ESRB
European Systemic Risk Board
European System of Financial Supervision

ESRB Occasional Paper

No. 7/July 2015

Network analysis of the EU insurance sector

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The ESRB's Insurance Expert Group provided useful comments and has contributed extensively to the data collection for this research. The ESRB's Expert Group on Interconnectedness also provided useful comments.

Contents

Executive summary

This paper contains an analysis of the network of the 29 largest European insurance groups and their financial counterparties. Insurance companies have direct exposures to other insurers, banks and other financial institutions through the holdings of debt, equity and other financial instruments. These exposures can cause direct contagion and thereby the spread of systemic risks. This analysis focuses on direct linkages between EU insurers and banks. Sectoral data show that at least 20% of insurers' assets are investments in banks. As a result insurers are an important source of funding for banks. This paper adds to the expanding research on financial market networks and on systemic risks in the insurance sector.

This paper considers these 29 insurers' top ten exposures for each instrument. They represent about 10% of their total assets, which indicates a low level of concentration. More than half of the reported exposures result from investments in bonds issued by banks. In addition, some insurers have a higher exposure to banks within their own financial conglomerate. Other exposures reported include securities lending transactions and repos (both mostly collateralised with cash), as well as interest rate swaps.

The network of insurance groups, banks and other financial institutions displays low interconnectivity overall, compared for instance to the interactions of the largest EU banks alone. The density of the network is relatively low. The characteristics of this network illustrate that credit and funding events cannot be expected to spread easily through direct contagion. The network shows a core-periphery structure, which partly results from the scope of the data collection: only 29 insurance groups reported exposures, and thus they form the core, while institutions from which no information was collected are in the periphery.

However, the systemic importance of a few insurance groups stands out. These groups show higher levels of connectivity, proximity to credit events within the network, and importance for financial flows. Network measures for each of these aspects refer to the criteria of interconnectedness and substitutability, which are well-known in the policy debate on the systemic relevance of financial institutions. While the particular form of institutional importance varies significantly across insurance groups, the central role of a few "champions" in this network may require supervisory attention.

Size, in terms of total assets and issued capital is an important factor but not the only one, determining an insurer's centrality in the network. Measures of the centrality of the banking counterparties also show a positive, non-linear relationship with the size of the banks.

Distress in the network, as expected, causes only limited direct contagion. Insurers' solvency positions are sufficiently large and their concentration of exposures is sufficiently low as to avoid direct contagion from a default of one of their counterparties, ultimately leading to their own default. This is also true for simultaneous distress at their top ten banking counterparties, with the exception of two insurance groups.

The analysis presented is partial, as it relies only on the information collected. In particular, the analysis would benefit from including the exposures of banks and other financial institutions to insurers. This could be a useful enhancement for consideration in the future.

1. Background and aims

Bilateral exposures between financial institutions can cause direct contagion and thereby the spread of systemic risks. Financial institutions are connected to each other by a series of bilateral transactions. In normal times, institutions' connections may result in efficient risk transfer. But in crises, connections can facilitate contagion, as initial problems lead to chains of defaults and liquidity shortages. The potential for contagion resulting from interconnectedness is a key component of systemic risk.

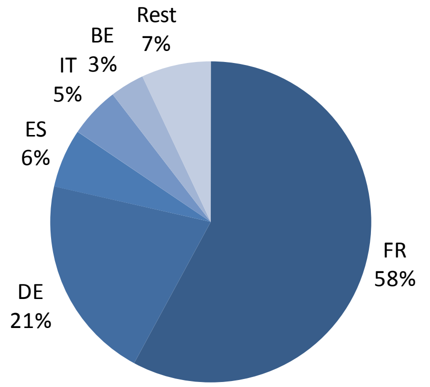
This analysis focuses on direct linkages between EU insurers and banks. As a first step towards understanding the mechanisms of direct contagion, the ESRB has analysed the structure and resilience of the European Interbank Market (Alves et al., 2013). This analysis focuses on the exposures of insurers to banks instead.

At a sectoral level insurers and banks are interlinked mostly through insurers' investments in bank debt. With assets worth more than EUR 8 trillion, insurers in the EU constitute an important part of the financial sector (Insurance Europe, 2015). The largest part of these assets is invested in sovereigns (27% of insurers' assets)[7] and the second largest part is invested in banks: 16% of insurers' assets are bank bonds and 4% are deposits and cash held with banks (EIOPA, 2015). In addition, insurers invest indirectly in banks' debt and equity through investment funds. Insurers are also counterparties with banks in derivatives and securities financing transactions (Keller et al., 2014).

As a result, insurers are an important source of funding for banks (IMF, 2015). This is especially true for specific market pockets. For instance long-term bank debt: 97% of the bank debt held by insurers has a maturity of more than two years.[8] And in some countries covered bonds: at year-end 2014 insurers in the euro area held 15% of the EUR 1 trillion outstanding covered bonds, issued by banks in the euro area; more than half of this was held by French insurers (Chart 1). Moreover, insurers mostly invest in banks of their own country, which suggests concentration of exposures (Chart 2).

[7] See ESRB (2015) for more details on these sovereign holdings.
[8] Source: ECB statistics, to be found at: http://www.ecb.europa.eu/stats/money/icpf/html/index.en.html

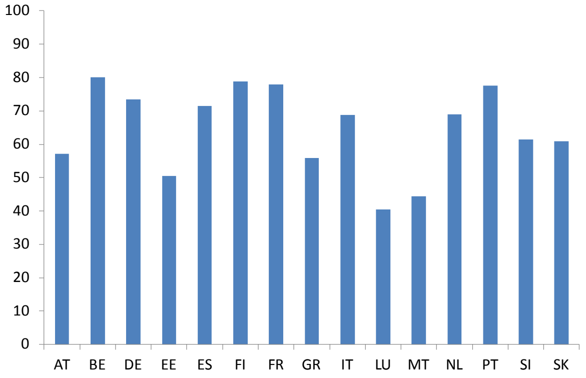
Chart 1: Distribution by country of Insurers' holdings of covered bonds issued by banks



Source: ECB. Notes: Euro area countries only. The distribution by country refers to the countries in which the insurance companies are based.

Chart 2: Home bias of insurers' holdings of deposits and bank debt

(percentage home country to entire euro area)



Source: ECB and own calculations. Notes: Euro area countries only. The bars represent for each country the percentage of insurers' holdings of deposits and bank debt of banks of the same country to insurers' total holding of deposits and bank debt of banks in the entire euro area.

A network analysis allows the assessment of possible contagion through these direct linkages. The key questions are as follows.

- To what extent are the largest EU insurers directly connected with banks and other insurers? What does the network of large EU insurers and banks look like? What are the most central entities? What types of direct connection are dominant?

- To what extent can distress in (part of) the banking sector have a direct impact on insurers' solvency? To what extent can distress in (part of) the insurance sector have a direct impact on (other) insurers' solvency?

In order to observe the network of these linkages the ESRB requested information from EIOPA on the exposures of the 29 largest EU insurance groups. These insurers (Annex 1) account for EUR 5 trillion of assets, more than 60% of the total EU insurance market. Specifically, each insurance group was asked to list their top ten exposures (at end-2013) to banks (debt, equity and deposits), insurers (debt and equity) and financial intermediaries (derivatives, repos and security lending positions). Consequently the ESRB received from each insurance group eight lists of their top ten exposures. In addition, data on the main balance sheet items and solvency positions were collected.

This network analysis is a partial analysis. The network does not contain all exposures between insurers and banks. First, it does not cover the interconnections between insurers through reinsurance contracts. Second, it does not include indirect connections through market price channels and information channels.[9] Third, the analysis does not contain the exposures of banks to insurers, because only insurers have been surveyed. Nevertheless, even though it is partial, this network analysis is a first step in understanding the relationships between insurers and banks.

[9] For studies on indirect connections see Billio M. et al. (2011); Engle, Jondeau and Rockinger (2012); Chen et al. (2014); Podlich and Wedow (2013) and Minderhoud (2003).

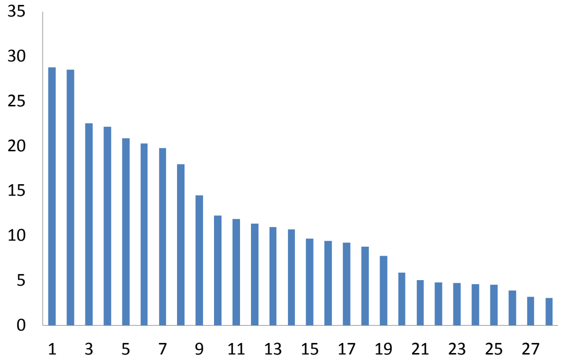
This paper is structured as follows. Section 2 gives a brief overview and an assessment at aggregated level of the data reported. Section 3 analyses the network of insurers only and section 4 the entire network of insurers, banks and other financial institutions. In section 5 distress in different entities of the network is simulated and analysed. Section 6 concludes.

2. Data reported

The top ten exposures reported represent about 10% of the total assets of the insurers, suggesting a low level of concentration. The insurers reported their top ten exposures to banks (through (covered) bonds, shares and deposits), other financial intermediaries (through securities lending, (reverse) repos and derivatives) and other insurers (through bonds and shares). This totalled EUR 545 billion, which is a significant but not a very large part of their EUR 5 trillion of assets.[10] In a similar vein, the top ten reported bank debt exposures constitute on average 12% of total debt exposures (Chart 3).

Chart 3: Top ten bank debt exposures of 28 insurers

(percentage of total debt exposures)



Source: ESRB. Notes: The bars depict the bank debt exposures reported by each insurer as a share of their total bond holdings as at end-2013. One insurer did not report total debt.

Most of the exposures reported are bank bonds. Exposures to banks and bank-led financial conglomerates represent around 95% of the reported exposures, while exposure to insurers, insurance-led financial conglomerates and other financial institutions account for around 5% (Chart 4).[11] More than half of the exposures reported are investments in bonds issued by banks. Half of these are covered bonds. Other exposures reported are deposits (13%), securities lending (10%), derivatives (7%), bonds issued by other insurance companies (6%) and (reverse) repos (5%). The 29 insurers hold limited amounts of shares, either issued by banks (4%), or other insurance companies (2%) (Chart 5).

[10] On average the 29 insurers held assets worth EUR 179 billion. The largest insurer held EUR 641 billion and the smallest held EUR 9 billion.

[11] Exposures have been reported at a consolidated sectoral level: exposures to banks within the same group or financial conglomerate have been reported but exposures to insurers within the same group have not been reported. Intragroup exposures in insurance groups are thus disregarded, whereas inter-sectoral exposures within financial conglomerates are included. This allows the analysis to focus on exposures of insurance groups, while at the same time looking at contagion between banks and insurers within financial conglomerates. Bank-led financial conglomerates are conglomerates that have more banking activities than insurance activities and insurance-led conglomerates are conglomerates that have more insurance activities than banking activities.

Chart 4: Share of reported exposures by financial intermediary

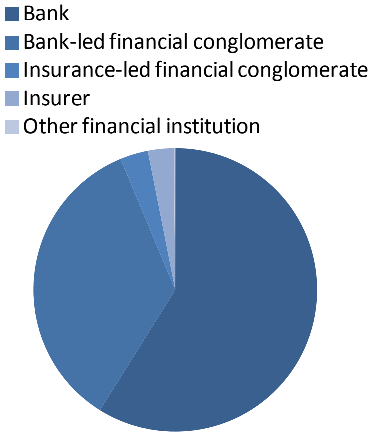
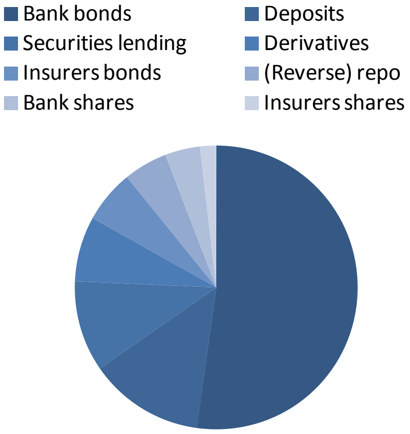


Chart 5: Share of reported exposures by financial instrument



Source: ESRB. Note: The pie charts depict the shares of the total exposures reported by counterparty and by instrument as at end-2013.

Some insurers have a high exposure to a bank within their own financial conglomerate. On average insurers have a higher exposure to banks that are not part of a financial conglomerate than to banks that are part of a financial conglomerate. But exposures to the former have a distribution with a long left tail while exposures to the latter have a long right tail (Chart 6). This shows that some insurers, probably those belonging to a bank-led financial conglomerate, have a relatively high exposure to banks within their own group. In addition, the distribution of exposures through deposits is skewed to the right, suggesting again that some insurers hold large deposits, possibly with the bank of the same financial conglomerate (Chart 7). Securities lending, (reverse) repos and financial derivatives are on average relatively small exposures, but with a few outliers.

Chart 6: Distributions of the exposures to banks and bank-led financial conglomerates

(percentage of total exposures reported)

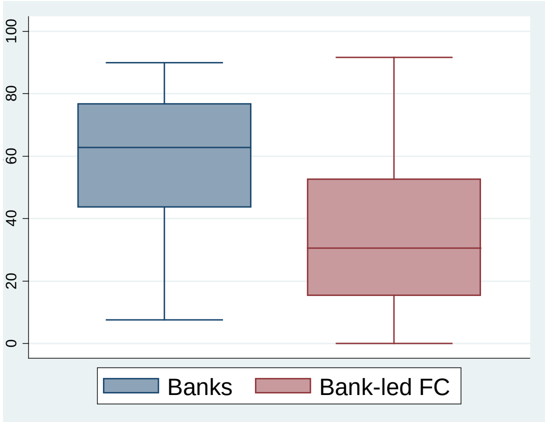
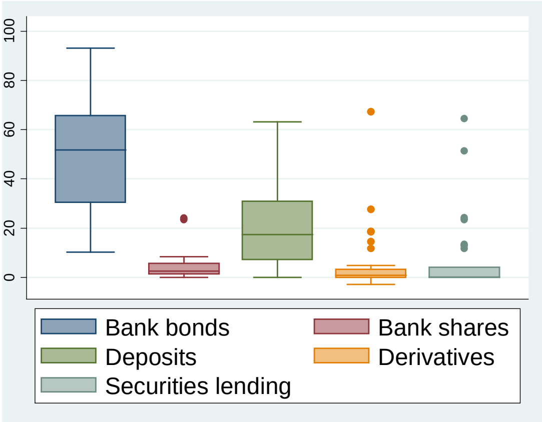


Chart 7: Distributions of the exposures to different financial instruments

(percentage of total exposures reported)



Source: ESRB. Notes: The box plot shows the interquartile range (IQR) between the 1st and 3rd quartile and the median (end-2013). The line shows the upper adjacent value (defined as the largest observation that is less than or equal to the third quartile plus 1.5*IQR) and lower adjacent value (defined as the smallest observation that is greater than or equal to the first quartile minus 1.5*IQR). Dots represent the outlier values.

Cash is the most-used collateral and interest rate swaps are the main derivatives in insurers' portfolios. The 29 insurers reported EUR 89 billion (gross market value) of exposures resulting from securities lending and repos. More than 50% of these are collateralised by cash (Chart 8). As regards the reported derivatives positions (EUR 41 billion of gross market value), two-thirds are interest rate swaps. Currency derivatives account for less than 5%, which signals that the large international groups either have little currency risk to hedge, or mostly hedge their currency risks without derivatives (Chart 9).

Chart 8: Share of collateral type used in securities lending and (reverse) repos

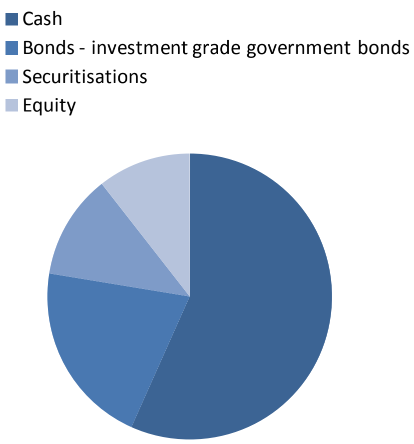
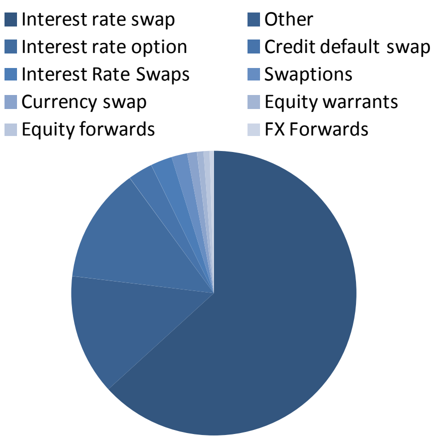


Chart 9: Share of derivative type



Source: ESRB.

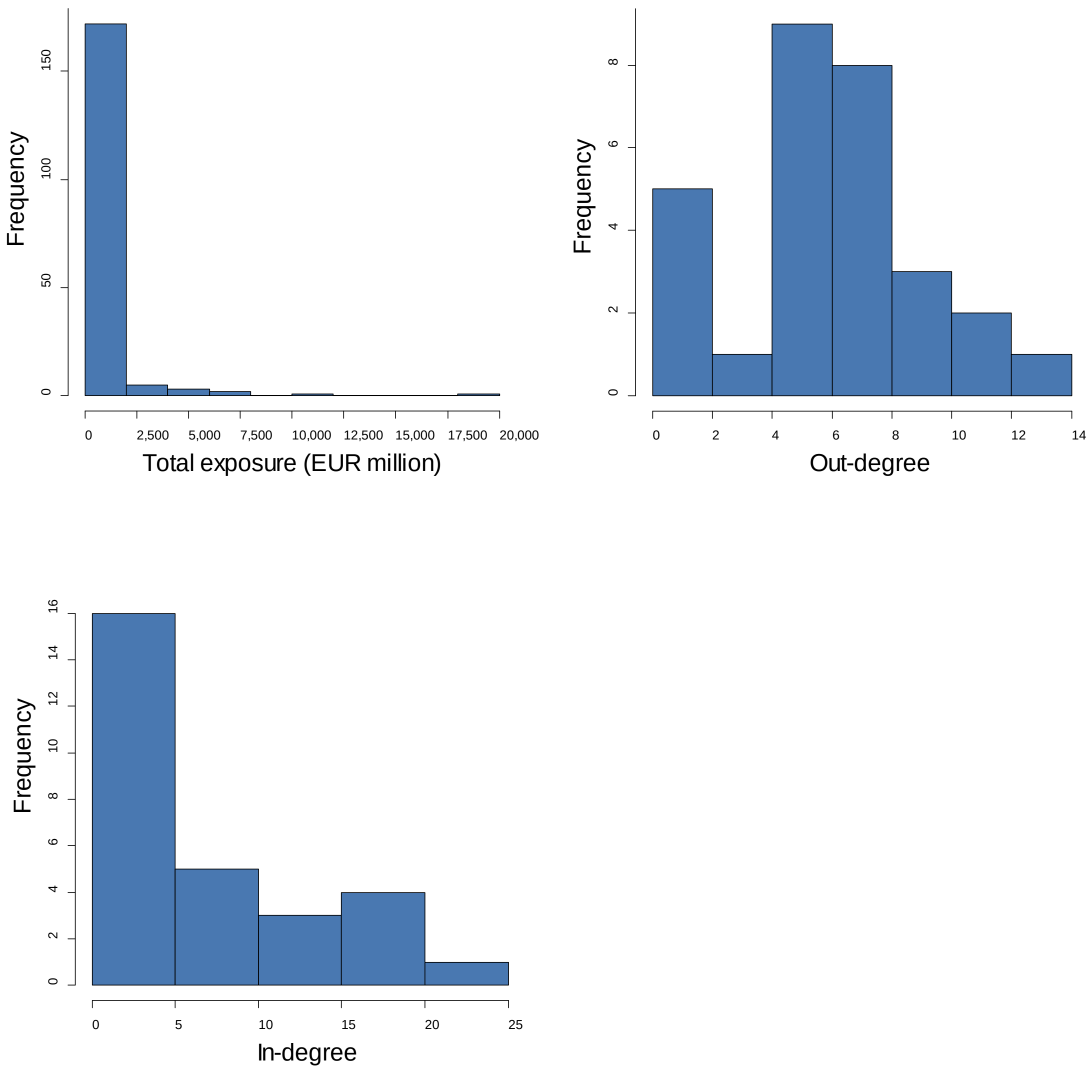
3. The insurance network

Insurers invest in the debt and equity of other insurers and thereby form a network of exposures. The insurance network is constructed on the basis of their cross-exposures only (the exposures to banks and other financial institutions are added in the next section). The characteristics of the insurance network are as follows (Chart 10).

- The size of the exposure is given by the (gross) market value of the exposure. The size distribution (i.e. of individual exposures vis-à-vis each other) is skewed, with almost all exposures corresponding to a total exposure of less than EUR 2 billion.
- The out-degree of insurer A is the number of A's exposures. A high out-degree means that an insurer is exposed to many other counterparties and could hint at, for example, a high degree of diversification of counterparty risk. In contrast, a small out-degree would mean that an insurer's exposures are concentrated. Most insurers have an out-degree of four to eight counterparties, and the distribution is fairly normal.
- The in-degree of insurer B is the total number of insurers with an exposure to B. A high in-degree would mean that insurer B has liabilities vis-à-vis many other insurers and its default would have an impact on a wide range of insurers. Out of the 29 reporting insurance groups eight have an in-degree of ten or more.[12]

[12] The maximum possible in-degree is 29.

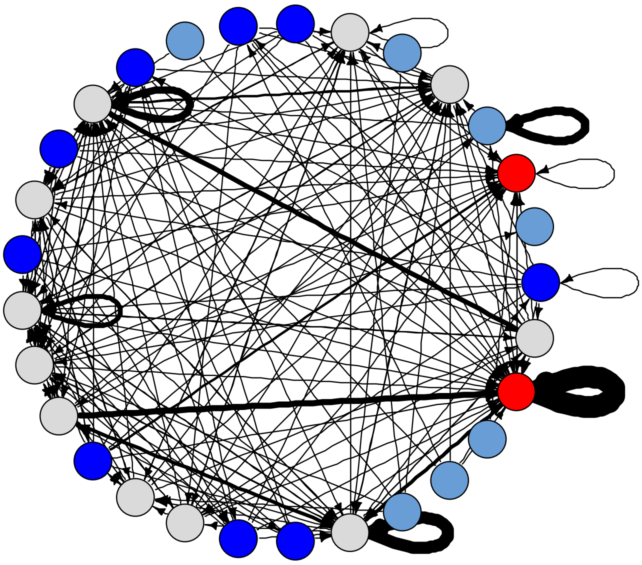
Chart 10: Distributions of size and degrees



Source: ESRB.

Chart 11 depicts the insurance network. There are nine insurers with an out-degree smaller than or equal to 5 (red and light blue), suggesting concentrated exposures. There are thirteen insurers with an in-degree larger than or equal to 5 (red and grey), suggesting larger systemic importance than the other insurers. Two insurers have relatively concentrated exposures and at least five other insurers are exposed to them (red). Furthermore, eight insurance groups have exposures to themselves, which are typically intragroup exposures to the banking entity of the financial conglomerate.

Chart 11: Full network of 29 EU insurance groups



Source: ESRB. Notes: The dots represent the 29 insurance groups. The arrows are exposures to other insurers. The thickness of the lines depicts the gross market value of the exposures. The colours of the dots represent the different in-degrees and out-degrees: blue means out-degree > 5 and in-degree < 5; light blue means out-degree ≤ 5 and in-degree < 5; grey means out-degree > 5 and in-degree ≥ 5; red means out-degree ≤ 5 and in-degree ≥ 5.

4. The network of insurers, banks and other financial institutions

This section describes and analyses the network of exposures of insurers to other insurers, to banks and to other financial institutions. This network provides a representation, albeit a partial one, of cross-sectoral exposures. This network is different from the insurance network (described in section 3) in two ways. First, it includes exposures to banks and other financial institutions, alongside exposures to insurers. Second, it is an "incomplete network", as it only includes exposures of insurers to other entities, but not the exposures of those entities to these insurers, whereas the insurance network is a complete network covering the exposures of insurers vis-à-vis each other.

4.1 Characteristics of the network

To infer economic meaning, it is useful to consider several measures of the interconnections, as captured by the network's topological structure. The fragility of relationships of insurance groups may stem from a variety of interconnection features which can be separately mapped and interpreted. For instance, the presence or absence of links between insurance groups and banks means that insurers that are well connected (many connections, either to other insurers, to banks or other financial institutions) can be identified, and thus channels of contagion across financial sectors can also be identified. Furthermore, the magnitude and direction of the linkages (funds granted or received) are helpful for establishing the relative importance of such relationships. Other dimensions can be assessed by looking at specific features of the relationships, such as the use of collateral or the maturity of exposures.

This section provides an overview of the different layers of interconnectedness between insurance groups, banks and other financial institutions. It highlights a number of representative analytical measures. These layers and measures are explained in the box.

Box: Layers and measures of interconnectedness

Assortativity: a measure of the tendency of insurers to attach to other insurers which are similar in some way, typically in terms of the insurers' degrees (see below).

Betweenness centrality: a measure of the influence of an insurer in the network. It quantifies the number of times an insurer acts as a bridge along the shortest path between two other insurers.

Closeness centrality: a measure of the proximity of an insurer to the rest of the network. (This is calculated as the reciprocal of the sum of an insurer's distances from all other insurers.)

Degree, also interconnectivity: the number of linkages with (out-degree) or exposures to (in-degree) other groups in the network.

Density: the ratio of the number of an insurer's linkages from (out) or to (in), relative to the number of possible from or to linkages.

Diameter: given the geodesic distances, the diameter is the longest of all. The diameter is representative of the linear size of the insurance network.

Eigenvector centrality: a measure of the influence of an insurer in the network. Relative scores are assigned to all insurers in the network. Connections to high-scoring insurers contribute more to the score of the insurer in question than connections to low-scoring insurers. Katz centrality (very similar to the Bonacich centrality) and PageRank centrality (also known as Google centrality) are methodological improvements, alongside the HITS (hyperlink-induced topic search) hub and authority centrality measures, which take account of the role (giver or receiver) of the insurer in providing funding.

Exponent alpha: the distribution of individual exposures typically tends to a power law distribution with a coefficient alpha, which denotes that the network is scale free. Larger values of alpha - yet closest to 2 - identify a greater interconnectivity importance of fewer insurers.

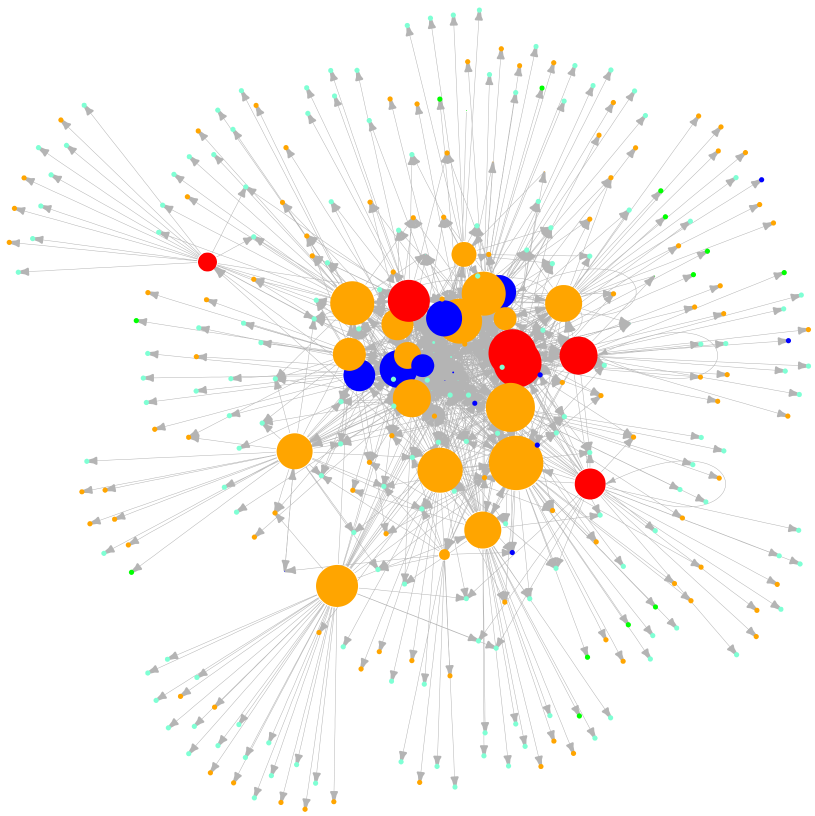
Geodesic distance/length of path: the shortest path length from each insurer to every other insurer.

Transitivity: if insurer A is related to insurer B, and B is in turn related to insurer C, then A is also related to C.

Reciprocity: a measure of the tendency of insurance pairs to form mutual linkages between each other.

The network shows low interconnectivity and a core-periphery structure. Overall, large insurers display low interconnectivity for most instruments and exposure types to other insurers, banks and other financial institutions. Insurers are "isolated". This is partly a result of the size and number of exposures and partly a result of the incomplete information on the exposures of insurers and banks.[13] The density of the network is about 1% to 3% of potential relationships (Table 1). The structure of the network displays a "core-periphery" structure, in which there is a comparatively small number of insurers in a "clump" or "core" surrounded by a less dense periphery of other entities (Chart 12) (Borgatti, 1999).

Chart 12: The network of the 29 largest EU insurance firms based on their exposures to banks and other financial institutions



Note: Network illustration of the linkages reported by the 29 largest insurance groups, where the dots represent institutions and institution size is calculated in terms of its degree (number of connections to other institutions). Insurance-led financial conglomerates and insurers are represented in red and orange respectively; bank-led financial conglomerates and banks are represented in blue and light green respectively; other financial institutions are represented in green.

Few linkages also result in paths being short in this network. As there are few relationships between institutions in the periphery and dense relationships between those in the core, it means geodesic

[13] Only the top ten exposures of insurers were collected. If exposures beyond this top ten had also been collected, this would have resulted to some extent in a denser network. More importantly, exposures were reported by only 29 insurers, whereas about 300 financial institutions were reported in the exposures of these insurers. Many of these 300 institutions have relationships with each other, but these are not part of the analysis and therefore this characteristic of the survey affects the results.

distances are generally well below 3. This contrasts with social networks, for instance, which have values well above 4 for this metric (Newman, 2010). Thus “incidents” (credit events) in the network are relatively “close”, and indirect exposures may be relevant. The measure of insurers’ closeness can be interpreted as their global centrality within the network, as it captures the tightness and close relationship of their activities.

Table 1: Network fragility measures

		Total value in EUR bn.	Number of groups	Number of linkages	Diameter	Density	Mean geodesic distance	Transitivity	Reciprocity	Assortativity	Graph level degree		Exponent alpha, degree distribution		Eigenvalue	Closeness centrality index	Betweenness centrality index
											Out	In	Out	In			
Debt instruments	total, *of which*	270.48	116	287	0.03	0.02	1.36	0.12	0.01	0.09	0.07	0.14	1.97	2.39	0.92	0.24	0.00
	Covered	134.45	78	152	0.07	0.02	1.25	0.10	0.01	0.07	0.10	0.12	2.00	2.52	0.90	0.22	0.00
	Securitisation	2.63	31	26	0.09	0.03	1.00	0.00	0.00	-0.27	0.17	0.11	2.18	4.33	1.00	0.21	0.00
	Not unit linked	118.79	109	267	0.04	0.02	1.36	0.12	0.01	0.06	0.07	0.14	1.95	2.38	0.93	0.23	0.01
	Unit linked	14.59	65	105	0.13	0.02	1.25	0.09	0.00	0.15	0.13	0.07	2.14	2.87	0.95	0.37	0.00
Bank ordinary share capital	total, *of which*	20.45	117	254	0.09	0.02	2.22	0.10	0.01	0.17	0.07	0.12	2.04	2.68	0.89	0.52	0.03
	Not unit linked	13.99	114	244	0.09	0.02	2.26	0.09	0.01	0.17	0.07	0.12	2.05	2.69	0.88	0.45	0.03
	Unit linked	6.46	43	68	0.29	0.04	1.08	0.04	0.00	-0.18	0.20	0.13	2.11	3.27	0.00	0.53	0.00
Deposits	total, *of which*	68.01	122	239	0.03	0.02	1.34	0.04	0.00	0.10	0.07	0.08	2.09	2.71	0.00	0.23	0.00
	Not unit linked	55.60	122	239	0.03	0.02	1.34	0.04	0.00	0.10	0.07	0.08	2.09	2.71	0.99	0.23	0.00
	Unit linked	12.41	29	35	0.15	0.04	1.03	0.00	0.00	-0.06	0.31	0.10	2.16	3.68	0.00	0.56	0.00
Banks which hold more than 5%	Market value of stocks	15.47	10	6	0.16	0.06	1.00	0.00	0.00	NA	0.04	0.16	Inf	2.14	1.00	0.06	0.00
Securities lending	Gross market value of securities lent	53.80	48	88	0.06	0.04	1.07	0.03	0.00	-0.04	0.17	0.13	2.02	2.56	1.00	0.44	0.00
	Market value cleared through a CCP	0.40	9	7	0.56	0.09	1.00	0.00	0.00	NA	0.65	0.03	2.32	Inf	0.00	1.76	0.00
Reverse repos	Gross cash amount exchanged	35.78	40	58	0.08	0.04	1.13	0.06	0.00	-0.38	0.22	0.12	2.06	4.37	0.00	0.33	0.00
	Total gross cash cleared through a CCP	1.66	10	9	0.62	0.09	1.00	0.00	0.00	NA	0.90	0.01	Inf	Inf	0.00	8.10	0.00
Net derivatives	Gross market value of total derivatives positions	40.76	58	171	0.04	0.05	3.02	0.06	0.00	0.27	0.12	0.16	1.74	2.16	0.86	0.77	0.09
	Market value cleared through a CCP	0.56	21	23	0.37	0.05	2.95	0.00	0.00	-0.67	0.25	0.20	2.94	3.88	0.58	1.23	0.22
Bonds issued by other insurers	total, *of which*	31.45	83	225	0.20	0.03	2.33	0.32	0.12	0.07	0.11	0.16	17.43	2.48	0.84	1.87	0.03
	Not unit linked	25.79	83	225	0.11	0.03	2.33	0.32	0.12	0.07	0.11	0.16	17.43	2.48	0.84	1.87	0.03
	Unit linked	5.66	28	43	0.59	0.05	1.77	0.07	0.05	-0.09	0.31	0.09	2.10	4.94	0.78	1.91	0.03
Ordinary share capital issued by other insurers	total, *of which*	9.63	101	205	0.08	0.02	2.77	0.20	0.11	0.07	0.13	0.14	2.05	2.97	0.88	2.62	0.04
	Not unit linked	6.81	98	193	0.11	0.02	2.59	0.21	0.09	0.07	0.13	0.14	2.07	3.03	0.88	1.70	0.03
	Unit linked	2.82	34	63	0.23	0.05	2.26	0.21	0.03	-0.39	0.25	0.19	2.00	2.91	0.72	6.52	0.04
Bank total		358.93	203	587	0.02	0.01	2.04	0.12	0.00	-0.04	0.12	0.10	7.51	2.19	0.91	0.56	0.01
Insurance total		41.08	134	354	0.15	0.02	2.50	0.28	0.11	-0.01	0.14	0.14	11.99	2.68	0.87	3.53	0.02
Total		545.82	0	1066	0.01	0.01	2.87	0.24	0.10	-0.06	0.16	0.07	2.29	2.15	0.87	11.75	0.02

Shocks in this network are not easily propagated. Low density and proximity are associated with low transitivity ("the friend of your friend is also my friend"), which is well below 30% for most instruments, suggesting low redundancy in the exposures. Transitivity also inversely affects the power-law characteristics of the degree distribution.[14] The network is "scale free", similar to other networks observed in the literature.[15]

There are few mutual exposures in this network. Mutual exposures (reciprocity) among institutions for certain types of instruments suggest that systemic risk might be low, since exposures may be (partly) netted. The level of reciprocity (i.e. the number of exposures that have a corresponding counter-exposure) between any two institutions is low, also reflecting the nature of the data.

The level of specialisation is not high. Negative values of assortativity imply that institutions are specialised in either receiving or providing in the network, in this case associated with institutions' degrees. These negative values are only observed for some layers, illustrating that there is not much specialisation in this network.

These network characteristics illustrate that credit and funding events are not expected to be widespread among insurers. Despite institutions being "close" to each other, they are not well connected. At the same time, the systemic impact of such contagion crucially depends on – among other things – the nature of the initial shock, the size of exposures, insurers' initial capital levels and the extent to which flows can be substituted.

4.2 Factors determining the significance of insurers in the network

This section describes "centrality measures" that capture the factors behind the importance of financial institutions in the network. Network characteristics, as described in section 4.1, cover important aspects of the network, but they fall short of analysing the importance of institutions within the network and clarifying what elements influence their systemic importance.

There are different measures to consider, which appeal to different drivers of systemic importance. Just as there are many ways to characterise the nature of the insurance network, as illustrated in section 4.1, there are many ways in which insurance groups can be important within the network. The International Association of Insurance Supervisors defines size, global activity, interconnectedness, substitutability and non-traditional and non-insurance activities as drivers of systemic importance (IAIS, 2013).

Two of these drivers have equivalent metrics in the analysis of networks. Most notable are the connectivity or the communication role of an institution (referring to interconnectedness), the institution's remoteness (referring to substitutability) and the extent to which an institution is an intermediary in financial flows (also referring to its substitutability).

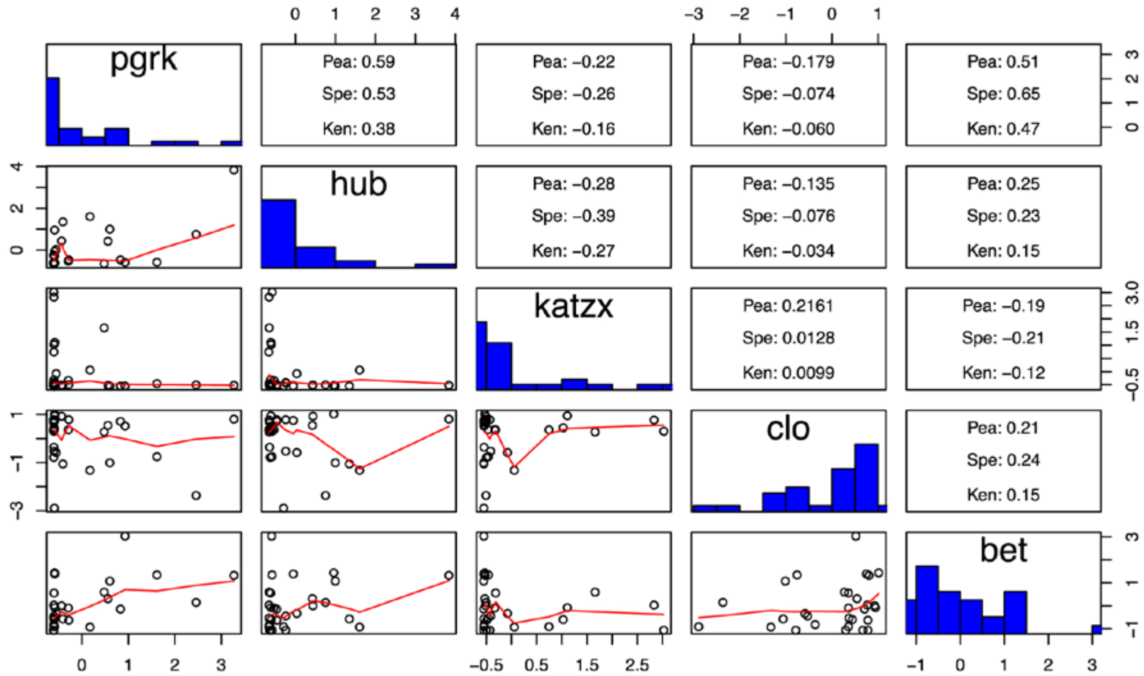
[14] This is an important metric measuring the fragility of the network as a whole to abrupt disruptions, and is captured by the parameter α of a power law. When this parameter exceeds 2, the distribution function associated with a process has a high propensity to experience sudden changes. For a general discussion on the role of power-law distributions see Newman (2006), and for details on the econometric estimation of α see Clauset et.al. (2009).

[15] For a review of the literature on this topic see Alves et al. (2013).

Some measures are capable of ranking insurers. A sample of these measures representing the three main metrics – connectivity, remoteness and intermediation – is presented in Chart 13.[16] A measure's spread captures its ability to discriminate across institutions. A larger spread indicates a greater ability to "separate" institutions.[17] HITS hub, PageRank and betweenness centralities, in this order, are capable of identifying an institution's importance.

Different measures result in different rankings for insurers. The measures displayed are distinctly "different" from one another. Compared with the banking network studied in Alves et al. (2013), these measures provide distinct rankings for insurers. This suggests that insurers' importance, in contrast to banks' importance, is not influenced by a common factor, but by insurers' different functions within the network, resulting in different "champions". This illustrates the problem of the multidimensionality that typically characterises network analysis.[18]

Chart 13: Correlation of centrality measures in the network of the 29 largest EU insurance firms based on their exposures to banks and other financial institutions (2013)

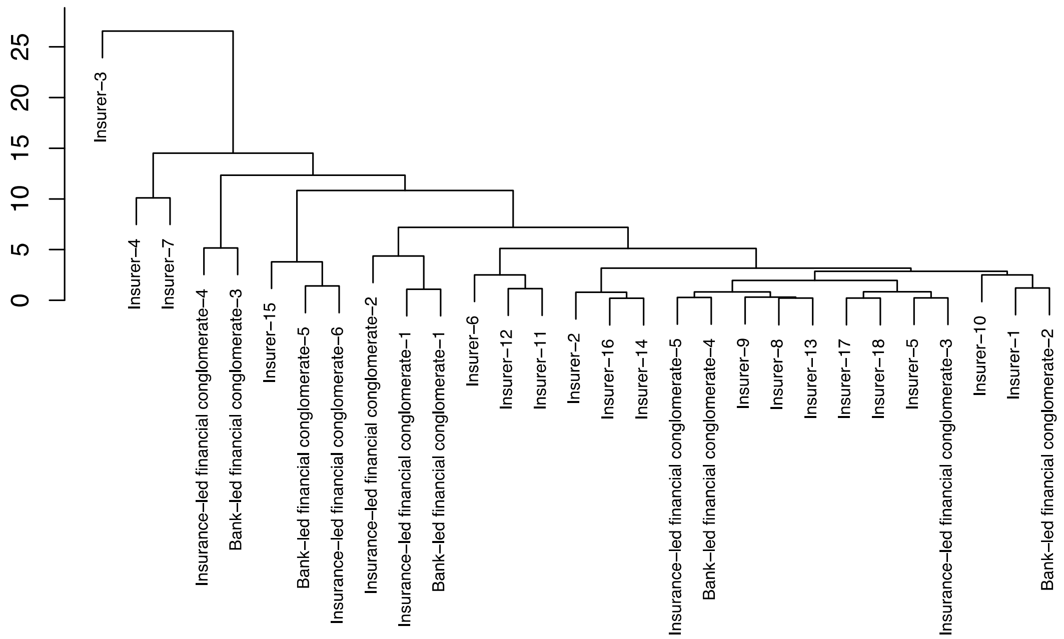


Source: ESRB. Notes: Pearson, Spearman and Kendall correlation metrics between selected institutional-centrality measures are shown. The measures (scaled and centred) are PageRank, Hub (HITS), Katz (or Bonacich), closeness and betweenness centralities.

[16] These measures are briefly described in the box. The first three (PageRank, Hub and Katz centrality) are representative of connectivity, whereas closeness and betweenness centrality are equivalents for remoteness and intermediation.
[17] Three metrics that do not have units are used to rank the centrality measures in Chart 13 according to their ability to create a "spread" across institutions. These are the coefficient of variation, the median-weighted interquartile range, and the median-weighted median absolute deviation from the median.
[18] No unique ranking of the institutions is possible from five different alternative rankings – a problem of multidimensionality.

The 29 insurers can be clustered in terms of relevance and uniqueness. Cluster analysis, summarising the information for the five different measures, can help identify the institutions that are most relevant and that are similar to each other (Chart 14). A handful of insurers play a central role within the network. It is not only financial conglomerates that are ranked among the most central entities. In fact, three insurers are ranked higher. This could of course be a very different picture, if the exposures of banks to insurers were also collected and taken into account. The most central insurers in this network are from the United Kingdom and France.

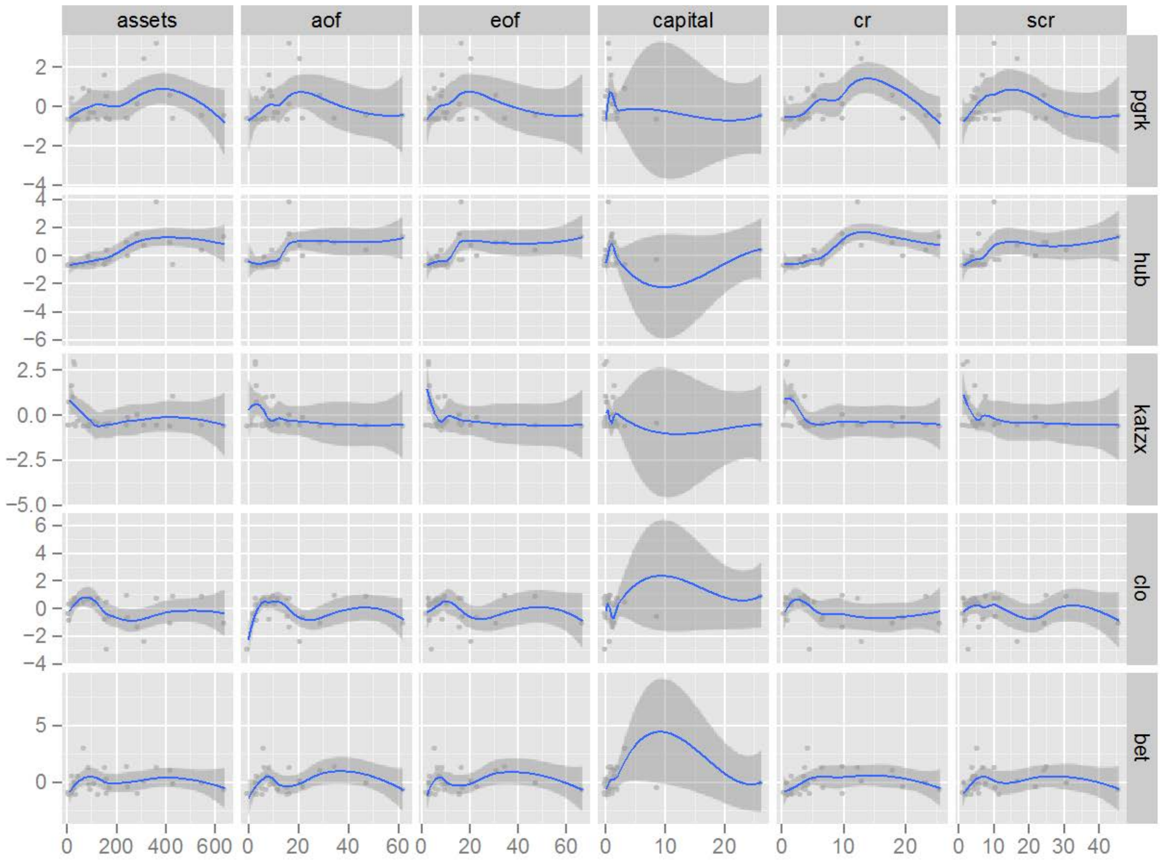
Chart 14: Dendogram of network centrality measures for the 29 largest EU insurance institutions



Source: ESRB. Notes: Institutions are referred to by their type (insurer, conglomerate) and are assigned arbitrary numbers. The clusters in the space spanned by the five measures of centrality are found using the Mahalanobis distance (which differs from Euclidian distance by normalising dependence on variables' correlation) and the "average method" algorithm. While the clusters are not a ranking of institutions by importance, they typically identify institutions that are distinctly relevant in one or more aspects.

Larger insurers are more central in the network than smaller ones. Some characteristics of the 29 largest European insurance groups or conglomerates are expected to determine their importance in the network, such as their size. One would expect larger groups to be more important in the network (Chart 15). Indeed, the size, as measured by the size of the total balance sheet of the 29 reporting insurers and conglomerates is positively related to their importance in the network, especially in the lower spectrum of size.[19] This relation holds when other variables which capture the size of the institutions are considered, such as own funds, share capital issued and regulatory capital requirements. PageRank, for example, identifies a subset of institutions for which the relationship between size and importance is quite marked (at smaller values of PageRank centrality), while for others (notably the ones with large values of PageRank centrality) this relationship is not evident.

Chart 15: Relationship between network centrality measures and institutional characteristics across the 29 largest EU insurance firms



Source: ESRB. Notes: For each characteristic/centrality pair, the local non-parametric fit (LOESS fit and shaded one standard deviation confidence interval) [20] of insurers' characteristics vs insurers' centrality (scaled and centred around zero) illustrates the relationship between the characteristic and the centrality, supplementing the information provided by a simple scatter plot. The characteristics considered are: total assets, available own funds, eligible own funds, share capital issued, Solvency I capital requirement and Solvency II capital requirement (all in EUR billions).

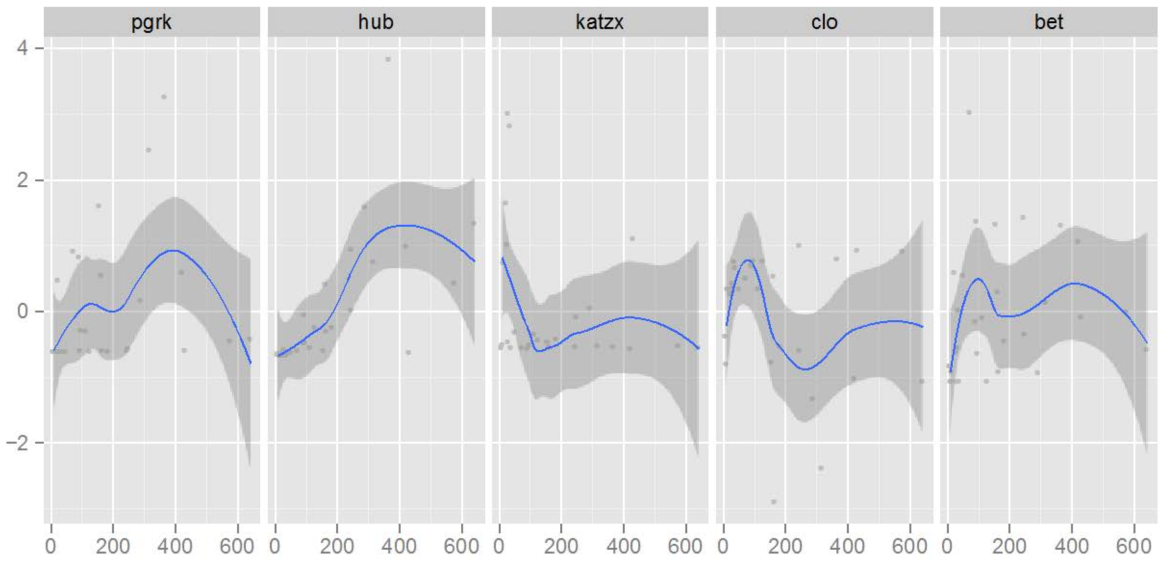
[19] The larger an institution becomes, the less important it is within the network at the margins. The only exception is that of Katz centrality (factoring in an additional importance beyond relations), which appears negatively related to size.

[20] The confidence interval simply illustrates how close the (non-parametric) relationship is between the centrality-characteristic pair, for instance highlighting that the relationship is stronger at lower values of the characteristic variables. It should not be interpreted as a measure of goodness of fit.

Size is an important factor but not the only one determining an insurers' importance in the network. The positive link between size and centrality at relatively low centrality values supports the long-held supervisory view that size is a key characteristic in regulating the interconnectedness of institutions in financial networks. At the same time, however, the results above illustrate that this relationship is not universal, both in terms of applying to all institutions and to different types of connectivity importance. This highlights the benefit of further refining regulations to account for other insurers' characteristics and/or activities, which also influence institutions' importance from an interconnectedness point of view.

The correlation between size and interconnectedness prevails when considering the total size of the balance sheet and share capital jointly (Chart 16). In this case as well, a non-modelled factor evidently seems to account for a different econometric relationship for a subset of institutions.[21]

Chart 16: Network centrality measures explained by balance sheet size and share capital of the 29 largest EU insurance firms



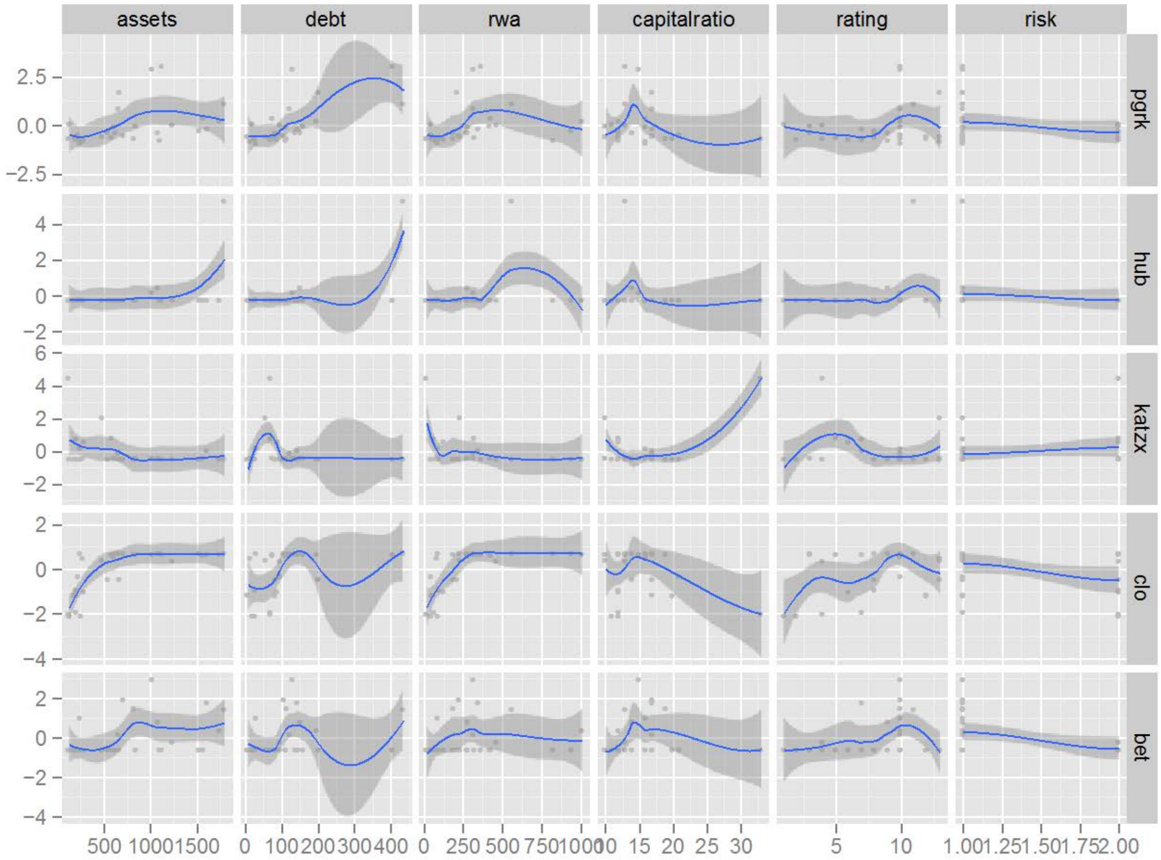
Source: ESRB. Notes: Local non-parametric fit (LOESS fit and shaded one standard deviation confidence interval)[22] of insurers' centrality (scaled and centred around zero) by size (total assets) and share capital issued. The remaining variables in Chart 15 are highly correlated with total assets and are thus excluded. The relationship is illustrative because a non-modelled factor seems to play a significant role, resulting in a high variance of the model errors.

The size of the counterparty also determines the centrality of this counterparty in the network. Of the approximately 300 counterparties reported, characteristics of the 31 most connected ones were collected and plotted in Chart 17. This revealed a positive relationship between banks' size (measured as total assets, risk-weighted assets and long-term debt issued) and their importance in the network.

[21] More refined information on the institutional characteristics would be important for identifying structural factors underlying significant systemic importance beyond the bi-variate relationships illustrated in Chart 15 or the regressions shown in Chart 16.
[22] See footnote 16.

This holds for most measures of centrality, in particular also at the low values of the explanatory variable. Again, these results are only partial, as the information does not include exposures that these banks have within the network and thus these centrality measures may not be accurate in this respect.

Chart 17: Network centrality measures and institutional characteristics of the 31 most central banks in the network



Note: Local non-parametric fit (LOESS fit and shaded standard confidence interval)[23] of banks' characteristics vs institutional centrality (scaled and centred around zero). The characteristics considered are: total assets, long-term debt, risk-weighted assets (all in EUR billions), Tier 1 capital ratio, rating and binary level of risk (low/high).

Measured by degree, central institutions in the network are mostly connected with less central ones. The tendency of institutions to connect with each other on the basis of an assumed characteristic difference is known as assortativity, and can be measured by the homophily coefficient (Table 2). An observation closer to -1 indicates a core-periphery structure (a difference in the characteristic drives the connection), and closer to 1 indicates an entirely sorted community (only similar institutions are connected with each other). Insurers' connectivity measured by their degree (a simpler measure of

[23] See footnote 16.

connectivity than PageRank) shows, as expected, a negative value of homophily (-0.1). This again suggests a core-periphery type of financial network, with central institutions connected to less central ones and with some institutions serving as hubs for others.

This is different when considering other centrality measures or characteristics related to size. Using measures other than the degree, insurers' tendency to link is not related to differences of such centralities. Similarly, differences in size of insurers (total assets) do not seem to drive linkages between insurers. In fact, their relationship is assortative (a positive homophily coefficient of total assets). That is, insurers' size differences do not explain the dissortative core-periphery structure of insurers' relationships.

Table 2: Indicators for the tendency of large insurers to associate with similar peers

Assortativity characteristic	Homophily coefficient
Degree	-0.113
PageRank	0.024
Closeness	0.011
Betweenness	-0.006
Total assets	0.024
Share capital	-0.027

Source: ESRB.

5. Simulation of distress in the network

In order to analyse the propagation of distress in the network, as described above, a contagion model has been built and several scenarios have been simulated. The contagion model is based on Gourieroux et al. (2012), who model solvency contagion as an equilibrium, distinguishing debt instruments (loans, bonds, deposits, etc.) from equity instruments (shares and capital investments). The equilibrium definition is derived from Merton's model of the value of the firm. This model considers the equity of an institution equal to the net value of its assets over its nominal debt and the value of the debt of an institution equal to the minimum of the value of its assets and its nominal debt. Bilateral exposures are written as a fraction of the debt or equity of institutions. More details on the model can be found in Annex 2.

Four types of shocks and a default threshold have been defined. The four shocks are: 1) the default of an insurer; 2) the default of a bank; 3) a loss in the value of all exposures to banks; 4) a combined loss in the value of all exposures to banks and the default of an insurer. After applying these shocks the equilibrium of the solvency of all insurers is calculated, assuming loss-given-default ratios for each type of exposure. Default is defined as the capital of the insurer being reduced below 35%[24] of its solvency capital requirement (SCR). In this case it is assumed that the minimum capital requirement (MCR) is also breached, which is the lowest capital requirement level in Solvency II (Directive 2009/138/EC), and that this immediately leads to the most severe supervisory measures. Capital requirements are assumed to remain constant after applying the shocks (i.e. there is no change to the SCR to reflect the shock).[25]

These simulations shed light on two "concepts" of systemic risk: the systemic importance of an institution and the systemic fragility of an institution. The first concept captures the contagion risk generated by a specific institution, i.e. the number of other institutions that default as a consequence of the default of this institution. The second concept captures the exposure to contagion risk, i.e. the number of scenarios, in which this institution defaults. It should be noted, however, that the simulated shocks neither imply nor rule out the systemic risk of individual insurers. This is the case because we are only considering a limited number of exposure types, such as direct investments. In reality, the default or distress of an insurer can affect the financial markets in many more ways than we have been able to capture in this analysis.

None of the 29 insurers can cause another insurer to default. The first simulation examines exposures between insurers. To analyse possible contagion risk, each insurer is assumed to default. In the event of a default we assume losses given default to be 100% for both the share and debt holdings of the defaulted insurer. The results show that none of the 29 insurance groups pose a risk to the others in the event of a default, as the solvency positions of the others are only marginally affected. Second-round effects are not relevant given the lack of first-round effects.

Similarly, none of the banking counterparties can cause the default of an insurer. The second simulation concerns a default of one of the large banks – a sort of "Lehman Brothers" event. As the top ten exposures of the 29 insurance groups are from 184 different banks, 184 default simulations were run.[26] The results show that none of the 184 banks pose a risk to an insurance group in the event of their default, as none of the 29 insurance groups would reach a solvency position lower than the MCR following the default of one of the banks. This includes the default of a bank within the same financial conglomerate. Looking at shortfalls relative to the SCR, a number of banks have the potential to move the capital position of a single insurer below the SCR in the event of their default. There is no single bank whose default would cause the default of more than one insurer; contagion is limited to one insurer in all cases.

Only the most severe crisis in the banking sector would have direct contagion effects to insurers. The third simulation considers a shock in the entire banking sector, which assumes that the value of all exposures to banks simultaneously decreases.[27] To this end, ten linear scenarios were run. The decreases in values applied are summarised in Table 3. The difference between the default of a single bank, simulated above, and the severest banking crisis scenarios, simulated here, is that in this case shocks are applied to all the top ten bank exposures instead of just one, but deposits retain their values, as these are assumed to not be bailed-in.

[24] This stylized MCR is assumed to be in the middle of the corridor between 45 % and 25 % of the SCR, to which the MCR is limited in Solvency II.
[25] This is similar to the EIOPA 2014 stress test (EIOPA, 2014).
[26] The following loss-given-default rates have been assumed: 100% for shares, deposits and unsecured debt; 50% for securitisation positions; 20% for covered bonds; 0% for exposures covering unit-linked policies (where the policy holder bears the loss).
[27] Note that only the top ten exposures are lowered, not the banking exposures beyond this top ten, as these are unknown.

Table 3: Decrease in the value of banks exposures (as percentages) assumed in ten scenarios

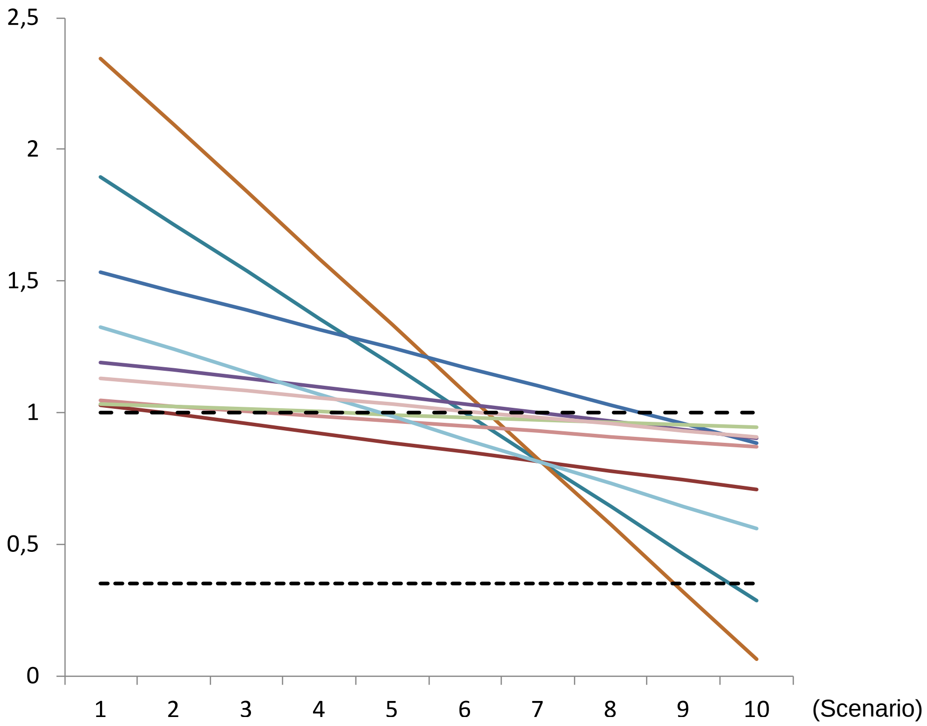
Scenario	1	2	3	4	5	6	7	8	9	10
Deposit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Covered bond	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
Securitisation	3.3	6.6	9.9	13.2	16.5	19.8	23.1	26.4	29.7	33.0
Unsecured debt	6.6	13.2	19.8	26.4	33.0	39.6	46.2	52.8	59.4	66.0
Share	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0

Source: ESRB

The results show that the vast majority of the 29 insurance groups are relatively insensitive to decreases in the values of their top ten bank exposures. The exceptions are two insurance groups. Their solvency positions decline fast as the values of their bank exposures decrease. Chart 18 shows the results of the nine insurance groups which are most notable because they are either most sensitive to changes in bank exposure values or have a solvency position which is moved below 100%. In the most severe scenario nine insurance groups did not meet their SCR, while two were in breach of their MCR.

Chart 18: The sensitivities of nine EU insurance groups to the values of their top ten bank exposures

(Capital/SCR)



Source: ESRB. Notes: The lines depict the capital position of nine insurers in ten different scenarios. The horizontal dotted lines are the SCR level (1) and the MCR level (0.35).

Combined scenarios result in breaches of the SCR but not of the MCR. The fourth simulation regards a banking crisis, combined with the default of an insurer. To this end scenario 4 of Table 3 is run in combination with the default of each insurer. This scenario does not result in the default of any other insurance groups (again defined as a breach of the MCR). This is not to say that this scenario does not have any impact on insurers at all; looking at breaches of the SCR instead, the default of any insurer in combination with this banking crisis scenario would move the capital of one to four other insurer(s) below their SCR.

6. Conclusion

Despite the strong linkages between insurers and banks at a sectoral level, at firm-level the exposures of insurers to banks are not concentrated. The sum of all the top ten exposures to banks, insurers and other financial institutions for all instruments, reported by the 29 insurance groups, represents about 10% of total assets of the insurers, suggesting a low level of concentration. The implication of this is that supervisors should not only monitor firm-level concentrations of exposures, but also sectoral-level exposure concentrations.[28]

The network characteristics illustrate that credit and funding events are not expected to be widespread among insurers. Despite institutions being "close" to each other, they are not well connected. The network shows a core-periphery structure. This, however, is partly caused by the nature of the exercise and the scope of the data collection. This can be resolved by adding banks' exposures to insurers to this network.

A handful of large insurers play a central role within the network. Some of these insurers, but not all, are part of a financial conglomerate. Size is an important factor but not the only one determining an insurers' importance in the network. This confirms the current approach taken by the IAIS in identifying the most systemically important insurers (IAIS, 2013).

Insurers' solvency positions are sufficiently large and the concentration of exposures is sufficiently low as to avoid direct contagion of a counterparty default. The simulation of stress on an insurance counterparty or on a banking counterparty does not lead to a default of any of the EU insurance groups through direct contagion. For the vast majority of insurance groups this is also true for simultaneous distress at their top ten banking counterparties, with the exception of two insurance groups. Direct contagion risks are thus limited for the EU insurance groups when considered in isolation.

This is only a partial analysis aimed at assessing direct contagion channels at firm level. There are a few important limitations attached to this network analysis.

- There is no data on banks' exposures to insurers. Therefore the contagion from insurers to banks is unknown.
- The network only contains the top ten exposures. Exposures beyond this top ten, which may not be small, given insurers' preference for diversification, are not included.
- Usually a banking crisis is accompanied by losses on other markets, such as the corporate bond, sovereign bond and equity markets, in which insurers also have large stakes.
- This analysis assumes no second-round effects on account of insurers' investment behaviour. Insurers may sell bank bonds in response to a shock in that market, exacerbating the shock. This indirect contagion channel has not been analysed.
- This analysis has only covered financial exposures other than insurance contracts (participations, debt, derivatives). Another contagion channel that could be investigated is the network of

[28] The Solvency II Directive contains a capital charge for concentration risk, related to a lack of diversification in the asset portfolio or to a large exposure to default risk by a single issuer of securities or a group of related issuers (Article 105(5f)).

reinsurance contracts. Particularly in a situation where the insurance sector is strained by falling asset prices and increased claims, the network may be more susceptible to shocks. For this, additional data on reinsurance contracts would be needed.

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Annex 1: The sample of the 29 largest EU insurers

Achmea (Eureko Group)

Aegon Group/Unirobe Meeùs Group

AGEAS

Allianz

Aviva

AXA

BNP Paribas

Grupo Catalana Occidente

CNP Assurances

Royal Bank of Scotland Group

Generali

Groupama

Groupe Crédit Agricole Assurances

HDI/Talanx

If P&C Insurance

ING Group

KBC

Legal & General Group plc

Mapfre

Munich Re

Old Mutual plc

Prudential

RSA Insurance Group

SCOR

Lloyds Banking Group

Standard Life Assurance Company

Unipol

UNIQA Insurance Group

Vienna Insurance Group

Annex 2: The contagion model

The underlying model is based on the one developed by Gourieroux, Héam and Monfort (2012) in their publication entitled Bilateral Exposures and Systemic Solvency Risk. We only model solvency contagion distinguishing debt instruments (loans, bonds, deposits…) from equity instruments (shares, capital investment…). The model is an extension of the model developed by Eisenberg and Noe (2001), as well as an extension of Merton's model of the value of the firm.

Let us consider a system formed of n institutions. The balance sheet of institution i is given in Table 1. On its liability side, Y_i denotes the value of its equity (all equity instruments) while L_i denotes the value of its debt (all debt instruments). On its asset side, $\pi_{i,j}$ denotes the fraction of the equity issued by j owned by i. For instance, $\pi_{i,j}$=10% means that institution i controls 10% of the capital of institution j. Therefore the value of equity exposures of institution i to institution j is $\pi_{i,j}Y_j$. Similarly, $\gamma_{i,j}$ denotes the fraction of the debt issued by j owned by i. For instance, $\gamma_{i,j}$=10% means that institution i owns 10% of the all the debt of institution j. Therefore the value of debt exposures of institution i to institution j is $\gamma_{i,j}L_j$. Finally, Ax_i gathers all the external assets (i.e. those outside the considered system), for instance, sovereign exposures and banks' exposures.

Balance sheet of institution i

Asset	Liability
$\pi_{i,1}Y_1$	
$\vdots$	L_i
$\pi_{i,n}Y_n$	
$\gamma_{i,1}L_1$	
$\vdots$	Y_i
$\gamma_{i,n}L_n$	
Ax_i	

Merton's model applied to each institution provides the 2n-system, where L_i^* is the nominal (or contractual) value of the debt issued by institution i:

$$\begin{cases} Y_i = \left[\sum_{j=1}^{n} (\pi_{i,j} Y_j) + \sum_{j=1}^{n} (\gamma_{i,j} L_j) + Ax_i - L_i \right]^+ , \\ L_i = \min \left[\sum_{j=1}^{n} (\pi_{i,j} Y_j) + \sum_{j=1}^{n} (\gamma_{i,j} L_j) + Ax_i \quad , \quad L_i^* \right], \qquad i = 1, ..., n. \end{cases}$$

In Gourieroux, Héam and Monfort (2012), it is demonstrated that under mild constraints this system, whose unknowns are the values of equity (all Y_i) and the values of debts (all L_i), has a unique solution.

The use of this model in a stress test framework is simple. First, we match equity (Y_i^0) with eligible funds (the superscript 0 indicates “initial”). We deduce the nominal value of the debt (L_i^*) as the difference between total assets and eligible funds. Since no institution is in default, we also know that $L_i^0 = L_i^*$ for all institutions. Then by dividing the bilateral exposures (excluding unit-link exposure) we get the coefficients $\pi_{i,j}$ and $\gamma_{i,j}$. Last we deduce the initial value of external assets as the difference between total assets and all the exposures. Note that exposures to institutions that are not in the system (i.e. banks) form part of the external assets.

A scenario is then defined as a deviation of the value of external assets. We keep fixed the nominal value of the debt, both coefficients $\pi_{i,j}$ and $\gamma_{i,j}$, and compute the solution of the 2n-sytem. The raw output is the value of equity (all Y_i^{eq}) and the values of debts (all L_i^{eq}) for all institutions. We use superscript “eq” to denote equilibrium value. Then we can derive indicators to assess the health of the system. For instance, we can compute the solvency ratio as Y_i^{eq}/SCR and count the number of institutions whose ratio is below a given threshold.