

Chart 3.1: Banking positions by sector counterpart: Luxembourg



Source: BIS Locational Banking Statistics. Units: Percent of total position. Period: average Q1 2012-Q4 2021

On the assets side, banks (60%) dominate non-banks (40%). This observation holds for cross-border claims while for local claims, the shares of banks and non-banks are evenly distributed. On the liabilities side, non-banks (57%) dominate banks (43%). However, the largest share is held by non-banks for local liabilities and by banks for cross-border liabilities.

On the assets side, for cross-border positions the bank inter-office share (31%) dominates the non-inter-office share (16%). The opposite is true for local positions, where the share of bank non-inter-office (11%) is larger than that of bank inter-office (2%). Hence, in the local market, resident banks lend mostly to resident banks affiliated to other groups, while in the international market, resident banks lend mostly to non-resident banks affiliated to the same group. This result is in line with Wintersteller (2013) who shows that many European banks channel international lending through their base in Luxembourg owing to economies of scale and financial expertise. Most resident subsidiaries hold excess deposits and act as net liquidity provider to their parent bank abroad.[6]

Moreover, resident banks present larger claims *vis-à-vis* the non-resident non-financial sector (19% for cross-border non-financial sector) than *vis-à-vis* the resident non-financial

[6] As a matter of facts, Wintersteller (2013) shows that "*during the Lehman Brothers crisis many foreign subsidiaries in Luxembourg pledged collateral with the ECB* [*via* the national central bank] *to obtain liquidity for their parents when interbank markets dried up*".

sector (8% for local non-financial sector). This can be explained by the fact that Luxembourg hosts a large number of foreign-controlled banks whose lending activity supports the business activity and corporate investments by MNEs outside Luxembourg.

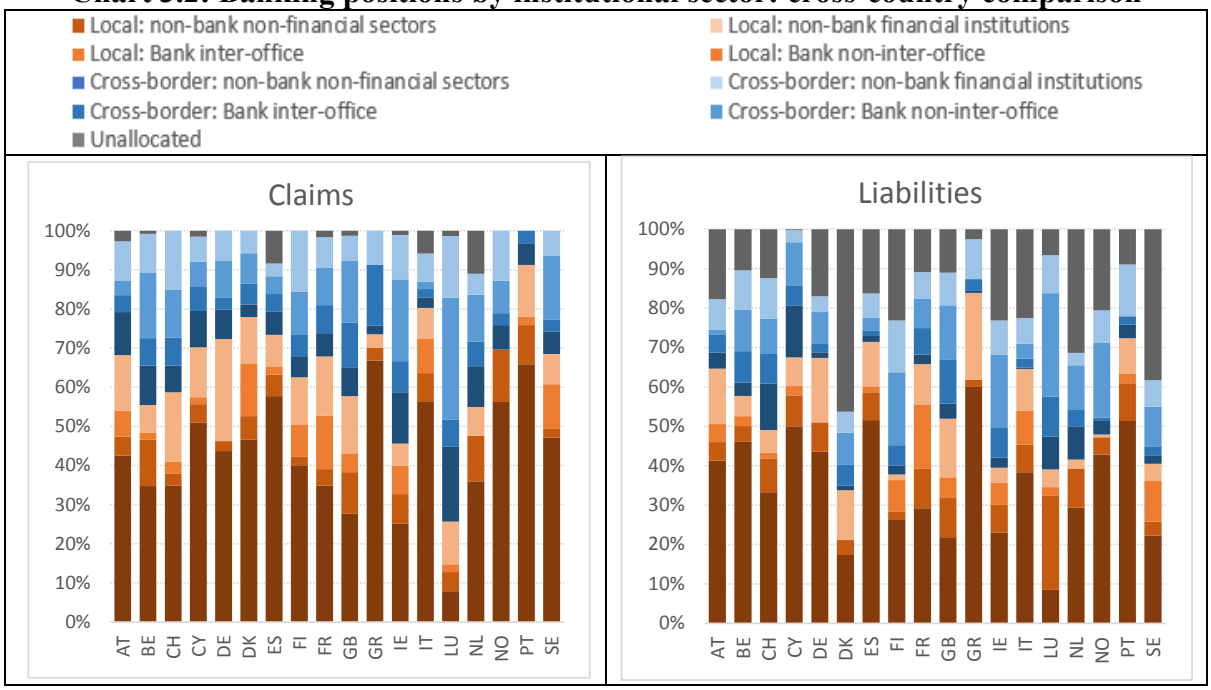
On the liabilities side, for cross-border positions the main counterpart is banks (36%), and notably banks affiliated to the same group (26%). For local positions, the main counterpart is non-banks (32%), and in particular non-bank financial institutions (24%). The latter include investment funds and captive financial institutions (BIS (2019)). This reflects the fact that Luxembourg hosts one of the most important fund industries in the world. The Luxembourg investment fund industry manages assets worth EUR 5,859 billion in Q4 2021 (EFAMA (2022)), placing it as the leading investment fund centre in Europe and the second largest at the global level, just behind the United States where the fund industry manages assets equal to EUR 30,156 billion in Q4 2021.[7] In addition, captive financial institutions (CFIs, sector S127) are particularly important in Luxembourg (Di Filippo and Pierret (2020a, 2020b, 2022)). Compared to the other sectors, CFIs account for the major share of the inward and outward stocks of foreign direct investment.[8] Indeed, the country acts as a global financial hub for multinational enterprises which resort to CFIs for managing their business activities and structuring their corporate investments.

Altogether, banks resident in Luxembourg mainly source funds from cross-border loans and deposits granted by affiliates of their group located abroad (26%) and from resident investment funds and captive financial institutions (24%). These funding sources account for about half of the total banking liabilities in Luxembourg. On the assets side, resident banks lend these funds primarily to non-resident banks affiliated to their group (31%), to the non-resident non-financial sector (19%) and to non-resident banks affiliated to a different group (16%). These investments account for about 65% of banking claims in Luxembourg.

[7] See EFAMA (2022), Table 5 "Total net assets excluding funds of funds by the type of funds", millions of euro, end of quarter, Q4 2021 p. 14.
[8] See appendix B

Chart 3.2 breaks down banking positions by sector counterpart across selected European countries. For most countries, the most important counterpart is local non-bank non-financial sectors, whether for claims or liabilities. This counterpart covers households and non-financial companies. Hence, unlike in Luxembourg, banks located in other European countries source their funds mostly from the resident non-financial sector and lend these funds mostly to the resident non-financial sector.

Chart 3.2: Banking positions by institutional sector: cross-country comparison

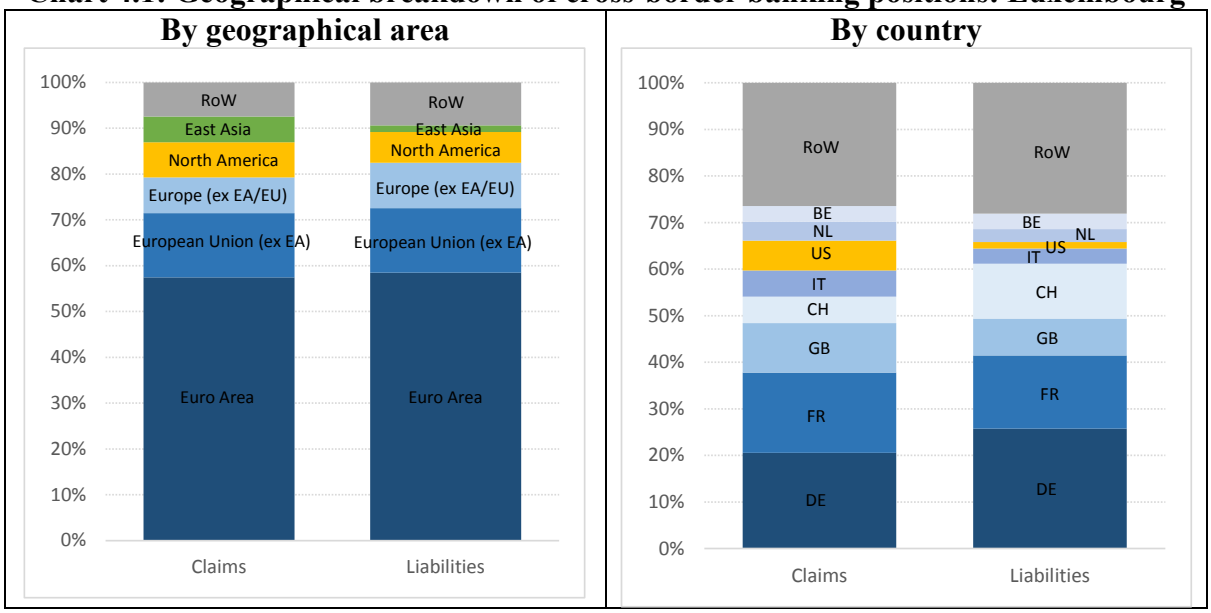


Source: BIS Locational Banking Statistics. Units: Percent of total position. Period: average Q1 2012-Q4 2021

3.4 Geographical breakdown of cross-border banking positions

Chart 4.1 decomposes the cross-border positions by geographical area and by country. Cross-border lending by resident banks is mainly to European countries. For cross-border banking positions, Europe represents 80% of claims and 82% of liabilities. When considering both claims and liabilities, the most important country counterparts are Germany (23%), France (16%), Great Britain (9%), Switzerland (9%), Italy (4%), the United States (4%), the Netherlands (3%) and Belgium (3%). Altogether, these jurisdictions account for more than 70% of cross-border banking positions in Luxembourg.

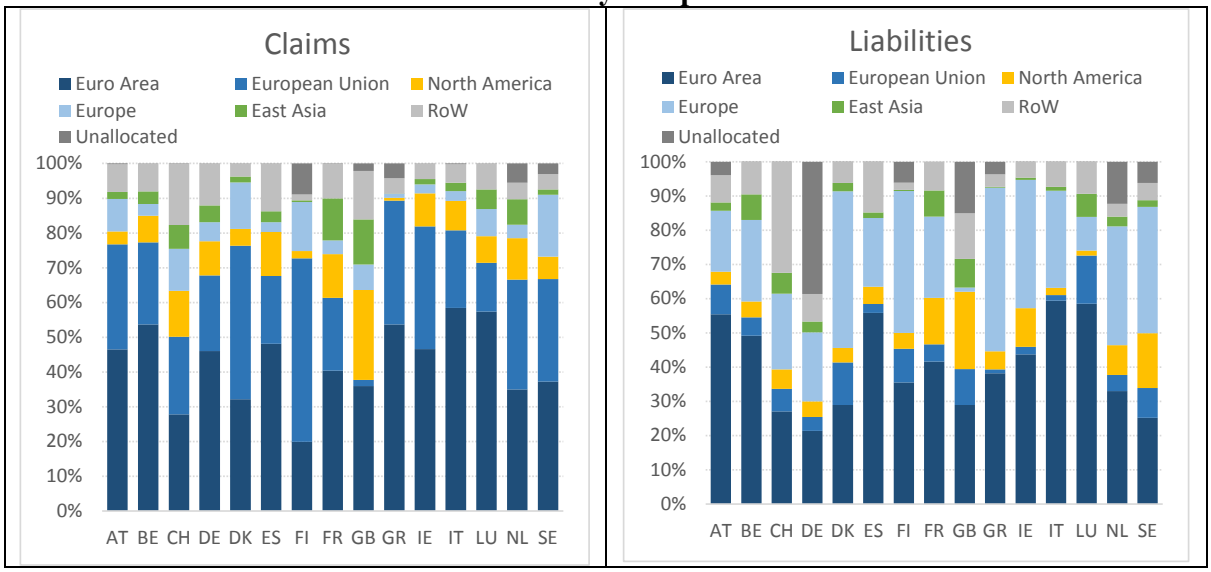
Chart 4.1: Geographical breakdown of cross-border banking positions: Luxembourg



Source: BIS Locational Banking Statistics. Units: Percent of total position. Period: average Q1 2012-Q4 2021

Chart 4.2 breaks down the cross-border banking positions of European countries by geographical area. For most countries, cross-border banking positions are mainly *vis-à-vis* Western Europe. Compared to the other European countries, Great Britain stands out because of the size of its positions *vis-à-vis* North America and more specifically, the United States.

Chart 4.2: Geographical breakdown of cross-border banking positions: cross-country comparison



Source: BIS Locational Banking Statistics. Units: Percent of total position. Period: average Q1 2012-Q4 2021. NB: Missing data for CY, NO and PT.

Overall, cross-border banking positions in Luxembourg and in other European countries are mostly *vis-à-vis* European jurisdictions. Thus banks in Europe take part in a regional - or European - network of cross-border lending flows.

4. Network analysis of cross-border banking positions

4.1 Main principles

Cross-border banking positions can be represented by a network structure featuring a set of nodes connected to each other with links (or edges).[9] Links can be either undirected or directed. When links feature a direction (from one node to another) and an associated value, the network is said to be directed and weighted.

To map the geographical linkages of banking exposures, this paper uses the BIS Locational Banking Statistics. The latter regroups 42 countries that report their cross-border banking positions of their resident banks *vis-à-vis* 212 jurisdictions. Cross-border banking positions cover all types of banking positions (loans and deposits, debt securities), all counterparty sectors (banks and non-banks) and all currencies. The database spans Q1 1998 to Q4 2021.

Within the international banking network, nodes represent a given country. Links represent cross-border banking positions between banks in different countries at a given time period. As cross-border banking positions entail claims and liabilities, the network is directed and weighted. Inward links illustrate banking liabilities held by a given country *vis-à-vis* its lending counterparties. Outward links represent banking claims held by a given jurisdiction *vis-à-vis* its borrowing counterparties. The weight of an outgoing link (respectively, incoming link) corresponds to the total amount of money lent by a creditor to a borrower (respectively, borrowed by a debtor from a lender).

[9] See for example, Hattori and Suda (2007), von Peter (2007), Minoiu and Reyes (2011), Cerutti and Zhou (2017) among others.

4.2 Network visualisation

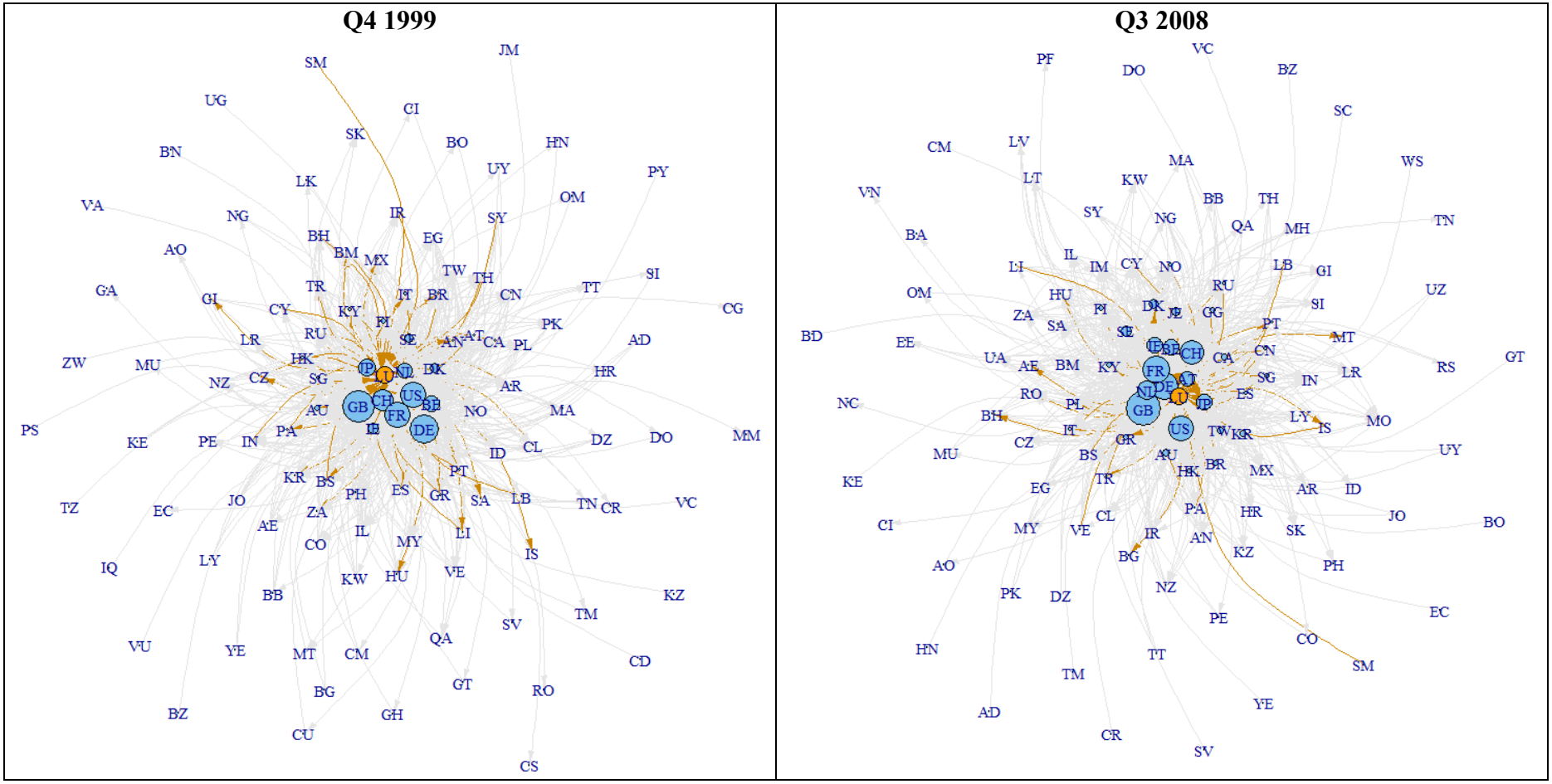
The drawing of a network layout is based on algorithms that return coordinates for each node in a network. The literature has developed a large number of approaches to draw network graphics. One general class of algorithms, called "force-directed algorithms" allows producing automatic network layouts that are easier to understand and interpret. Intuitively, force-directed algorithms pull connected nodes closer to one another, while pushing unconnected nodes away from each other. This results in network layouts that are more readable (Fruchterman and Reingold (1991), Luke (2015), Ognyanova (2021)).

Charts 5.1 and 5.2 present four snapshots of the international banking network (grey edges and blue nodes), including that of Luxembourg (orange edges and nodes) within this network, for specific periods. The charts map the network by using a force-directed algorithm called large graph layout (or LGL), put forward by Adai *et al*. (2004).[10] The LGL algorithm is suitable for big datasets featuring a large number of countries and interconnections.

The resulting network layouts illustrate the unbalanced nature of the international banking system, with a small number of countries accounting for most of the connections. This is notably the case of Great Britain, the United States, Germany, France, Japan, Switzerland, the Netherlands, Luxembourg, Belgium and Ireland.

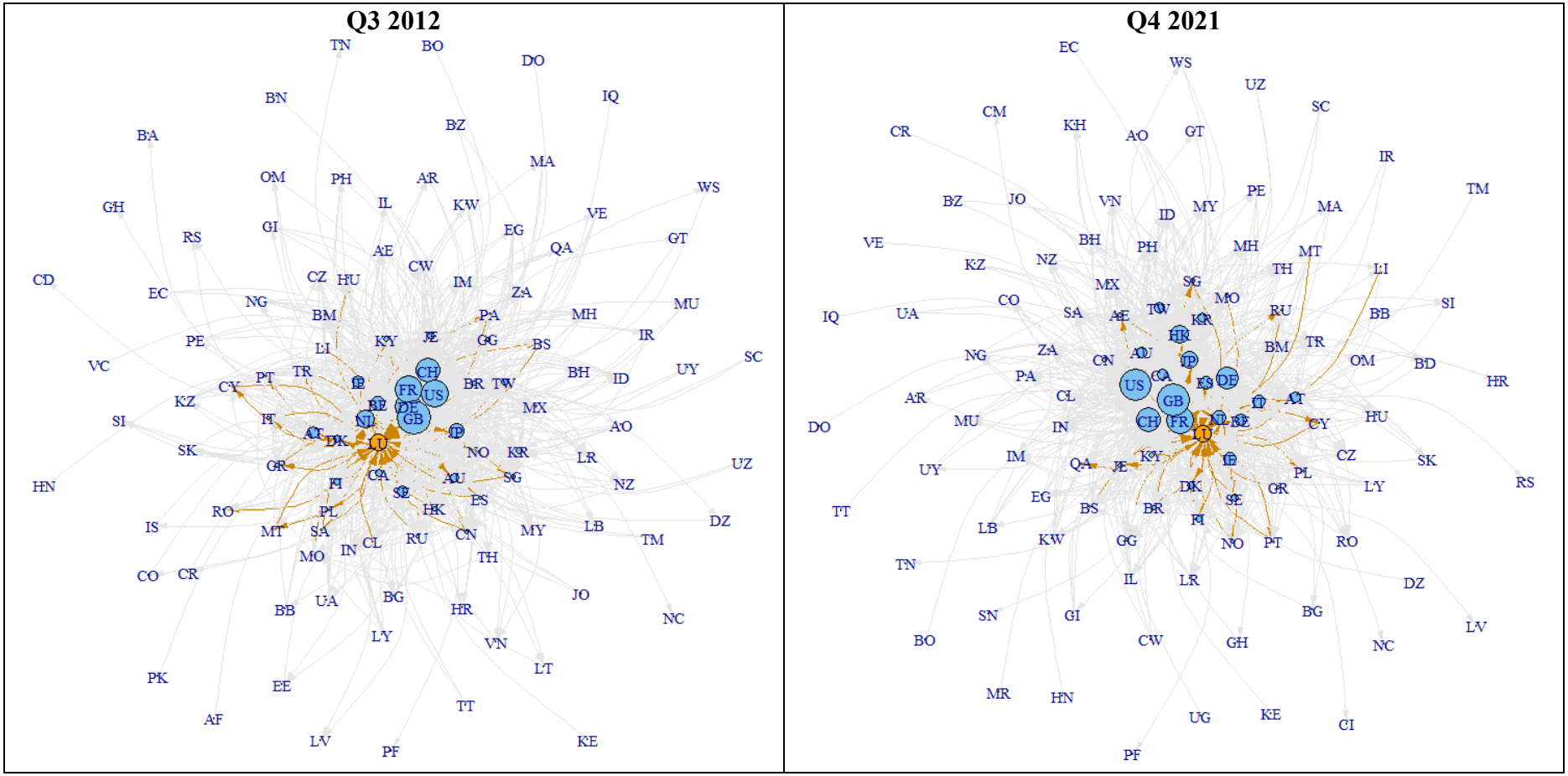
[10] The paper uses the R software to implement the network analysis (Luke (2015), Ognyanova (2021)).

Chart 5.1: Network visualisation



NB: The network is represented with the LGL algorithm (Adai *et al*. (2004)). Edges represent cross-border claims and liabilities held by a given country *vis-à-vis* the other countries. The size of the nodes is proportional to its degree. The Luxembourg network is represented in orange. The rest of the network is represented with edges in grey and nodes in blue.

Chart 5.2: Network visualisation

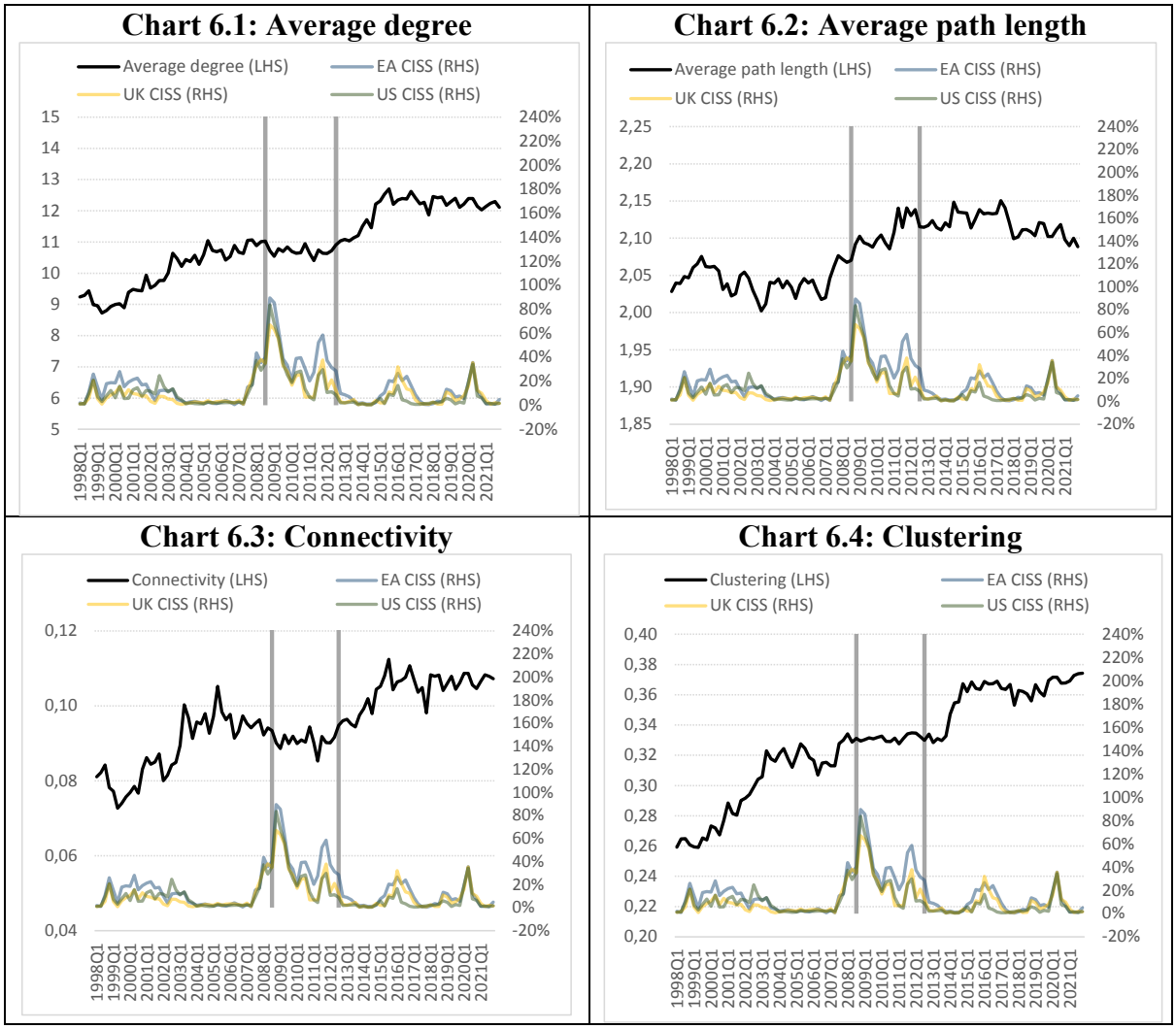


NB: The network is represented with the LGL algorithm (Adai *et al*. (2004)). Edges represent cross-border claims and liabilities held by a given country *vis-à-vis* the other countries. The size of the nodes is proportional to its degree. The Luxembourg network is represented in orange. The rest of the network is represented with edges in grey and nodes in blue.

This visualisation of the entire international banking network only provides a heuristic characterisation, but omits quantitative details of the network's evolution. In order to improve upon this, the paper subsequently uses specific network metrics to analyse the properties of the network.

4.3 Network-aggregate indicators

Network characteristics are often gauged using different metrics. Charts 6.1 to 6.4 plot the evolution of four basic structural indicators: average degree, average path length, connectivity and clustering.



NB: The grey bars represent respectively, the Lehman Brothers bankruptcy (2008Q3) and the end of the European sovereign debt crisis (2012Q3). The CISS is a composite indicator of systemic stress in the financial system (Holló *et al*. (2012)).

The average degree of a network (Chart 6.1) is simply the average number of edges (whether inward or outward) per node. The average degree is computed as the total number of edges over the total number of nodes. The average degree generally appears to trend upwards, but it levels off or even declines during periods when the financial system features systemic stress. This suggests that in tranquil periods, when financial stress is low, the number of cross-border banking exposures between countries increases. In times of heightened financial stress, the number of cross-border banking exposures between countries stabilises or becomes lower. In other words, banks become less interconnected in times of financial turmoil.

The average path length (Chart 6.2) reports the average number of steps along the shortest paths for all possible pairs of network nodes. It shows how many steps on average are required to move from one node to another in a network. It provides a measure of the efficiency of connections in a network. Complicated and inefficient networks feature longer average path lengths than efficient networks. The average path length trends downwards before the 2007-2008 global financial crisis, increases during the subprime crisis of 2007-2008 and the European sovereign debt crisis of 2010-2012 and trends downwards again afterwards. This suggests that the network is less efficient in times of financial stress.

Connectivity (Chart 6.3) is the minimum number of elements (nodes or edges) that need to be removed to separate the remaining nodes into two or more isolated sub-networks. The connectivity of a network is an important measure of its resilience. Higher connectivity indicates a more resilient network. Connectivity trends upwards before the 2007-2008 global financial crisis, declines during the subprime crisis of 2007-2008 and the European sovereign debt crisis of 2010-2012 and recovers afterwards. Hence, network resilience diminishes during periods of financial stress (and *vice versa*). During periods of financial turmoil, the density of connections in the network becomes lower, increasing its porosity and decreasing its resilience.

Clustering (Chart 6.4) reports the average clustering coefficient of all nodes in the network. The clustering coefficient of a node measures the number of connections between the nodes of its neighbourhood. For a given node, higher clustering indicates a higher number of connections between nodes located in its neighbourhood. Clustering thus measures the degree to which nodes in a network tend to cluster together. Clustering trends upwards before the 2007-2008 global financial crisis and after the European sovereign debt crisis of 2010-2012. It stabilises during the subprime crisis of 2007-2008 and the European sovereign debt crisis of

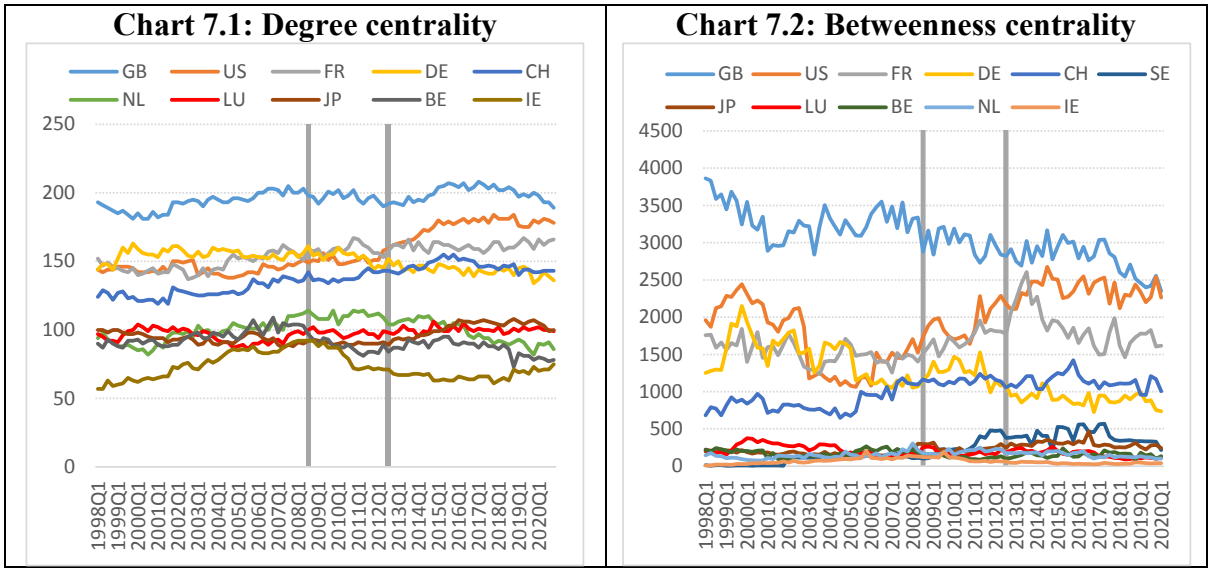
2010-2012. Hence, the network develops more connections during tranquil periods than in times of financial stress.

Altogether, charts 6.1 to 6.4 suggest that the structure of the international banking network evolves over time. This evolution seems linked to the evolution of systemic stress in the financial system.

4.4 Node-specific indicators

While network-aggregate indicators characterise the international banking network as a whole, node-specific indicators focus on the position of individual countries within the network. Some nodes are more closely related to other nodes, and their fluctuations tend to exert stronger influence on the whole network. These countries could therefore be considered as systemically important jurisdictions in the network and be qualified as hubs. The analysis below considers two indicators: degree centrality and betweenness centrality, where the centrality concept captures the "prominence" of a node in a network.

Chart 7.1 presents the countries with the highest "degree centrality" over the period of analysis. Degree centrality measures the number of connections (whether inward or outward) of a given node *vis-à-vis* the others. It indicates how well a node is connected in terms of direct connections. In other words, the degree represents the number of banking positions with other countries in the global banking network. Over time, Great Britain features the highest number of positions (whether claims or liabilities) *vis-à-vis* other countries in the network, marking this country the leading international banking centre within the international banking network. Great Britain is followed by a group of countries including the United States, France, Germany and Switzerland. These are followed by a second group of countries including the Netherlands, Luxembourg, Japan, Belgium and Ireland.



NB: The grey bars represent respectively, the Lehman Brothers bankruptcy (2008Q3) and the end of the European sovereign debt crisis (2012Q3). To ease the readability of the results, charts 7.1 and 7.2 present the countries with the highest "degree centrality" and "betweenness centrality".

Chart 7.2 presents the countries with the highest "betweenness centrality" over time. The betweenness of a given node is defined as the number of shortest paths passing through this node. Betweenness is based on how important a node is in terms of connecting other nodes. A high betweenness implies a greater importance of the node in the network in terms of information transmission. Removing this node will exert a substantial impact on the transmission of information within the network. Great Britain features the highest betweenness, followed by the United States and France. The betweenness of Luxembourg is close to that of Belgium, Ireland, Japan and the Netherlands.

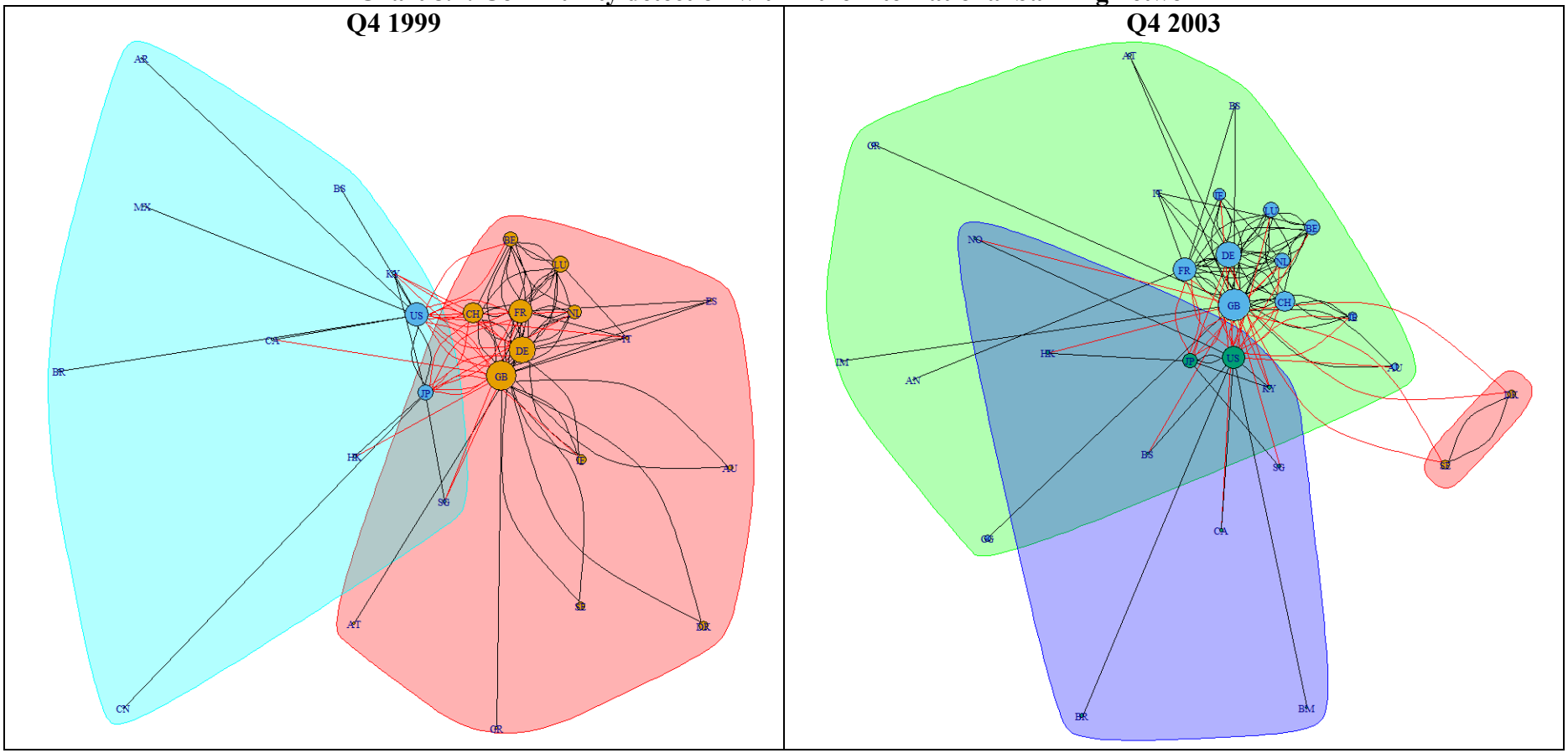
4.5 Community detection

Networks can often be organised into communities. A community is a set of nodes having a lot of connections between each other, compared to nodes outside the community. In addition, each community can be separated into sub-communities. The literature puts forward various algorithms to detect communities. Charts 8.1 to 8.3 rely on the Louvain algorithm (Blondel *et al*. (2008)) to highlight communities within the international banking network. These charts illustrate the network communities with different coloured areas that surround groups of nodes (or countries).

Charts 8.1 to 8.3 show that Luxembourg is positioned in a community (or sub-network) that mainly regroups European countries. This can be explained by historical ties, but also cultural and political reasons (Moyse *et al*. (2014)) as well as geographical distances.

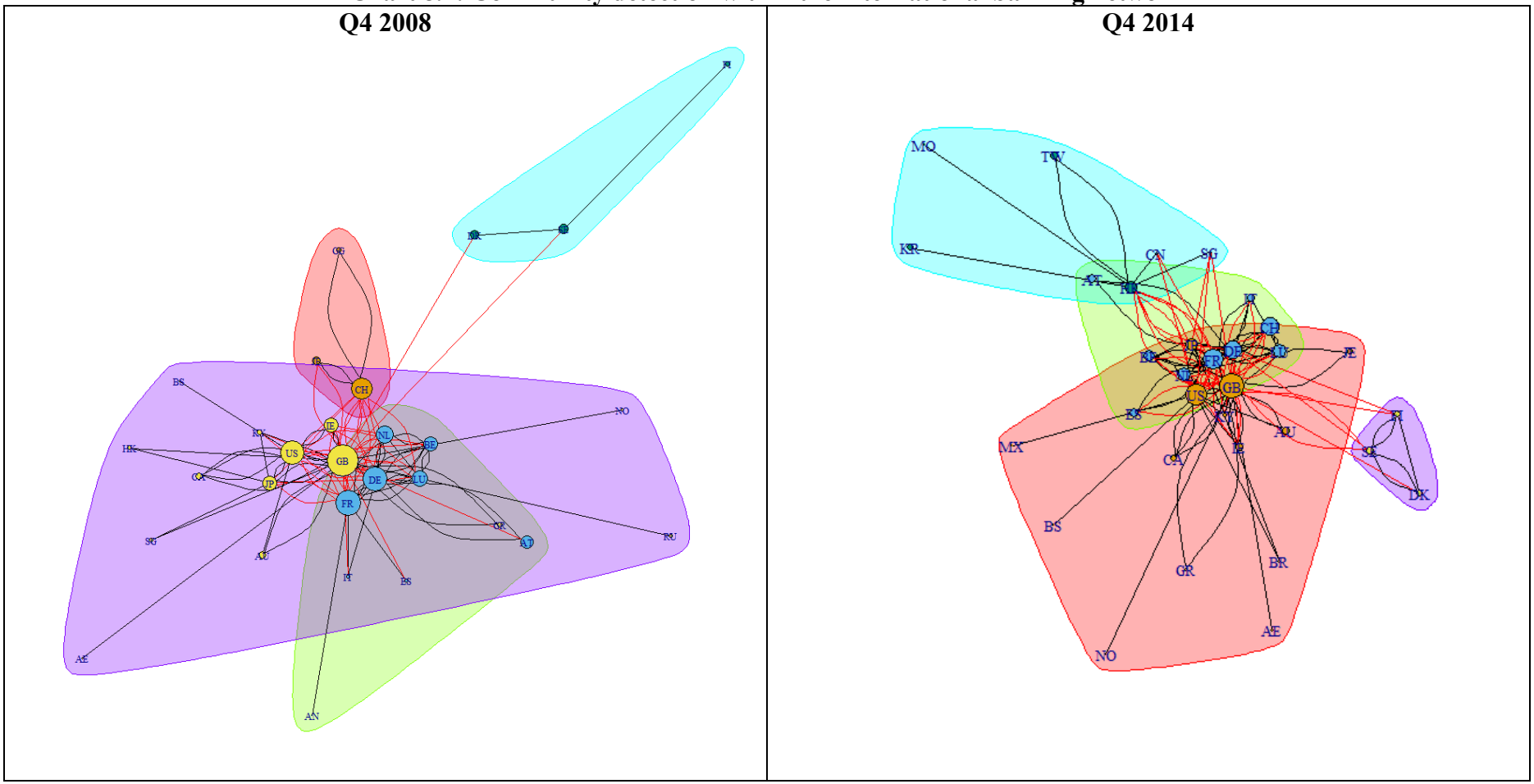
Over time, the international banking network became more fragmented with more communities composing the network. In Q4 1999, the network regrouped two communities with European countries on the one side and American-Asian countries on the other side. In Q4 2003, a third community appears for Scandinavian countries (Denmark and Sweden). From Q4 2008 onwards, the international banking network features four communities. As of Q4 2021, these communities cover Western Continental European countries (Austria, Belgium, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Spain and Switzerland), Nordic countries (Denmark, Finland, Norway and Sweden), East-Asian countries (China, Hong Kong, Macao, Singapore, Taiwan) and a final community including countries from the rest of the world, mainly Great Britain and countries from America (Brazil, Canada, Mexico, the United States), Middle East (Saudi Arabia, the United Arab Emirates), Oceania (Australia) and East Asia (Japan, South Korea). The larger number of communities over time suggests a regionalisation of cross-border banking flows, as cross-border banking activity keeps concentrating within specific groups of countries.

Chart 8.1: Community detection within the international banking network



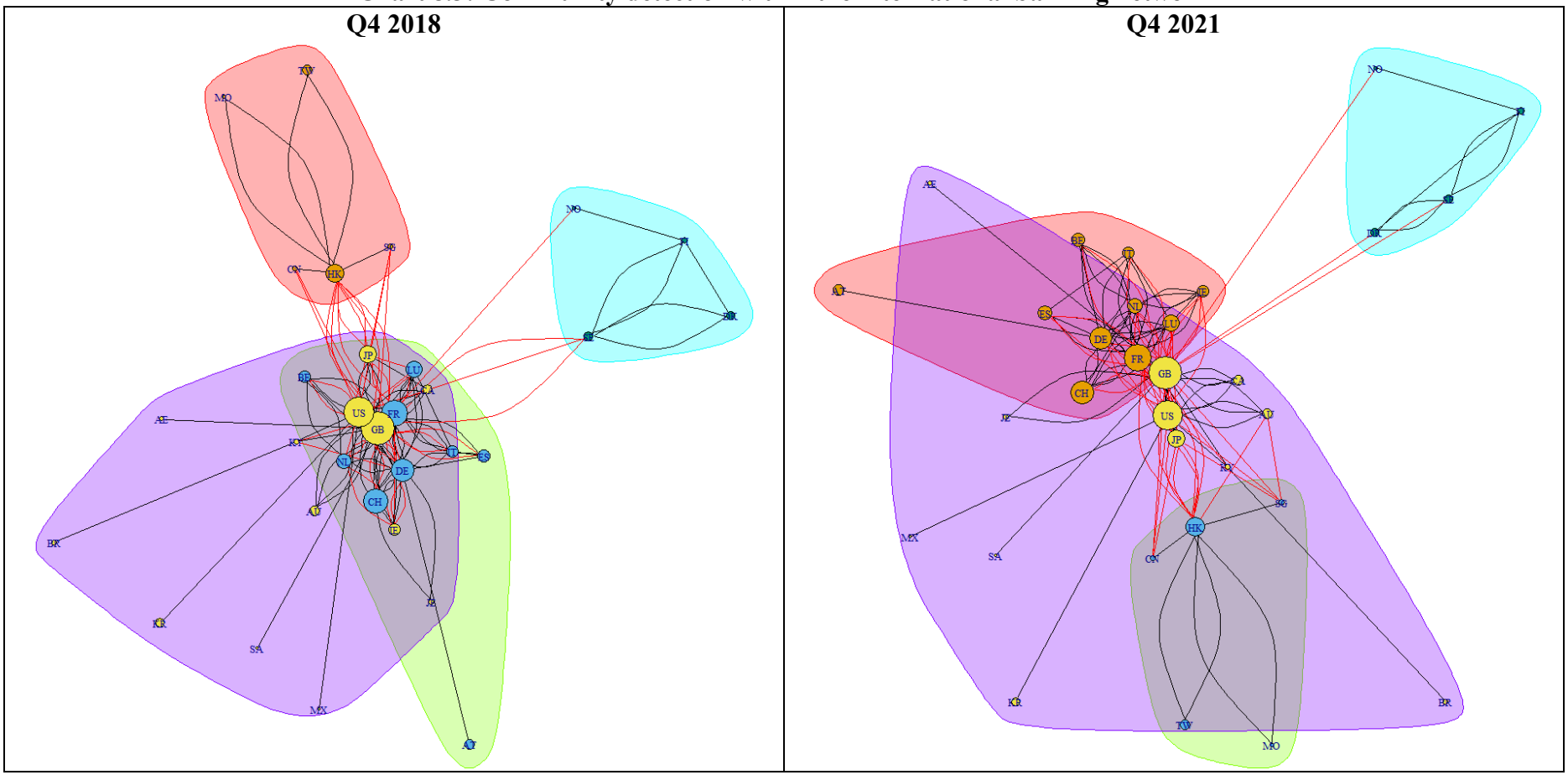
NB: Communities are identified with the Louvain algorithm (Blondel *et al*. (2008)). Edges represent cross-border claims and liabilities held by a given country *vis-à-vis* the other countries. The size of the nodes is proportional to its degree.

Chart 8.2: Community detection within the international banking network



NB: Communities are identified with the Louvain algorithm (Blondel *et al*. (2008)). Edges represent cross-border claims and liabilities held by a given country *vis-à-vis* the other countries. The size of the nodes is proportional to its degree.

Chart 8.3: Community detection within the international banking network



NB: Communities are identified with the Louvain algorithm (Blondel *et al*. (2008)). Edges represent cross-border claims and liabilities held by a given country *vis-à-vis* the other countries. The size of the nodes is proportional to its degree.

5. Conclusion

This paper examined the role of Luxembourg in the international banking system using cross-border banking positions in the Locational Banking Statistics compiled by the Bank for International Settlements.

Across European countries, Luxembourg features the largest banking positions relative to GDP, owing to its small size and the importance of its financial centre. Claims and liabilities held by banks resident in Luxembourg are mainly cross-border. This reflects Luxembourg's position as a small open economy, acting as an international financial centre, with mainly foreign-owned banks. Whether on the assets side or on the liabilities side, these cross-border banking positions are mostly loans and deposits between banks, including intragroup banking positions. Although secondary, the non-financial sector remains a relatively important counterpart in cross-border banking positions. This reflects the fact that foreign-controlled banks in Luxembourg provide financial services to support business activity and corporate investments by multinational enterprises outside Luxembourg. Cross-border banking positions in Luxembourg are mainly linked to Western European countries (especially the euro area) and North America (notably the United States), whether for assets or liabilities. By order of importance, the main country counterparts are Germany, France, Great Britain, Switzerland, Italy, the United States, the Netherlands and Belgium.

The analysis of the international banking network shows that Luxembourg's position resembles that of Belgium, Ireland, Japan and the Netherlands when considering the number of connections (or cross-border banking positions). These countries feature fewer connections than the United States, Germany and France. At the top of the network, Great Britain stands as the leading international banking centre. The structure of the international banking network evolves over time. Its evolution follows that of systemic stress in the financial system. In particular, during periods of financial stress, the density of connections stagnates or declines and the international banking network becomes less resilient. This was notably the case during the global financial crisis of 2007-2008 and the European sovereign debt crisis of 2010-2012. Over time, the international banking network has become more fragmented, with more communities composing the network. This suggests a regionalisation of cross-border banking flows, as cross-border banking activity concentrates within specific groups of countries.

In addition to exploiting BIS Locational Banking Statistics for Luxembourg, the paper shows that network analysis (section 4) can be a more suitable tool to analyse the position of Luxembourg within the international banking system, compared to the ratio of (cross-border)

banking positions-to-GDP (section 3). Indeed, the interpretation of the latter ratio can lead to overweight the position of Luxembourg in the international banking system, compared to other countries (chart 1, section 3).

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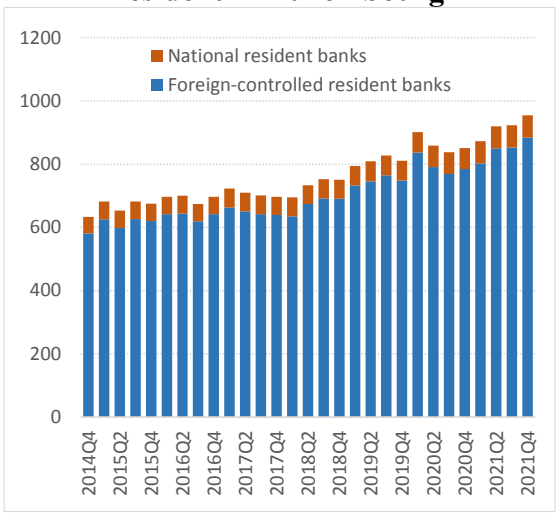
Appendix

A. Foreign-controlled resident banks *versus* national resident banks

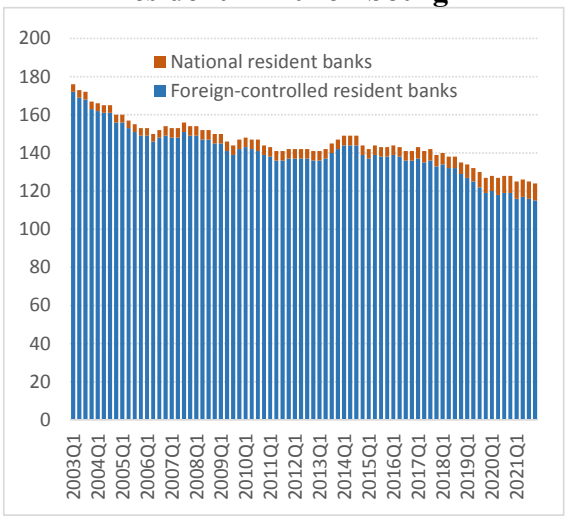
Charts A.1 and A2 present the total assets and total number of foreign-controlled banks *versus* national banks in Luxembourg. On average over the period Q4 2014-Q4 2021, foreign banks account for 92% of total assets in the Luxembourg banking sector. On average over the period Q1 2003-Q4 2021, foreign banks account for more than 96% of the total number of banks resident in Luxembourg.

Chart A.1: Total assets held by banks resident in Luxembourg



Source: BCL. Units: EUR billion

Chart A.2: Total number of banks resident in Luxembourg



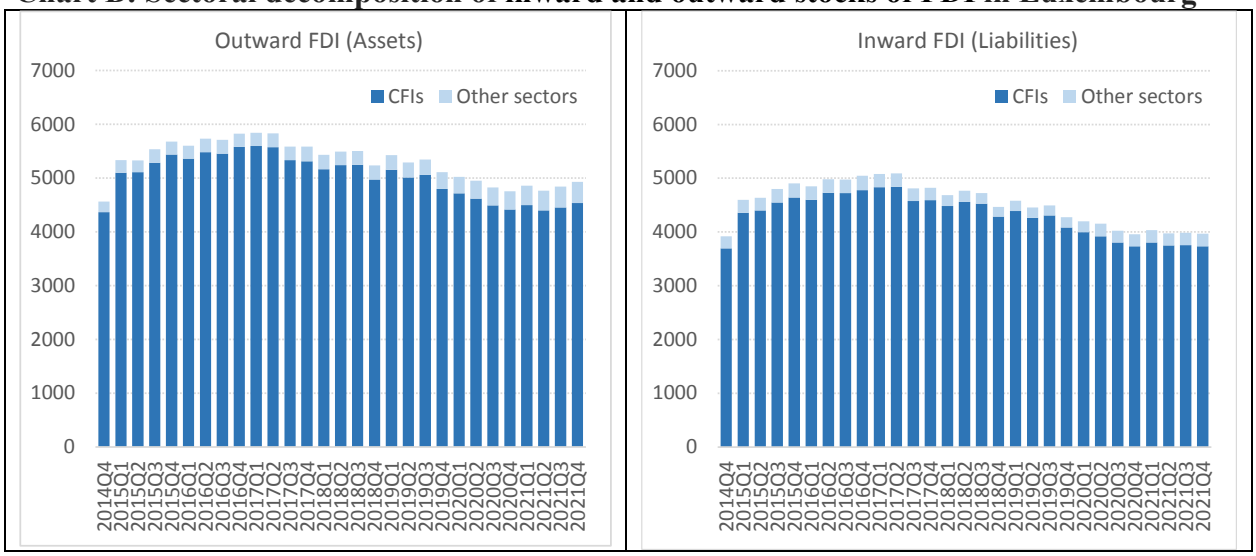
Source: BCL, Table 11.01. Units: Total number

Source: https://www.bcl.lu/en/statistics/series_statistiques_luxembourg/11_credit_institutions/index.html

B. Sectoral decomposition of inward and outward stocks of foreign direct investment

Chart B shows that in Luxembourg, captive financial institutions and money lenders (CFIs, sector S127) hold most of the inward and outward stocks of foreign direct investment (FDI) compared to other sectors. On average over the period Q4 2014 - Q4 2021, CFIs account for 95% of outward FDI (assets side) and inward FDI (liabilities side).

Chart B: Sectoral decomposition of inward and outward stocks of FDI in Luxembourg



Source: BCL. Unit: EUR billion. Foreign Direct Investment (FDI) stocks measure the total level of direct investment at the end of a quarter. The outward FDI stock is the value of the resident investors' equity in and net loans to enterprises in foreign economies (hence residents' assets). The inward FDI stock is the value of non-resident investors' equity in and net loans to enterprises resident in the reporting economy (hence residents' liabilities).

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