1. BANK-INVESTMENT FUND INTERCONNECTIONS AND SYSTEMICALLY IMPORTANT INSTITUTIONS IN LUXEMBOURG

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ABSTRACT

Recent international financial market volatility has reinforced the role of the Financial Stability Board's recommendation to enhance monitoring of the linkages between investment funds and the banking sector. Following the global financial crisis, Luxembourg's investment fund sector has exhibited sustained increases in the value of funds' total assets. This increase combined with elevated financial market volatility and risks from emerging market economies suggest that the connections between the investment fund sector and the banking system warrant enhanced monitoring from a macroprudential perspective. The results of this study show that the Luxembourg banking sector has some interconnections with the investment fund industry, notably on the liability side of banks' balance sheets, which may be relevant from a systemic risk perspective. External shocks to the investment fund sector could potentially spread to the domestic banking sector, thereby posing a threat to financial stability.

This paper applies network analysis tools to quantify the structural features of this bank-investment fund network that are relevant from a systemic risk perspective and to determine which banks are most significant within this network based on centrality measures. In a second step, the most pertinent measure is included in the *other systemically important institutions (O-SIIs) framework* to assess if the composition of identified systemic domestic banks changes when investment fund linkages are taken into account. The results reveal that the network of domestic banks and investment funds can be characterized as having a relatively low number of direct connections. Moreover, bank-investment fund and interbank distances are rather small and only a few institutions act as pivots within the network. Such a system could potentially propagate shocks very rapidly.

In terms of connectivity, out of a total of five commonly used measures, betweenness and PageRank appear the most suited for the investment fund and bank network in Luxembourg as the first best captures the banks that constitute pivotal points within the network and the second takes best account of the direct and indirect investment fund and bank connections. Even when the network analysis is not accounted for, this study shows that the standard O-SII assessment is already able to identify a large share of the banks with a high betweenness score as systemic. However, the same is not true for banks with a high PageRank score. When the latter measure is included in the O-SII assessment, two additional custodian banks turn out to be systemic.

1 INTRODUCTION

Links in the form of exposures and liabilities between investment funds and Luxembourg banks are of particular interest for domestic macroprudential authorities given their potential financial stability implications. In the event of a financial crisis, large shocks could be propagated through the financial sector. Indeed, domestic credit institutions' investment fund liabilities amounted to €123 billion or 16% of total assets as of 2016Q4, the majority of it provided by domestic investment funds (87%) and in the form of demand deposits (93%). The 16% share of total assets appears elevated compared to the 2%

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ratio of euro area investment fund deposits at euro area banks.[62] A large share of investment fund deposits could, for instance, be a source of potential risk if the fund sector were to face a significant redemption shock from investors. A redemption shock could potentially trigger a run on bank deposits by these same funds. Such a scenario could occur in market segments where investment funds engage in activities such as liquidity transformation or leverage and simultaneously offer frequent redemptions. If domestic banks suffer a run on their deposits by funds, this might have negative consequences such as fire-sales of part of their assets. Fire sales could trigger losses and defaults on interbank loans, or lead to a stoppage of financing provisions to other banks. Ultimately, this could propagate the shock within the interbank market. It is worth noting that an initial shock arising in the investment fund sector is not likely to occur in isolation or at the national level, but rather in the context of financial turmoil on a European or global scale, for example through a broader reassessment of risk premia. The structure and composition of Luxembourg's investment fund sector make it sensitive to developments and volatility in international financial markets.

Beyond the liability side of the balance sheet, domestic banks' exposure towards investment funds represents €13 billion or 2% of total assets. These exposures appear small but are highly concentrated as one single institution holds 28% and the top-5 institutions 54% of the €13 billion. Thus, it can still constitute a potential channel for contagion as the asset holdings are not fully diversified across banks.

The paper relies on network analysis tools to evaluate financial sector interconnections and focuses on three layers. First, the overall structure of a network consisting of Luxembourg banks' investment fund exposures and liabilities as well as the domestic interbank market exposures will be analysed in order to determine structural features relevant for systemic risk. Second, the institutions that are most important within this network will be identified by using centrality measures. Such measures quantify different aspects of importance within a network, such as the number of links, the distance to other network nodes, or the importance of the connected nodes. Ultimately, the goal will be to determine the most appropriate centrality measure to include as an additional indicator in the O-SII framework in order to ascertain if its explicit inclusion reveals banks to be systemic other than those identified in the standard assessment. The last point is of particular relevance so that macroprudential authorities are not limited to the analysis of existing financial interconnections but have a broad toolkit of measures aimed at fostering banks' resilience. Such a toolkit would include the O-SII framework, which allows authorities to assign additional capital buffers to systemic banks as well as complementary assessment tools. There is a need for additional analytical tools as the standard O-SII assessment has limitations in the sense that it does not entirely account for Luxembourg's specificity regarding investment fund linkages with banks and only considers financial sector interconnections in terms of direct exposures.[63] Reliance on direct exposures alone ignores the indirect exposures created through counterparties' counterparties. This paper aims addressing these national specificities.

62 ESRB EU Shadow Banking Monitor, No 1 / July 2016.

63 The interconnectedness indicators considered are inter-financial system assets and liabilities, as well as debt securities outstanding. See EBA/GL/2014/10 (GL on criteria for the assessment of O-SIIs).

2 NETWORK CONSTRUCTION AND CENTRALITY MEASURES

In this section we outline and describe the network set-up as well as the centrality measures used in the study. The underlying network is taken to be comprised of two components, the Luxembourg interbank market and the market involving investment funds and domestic banks. The interbank network is constructed from banks' large exposure data[64] reported according to regulation (EU) No 575/2013 on prudential requirements for credit institutions.[65] The bank-investment fund network is constructed from individual bank balance sheet data. In this case the more granular large exposure data is not employed since this only includes the asset side of the balance sheet and therefore ignores the more significant liability side.

Within the network model each bank, as well as the investment fund sector as a whole, is represented by a node. These nodes are connected via edges, which can either be directed or non-directed. This means that if bank A has an asset exposure towards bank B and vice versa, then this counts as two separate edges in the directed network and as only one edge that sums up both transactions in the non-directed network. The edges can either all have the same weight, usually equal to one, or they can be weighted according to the exposure amount or its inverse.

A resulting network, be it directed, weighted, or not, can be mathematically represented by an adjacency matrix A. This is an $(n \times n)$ matrix with elements a_{ij} describing the edges of the network, where n is equal to the number of nodes. In a directed network, a_{ij} represents the edge going from node j to node i. Furthermore, if the network is weighted, a_{ij} equals the exposure amount j has towards i.[66] If it is non-weighted, a_{ij} equals one if there is a link and zero otherwise. In a non-directed network, matrix A is symmetric ($a_{ij} = a_{ji}$) because no distinction is made between incoming and outgoing links. If there is a link between nodes i and j, then in the weighted network, a_{ij} equals the sum of asset exposures and liabilities and in the non-weighted network, it equals one. As banks do not lend to or borrow from themselves, the diagonal elements of A are always equal to zero. The following example should illustrate the difference between weighted and non-weighted, as well as directed and non-directed networks. If we consider a network where bank 1 lends an amount of 6 to bank 2, then the four adjacency matrices can be constructed as follows:

$$A_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix},\ A_2 = \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix},\ A_3 = \begin{pmatrix} 0 & 6 \\ 6 & 0 \end{pmatrix} \text{ and } A_3 = \begin{pmatrix} 0 & 0 \\ 6 & 0 \end{pmatrix},$$

Here matrix A_1 is non-directed and non-weighted, A_2 is directed but non-weighted, A_3 is weighted but non-directed, and A_4 is directed and weighted.

Based on the interbank-investment fund network, the following five commonly used centrality measures will be considered in order to assess banks' importance: (i) degree centrality, (ii) betweenness centrality, (iii) closeness centrality, (iv) eigenvector centrality, and (v) PageRank.

64 Intra-group exposures within Luxembourg are included. Branches that do not report large exposure data may also be included in case other banks have asset exposures towards them.

65 Regulation (EU) No 575/2013 of the European Parliament and the Council of 26 June 2013 on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012.

66 For centrality measures based on distances it can also be the inverse of the exposure amount.

i) Degree centrality

Degree centrality constitutes the most basic indicator to measure a node's importance within a network as it sums up the nodes' edges. In a directed network, one can distinguish between a bank's degree centrality in terms of lending funds (out-degree) and borrowing funds (in-degree). In a non-exposure weighted network, out-degree equals the number of outgoing edges and in-degree the number of in-coming edges. In an exposure weighted network, out-degree equals the sum of all asset exposures and in-degree the sum of all liabilities. Formally, out- and in-degree can be respectively written as follows:

$$D_i^{OUT} = \sum_{j=1}^{n} a_{ji} \quad \text{and} \quad D_i^{IN} = \sum_{j=1}^{n} a_{ij} \tag{1}$$

In a directed graph, bank i's overall degree centrality can be obtained as follows:

$$D_i = D_i^{OUT} + D_i^{IN} \tag{2}$$

In a non-directed network, overall degree centrality, out-degree, and in-degree are equivalent:

$$D_i = \sum_{j=1}^{n} a_{ji} = \sum_{j=1}^{n} a_{ij} \tag{3}$$

The standard O-SII framework interconnectedness indicators "intra-financial system assets", "intra-financial system liabilities" and "debt securities outstanding" essentially constitute degree centrality measures for an exposure-weighted directed network.

ii) Betweenness centrality

Betweenness centrality assigns high values to nodes that act as crossroads, thereby controlling network activity. In a non-exposure weighted network, the edges all have the same length while in an exposure weighted network, the length of an edge equals the inverse of the exposure amount. Following Freeman (1979), the betweenness centrality score of node i can be written as follows:

$$B_i = \sum_{i \neq j \neq k} \frac{\rho_{jk}(i)}{\rho_{jk}} \tag{4}$$

with j and k being nodes different from i, ρ_{jk} being the number of shortest paths connecting j and k, and ρ_{jk} (i) being the number of shortest paths connecting j and k that pass through i.

iii) Closeness centrality

Closeness centrality is based on the distance between a node and the other nodes in the network. In a non-exposure weighted network, all edges have the same length while in an exposure weighted network, the length of the edges corresponds to the inverse of their exposure amount. The closeness centrality score of node i is calculated as follows (Freeman, 1979):

$$C_i = \left(\sum_{j=1}^{n} d_{(i,j)} \right)^{-1} \tag{5}$$

with $d(i,j)$ being the shortest distance between nodes j and i. Thus, the closeness centrality score equals the inverse of the sum of all distances between i and the other nodes in the network.

iv) Eigenvector centrality

Eigenvector centrality constitutes an extension of degree centrality. Instead of simply summing up the number or weights of the edges of a node, they are further weighted by the centrality of the nodes to which they connect. The eigenvector centrality score of node i is defined as follows (Newman, 2004):

$$x_i = \frac{1}{\lambda} \sum_{j=1}^{n} a_{ij} x_j \tag{6}$$

with λ being a constant. Thus, in a non-exposure weighted network, the eigenvector centrality score of node i, namely x_i equals the sum of the eigenvector centrality scores of the nodes with which it has a connection divided by λ. This is the case because a_{ij}= 1 if a connection exists and zero otherwise. In an exposure weighted network, the eigenvector centrality score of i equals the sum of the eigenvector centrality scores of the neighbours weighted by the exposure amount a_{ij} and divided by λ. Hence, a node has a higher eigenvector centrality if it is connected to other nodes with a high eigenvector centrality score and in the case of a weighted network if the exposure amount is large. Equation (6) can be rewritten in matrix notation:

$$Ax = \lambda x \tag{7}$$

with A being the adjacency matrix, x an eigenvector of A and λ the corresponding eigenvalue. To guarantee the non-negativity of the obtained centralities, the chosen eigenvector should be associated with the largest eigenvalue of A (Newman, 2004).

v) PageRank

PageRank is a variant of eigenvector centrality that is employed by Google to rank websites according to their importance. A page is considered to be more important depending on the number links from other important websites that lead to it. In this study, the standard PageRank is applied to a directed graph and measures the centrality in terms of incoming links. As noted by Kaltwasser and Spelta (2015), the PageRank score of a website indicates the probability that a random walker who moves around within the web is present at the website in question. Mathematically, it can be written as follows:

$$PR_i^{in} = \alpha \sum_{j=1}^{n} \left[a_{ij} * min\left(\frac{1}{\sum_{k=1}^{n} a_{kj}}, 1\right) + \frac{1}{n} d_j^{out} \right] PR_i^{in} + \frac{1-\alpha}{n} \tag{8}$$

where it is common to assume $\alpha=0.85$. d_j^{out} equals 1 if j has no outgoing links (i.e. $\sum_{k=1}^{n} a_{kj} = 0$) and zero otherwise. In our context, equation (8) describes the importance of a node in terms of the funds it borrowed.

Relative to eigenvector centrality there are three major differences. First, since a directed network is considered, the term $n^{-1} d_j^{out}$ is added to assure that a random walker that arrives at a node j without outgoing links (i.e. $a_{ij} = 0$ and $\sum_{k=1}^{n} a_{kj} = 0$) will not get stuck but can leave the node. Second, the term $(1-\alpha)\ n^{-1}$ prevents the same random walker from getting stuck in a sub-graph which might have incoming links but no outgoing links. Third, if node j has outgoing links, the centrality PR_j^{in} will not get fully assigned to node i. Instead node i has to share it with the other neighbours of node j and gets only assigned the fraction $a_{ij} / \sum_{k=1}^{n} a_{kj}$ of PR_j^{in}.

Although less common in standard PageRank applications, an equation similar to (8) can also be written for outgoing links (Kaltwasser and Spelta, 2015):

$$PR_i^{out} = \alpha \sum_{j=1}^{n} \left[a_{ji} * min\left(\frac{1}{\sum_{k=1}^{n} a_{jk}}, 1\right) + \frac{1}{n} d_j^{in} \right] PR_j^{out} + \frac{1-\alpha}{n} \tag{9}$$

where d_j^{in} equals 1 if j has no incoming links (i.e. $\sum_{k=1}^{n} a_{jk} = 0$) and zero otherwise. Equation (9) gives the PageRank score of node i in terms of the funds it lends out. Equation (8) will be referred to as In-PageRank and equation (9) as Out-PageRank.

vi) Centralisation measures

Based on centrality measures, the structure of a network as a whole can be characterised via centralisation measures. These measures were developed by Freeman (1977) and are calculated from the degree, betweenness and closeness centrality scores of the individual nodes, based on the non-weighted and non-directed network. They describe the tendency of a single node to be more central than all other nodes and are expressed in per cent. An example of a network with 0% centralisation is a fully connected network, i.e. one that has the maximum number of possible edges. A network with 100% centralisation is a star, i.e. a graph in which the only existing edges connect one central node to all other nodes. Centralisation measures can generally be written as follows:

$$C = \frac{\sum_{i=1}^{n} [x^* - x_i]}{max \sum_{i=1}^{n} [x^* - x_i]} \tag{10}$$

where x^* corresponds to the highest centrality score of all nodes, the numerator equals the sum of the differences between x^* and all other centrality scores and the denominator equals the highest possible value of the numerator. As shown in Freeman (1977), the centralisation measures for degree, betweenness and closeness can be written as follows:

$$C_D = \frac{\sum_{i=1}^{n} [D^* - D_i]}{(n^2 - 3n + 2)} \tag{11}$$

$$C_B = \frac{\sum_{i=1}^{n} [B^* - B_i]}{(n^3 - 4n^2 + 5n - 2)} \tag{12}$$

$$C_C = \frac{\sum_{i=1}^{n} [C^* - C_i]}{(n - 2) / (2n - 3)} \tag{13}$$

3 THE OVERALL NETWORK STRUCTURE

Table 1 provides summary statistics of the measures regarding the amounts of financing exchanged within the network. Over the period 2015Q4-2016Q4, asset exposures and liabilities of banks towards investment funds have on average increased by 15% and 11% respectively. The average interbank transaction volume also went up by 50%. The highest investment fund exposure and liability also increased and the highest interbank transaction volume went up by more than €3 billion.[67]

67 This high amount is due to an intra-group transaction. The highest non intra-group transaction equals €1.4 billion.

Table 1:

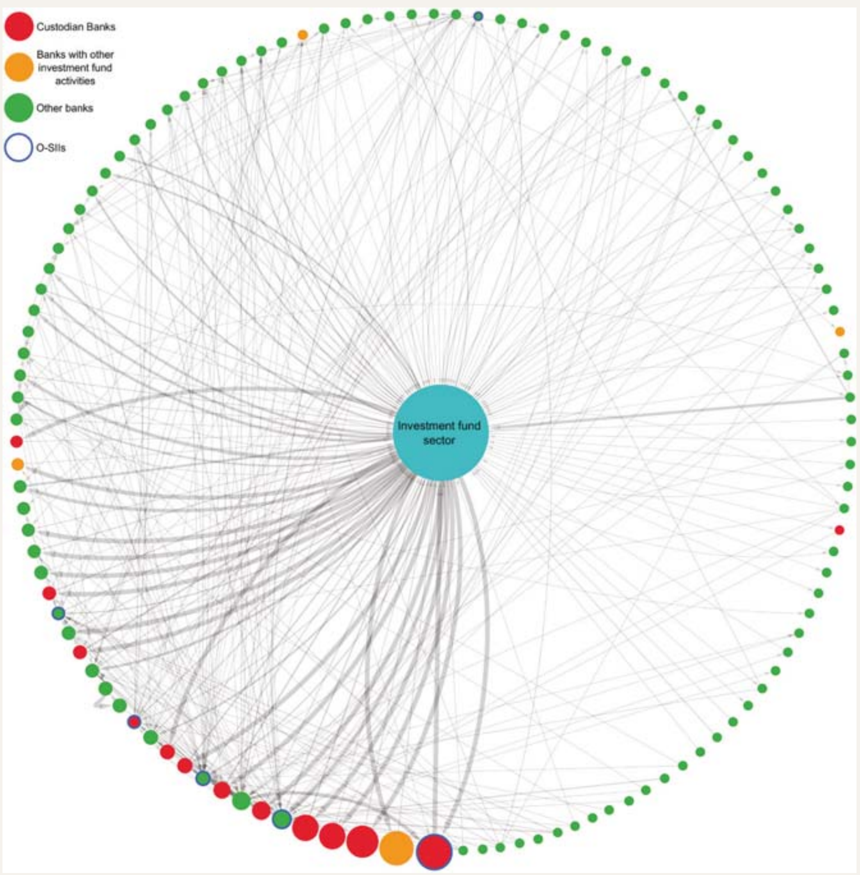
Volume measures at network level (in million EUR)

	AVERAGE		MAXIMUM	
	2015Q4	2016Q4	2015Q4	2016Q4
Investment fund asset exposure of banks	147	169	3 479	3 602
Investment fund liabilities of banks	1 359	1 506	15 302	16 779
Interbank transactions	40	60	452	3 746

Source: BCL.

Figure 1 provides a graphical representation of the network for 2016Q4. The size of the nodes is proportional to the PageRank score for incoming funds calculated using equation (8). The first observation that can be made from the network visualisation is that the most important banks in the network appear to be custodian banks[68], O-SIIs and one bank pursuing other activities linked to investment funds.[69] The second observation that can be made is that the network is highly centralised on the investment fund sector. Indeed, from the 117 banks active in the network, 92 have a direct connection to the investment fund sector.

Figure 1
The interbank network and bank-investment fund links, 2016Q4



Source: BCL
Notes: Custodian banks are marked in red, banks with other investment fund activities in orange, other banks in green and O-SIIs are depicted with a blue boarder. The size of the bank nodes is proportional to their PageRank score for borrowed funds, based on an exposure weighted network. The highest scoring bank is placed at the bottom and scores decrease clockwise. The direction of the arrows goes from asset holder (lender) to liability issuer (borrower). The thickness of the arrows represents the size of the transferred amount.

Table 2 presents different metrics for quantifying the general network structure in figure 1. The visual depiction of a high grade of network centralisation on the investment fund node is confirmed by the quantitative measures since all three metrics score around 70%. This indicates that the network's shape is closer to a star, with the investment fund node as centre, than to a network where most nodes are equally well connected. This result is worth mentioning as the centralisation measures are calculated from a network that does not include exposure-weighted edges, thereby potentially

68 Custodian banks are defined as the 14 banks with the most assets under custody as of 2015Q4. The definition does not exclude that custodians pursue other lines of business in parallel. One of the 14 banks is not included in the network because it has no interbank nor investment fund link.

69 The information is provided from an internal business model classification scheme of the CSSF.

underestimating the importance of the investment fund node since the amounts involved are usually larger than in the interbank market.

Table 2:

Metrics at the network level

	2015Q4	2016Q4
Degree centralisation (%)	75.3	73.2
Betweenness centralisation (%)	80.0	69.2
Closeness centralisation (%)	75.7	73.2
Diameter	4.0	4.0
Average distance	2.3	2.3
Diameter (only interbank)	8.0	6.0
Average distance (only interbank)	3.0	2.6
Density (%)	2.3	2.6
Average number of interbank connections	3.5	4.0

Source: BCL
Notes: Degree, betweenness and closeness centralisation, as well as the diameter, the average distance and the average number of interbank connections are calculated from a non-weighted undirected network. The density is calculated from a non-weighted directed network.

Distances between nodes within the network appear to be very limited since the network diameter, i.e. the longest distance[70] between any pair of nodes, comprises only four edges. The average distance of 2.3 edges between two nodes is also very short. Given the high level of betweenness centralisation, the short average distance can be to a significant extent explained by the fact that the investment fund node acts as bridge between bank node pairs. However, the 11 percentage point drop in betweenness centralisation over the period 2015Q4-2016Q4, combined with a low and decreasing average distance in the interbank sub-graph suggests that bank nodes may be increasingly acting as bridges within the network instead of the investment fund node. Generally, the short distances between nodes can potentially translate into a heightened threat of contagion following an initial shock in the network, for instance from the investment fund sector. The network also appears to be rather sparse since the density[71] of the network equals 2.6% with four interbank edges per bank. Consequently, a low number of existing edges combined with short distances within the network indicates that several well connected nodes, among which notably the investment fund sector, must act as pivots and could be considered as systemic in the network.

4 RESULTS AT THE NODE LEVEL

To determine the most systemic nodes, the aforementioned centrality measures are calculated. Table 3 summarises the results. Except for in- and out-degree, the score for each node is divided by the sum of the scores of all nodes and multiplied by 10 000 in order to make the indicators more comparable. Hence individual scores are expressed in basis points, the sum of the scores equals 10 000 and all measures have a mean value of 88.

70 Distance refers to the shortest path between two nodes.

71 The density equals the ratio of the effective number of existing edges to the maximum number of possible edges for a directed network.

Table 3:

Centrality results for the nodes

	STD. DEV.	MIN.	MEDIAN	90TH PERC.	MAX.
In-degree	8	0	1	6	76
Out-degree	8	0	1	5	82
Betweenness	630	0	0	106	6 799
Closeness	19	2	93	93	93
Degree	431	0	6	121	4 592
Eigenvector centrality	252	0	4	167	2 032
In-PageRank	342	15	23	109	3 663
Out-PageRank	346	16	23	109	3 671

Source: BCL

Notes: 2016Q4 data. Std. dev. stands for standard deviation, 90th perc. for 90th percentile. Except for in- and out-degree, the sum of the scores per measure equals 10000 and the mean 85. In- and out-degree are calculated from the directed non-weighted network. Betweenness, closeness, degree and eigenvector centrality are calculated from the undirected exposure-weighted network. In- and Out-PageRank refer to the measures for incoming and outgoing funds respectively and are calculated from the directed exposure-weighted network.

For each measure the highest score is obtained by the investment fund node, in line with the previous network centralisation results. The median and 90th percentile values for in- and out-degree respectively also lend support to the finding that only a small number of nodes within the network are very well connected. The betweenness scores are widely dispersed, as indicated by the highest standard deviation of all indicators, and concentrated on only a few nodes since the investment fund sector scores 68% of all points, 12 banks score between 1% and 5% of all points, and 94 banks score 0 points. This illustrates that, apart from the investment fund node, there are only a couple of banks that function as pivots within the network. The very low standard deviation of the closeness indicator further demonstrates that distances between nodes are not only on average very short but that they are distributed almost uniformly. This suggests that the network can be considered as compact.

Degree and eigenvector centrality produce scores that are more evenly distributed than betweenness on the right side of the distribution, with the former having a higher standard deviation due to the much higher score of the investment fund node. Nevertheless, the scores of both measures are still very much concentrated, with the top-10 nodes scoring more than 70% of all points. This is mostly due to the significant investment fund links of a sample consisting mainly of custodian banks. As a consequence, the top-12 most systemic banks identified by degree centrality include 9 custodian banks and the top-12 identified by eigenvector centrality 10 custodian banks, often without significant interbank ties. In addition, despite the fact that degree considers only first-order exposures and eigenvector centrality also higher-order exposures, both measures tend to yield similar results for the sample in question. Indeed, if the investment fund node's score is excluded, the correlation between both measures is 0.97. This indicates that, for this paper's dataset, eigenvector centrality does not add much information to the scores produced by the basic degree measure. This is likely due to the fact that for the network under consideration, eigenvector centrality, unlike PageRank, has the drawback that it assigns the full centrality of the dominant investment fund node to all neighbouring nodes. This means that a bank with a large investment fund connection, but no interbank links, might get a higher centrality score than a bank with a somewhat lower investment fund connection but considerable interbank ties. However, from a systemic risk perspective the latter bank should be more important than the former. Thus, in the context of this analysis, the more sophisticated PageRank measure is better suited for identifying systemic banks. Indeed, both PageRank measures identify a set of banks consisting not only of custodians but also of banks with significant interbank activity as the most systemic banks. Like in- and out-degree, they also make it possible to assess if banks tend to be specialised in either borrowing or lending funds. Correlations[72] between the degree measures and between the PageRank measures are equal to 0.56 and 0.66 respectively, which indicates that banks that are active in lending out funds to the investment fund sector or domestic banks also tend to receive more funds from these entities. Hence, banks that are systemic in terms of their interconnectedness are likely to simultaneously have asset exposures and liabilities towards other nodes in the network.

The ultimate goal of determining the most important banks within the interbank-investment fund network is to include the findings within the O-SII framework in order to assess if the composition of the list of identified systemic banks should be altered. The two measures that are best suited for this purpose are betweenness and PageRank. The former because it identifies a small set of banks that act as likely pivots for spreading shocks towards the rest of the banking sector, the latter because it takes into account first-order and higher-order exposures of banks while giving more weight to interbank connections than eigenvector centrality. In-PageRank, which measures entities importance in terms of receiving funds, should be particularly pertinent as banks' liabilities towards the investment sector are notably higher than their exposures. Degree centrality has the clear drawback vis-à-vis PageRank that it only considers first-order exposures while the closeness measure is not a useful indicator to be included in the O-SII framework as the quantitative difference between most scores is marginal.

5 THE O-SII ASSESSMENT INCLUDING CENTRALITY MEASURES

Table 4 identifies the types of banks that are most important according to PageRank and betweenness. The shares are calculated relative to the sum of all bank scores while excluding the investment fund node. The categories are not mutually exclusive, except for custodian and other investment fund activities. Regarding betweenness, domestically oriented commercial banks (DOCBs)[73] account for 58% of total banking sector scores. Hence, banks with strong links towards the real sector of the Luxembourg economy are also those which are highly active in the interbank market and are positioned as crossroads within the investment fund-interbank network.

Table 4:

Share of total bank centrality scores by type (in %)

	CUSTODIAN	OTHER IF ACTIVITIES	DOCB	O-SII
Betweenness	18	0	58	45
In-PageRank	37	9	10	16
Out-PageRank	32	2	13	25
Average PageRank	35	5	12	20
No. of banks	13	4	7	6

Source: BCL

Notes: 2016Q4 data. "Other IF activities" refers to banks that pursue investment fund activities different from custody services. DOCB refers to domestically oriented commercial bank. Apart from "custodian" and "other IF activities", the categories are not mutually exclusive.

72 Correlations are calculated only from bank scores, i.e. excluding the investment fund node which constitutes a large outlier. If the latter is included, PageRank correlation equals 0.97 and degree correlation 0.93.

73 DOCBs are defined as the seven banks with the highest amount of liabilities from domestic non-financial corporations and households. They account for 85% of the total.

O-SIIs, which include several DOCBs, score almost half of the betweenness points available for the whole banking sector. This indicates that the O-SII framework already accounts to a large extent for the information content of the betweenness indicator. In other words, many banks with high betweenness have already been identified as systemic. This is to a much lesser extent true for banks with high PageRank scores and especially for the In-PageRank, as O-SIIs score 16% of all available points, while institutions with strong investment fund business links such as custodians and banks with other investment fund activities score 46% of all points. We cannot exclude that some banks have not been identified as systemic, although they nevertheless might be "too interconnected to fail". Hence, table 5 presents the number of banks by type that would have been eligible to be identified as an O-SII[74] if some version of PageRank had been included in the 2016 assessment. The standard O-SII assessment is based on four equally weighted criteria, of which one is interconnectedness.[75] Thus, PageRank can either be included as a separate fifth criterion or within the existing interconnectedness criterion. Note that the standard assessment identified six O-SIIs. If included as a fifth criterion, than a 20% weighting appears the most plausible in order to have five equally weighted criteria. Other weights are also included to assess the sensitivity of the results.

Table 5:

Number of O-SIIs with the inclusion of PageRank

PAGERANK INCLUDED AS/IN	INDICATOR	WEIGHT	CURRENT O-SIIS	CUSTODIANS	OTHER BANKS
Separate criterion	In-PageRank	5%	6	0	0
		10%	6	1	0
		15%	6	1	0
		20%	6	2	0
		25%	6	2	1
Separate criterion	Out-PageRank	5%	6	0	0
		10%	6	0	0
		15%	5	0	0
		20%	5	0	0
		25%	5	0	0
Separate criterion	Average PageRank	5%	6	0	0
		10%	6	0	0
		15%	6	0	0
		20%	5	0	0
		25%	5	1	0
Interconnectedness criterion	In-PageRank	5%	6	0	0
	Out-PageRank	5%			

Source: BCL

Notes: 2016 O-SII assessment, based on 2015Q4 data. PageRank can be included as a separate fifth criterion or as indicator within the existing interconnectedness criterion. "Weight" refers to the share with which PageRank enters the O-SII score. "Current O-SIIs" corresponds to the six banks identified in the 2016 standard assessment. "Custodians" refers to the additional number of custodians that were not identified as O-SII in the standard framework. Current O-SIIs already includes two custodians.

74 In this context, being eligible means that a bank scores at least 275 basis points in the O-SII assessment. See EBA/GL/2014/10 (GL on criteria for the assessment of O-SIIs).

75 The other three criteria are size, importance, and complexity/cross-border activity.

If the In-PageRank metric, which captures banks' liabilities towards investment funds, was incorporated as a separate criterion, the six current O-SIIs would still qualify as systemic. Note that the O-SIIs identified to date already include two custodian banks. Additionally, if the weight was 10% or more, one additional custodian would qualify as a systemic bank and at 20% two additional custodians would qualify as such. At 25%, a bank that is very active in the interbank market would also be eligible for being an O-SII. The most plausible weight for a fifth criterion though, as previously mentioned, is 20% as this would make all five criteria equally-weighted. Under the other three scenarios, not all current O-SIIs would qualify as systemic depending on the weighting, without additional custodians or other banks qualifying as such. The only exception is the 25% weighting for the average PageRank. Overall these results appear to be intuitive as many domestic banks, notably custodians, are dependent on inflows of funding from the investment fund sector. As noted previously, those banks' asset exposures are comparably smaller. Given that the largest potential risk arising from interconnections comes from the liability side of banks' balance sheets, In-PageRank seems to be the most appropriate measure and a 20% weighting is the most plausible choice for the O-SII assessment.

6 CONCLUSION

The network consisting of interbank exposures and financial links between banks and investment funds has a rather low number of direct connections, the individual nodes are not too distant from each other and a relatively small set of banks act as pivots within this network. Such a network structure could potentially propagate shocks very rapidly. At a more granular level, the most important institutions functioning as crossroads are domestically oriented commercial banks. Four of these banks have already been identified as systemic under the EBA guidelines for O-SII assessment. On the other hand, the most important institutions in terms of first- and higher-order exposures and liabilities towards investment funds and domestic banks are custodians. So far, only two such banks have been identified as being systemic. A modified O-SII assessment methodology, including a measure to account for this type of centrality, reveals two further custodian banks to be systemic. The results of this study illustrate the effect of including an additional interconnectedness indicator accounting for bank-investment fund linkages in order to enhance the standard O-SII framework in Luxembourg.

REFERENCES

Freeman, L. C. (1979). Centrality in social networks: Conceptual clarification. *Social networks, 1*(3), 215-239.

Kaltwasser, P. R., & Spelta, A. (2015). Systemic risk in the interbank market with heterogeneous agents. *Macro-Risk Assessment and Stabilization Policies with New Early Warning Signals*, SSH.2012.1.3-1.

Newman, M. E. (2004). Analysis of weighted networks. *Physical review E, 70*(5), 056131.