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Mapping bank securities across euro area sectors: comparing funding and exposure networks

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Abstract

We present new evidence on the structure of euro area securities markets using a multilayer network approach. Layers are broken down by key instruments and maturities as well as the secured nature of the transaction. This paper utilizes a unique dataset of banking sector cross-holdings of securities to map these exposures among banks and economic and financial sectors. We can compare and contrast funding and exposure networks among banks themselves and of banks, non-banks and the wider economy. The analytical approach presented here is highly relevant for the design of appropriate prudential measures, since it supports the identification of counterparty risk, concentration risk and funding risk within the interbank network and the wider macro-financial network.

Keywords: *Interbank networks, macro-financial networks, multilayer networks, market microstructure, macroprudential analysis.*

JEL: *D85, E44, G21, L14.*

Non-technical summary

This paper combines the European Central Bank (ECB) Securities Holdings Statistics by Group (SHSG) with the ECB Securities Holdings Statistics by Sector (SHSS) as well as the Centralised Securities Database (CSDB) to build an interbank network of large euro area banking groups and then extending it to a macro-financial network including sectoral exposures of banks, further broken down by euro area country.

First we focus on the 26 largest euro area banking groups, for which we have the exact network of securities cross-holdings. Typically in the financial networks literature bilateral exposures are estimated due to a lack of detailed counterparty data. Thanks to the availability of detailed characteristics of the securities in the CSDB, we can build three different multilayer networks according to three different splits of the dataset. The first multilayer network has four layers split by seniority (equity, subordinated debt, senior unsecured debt, secured debt), the second multilayer network splits the exposures according to maturity into two layers (short- and long-term debt) and the third multilayer network has also two layers distinguished by whether the debt instrument is covered or securitized. For each multilayer network, we additionally build a layer which aggregates up all the other layers in order to assess whether the disaggregated layers yield additional information. We find that for the three multilayer networks, the disaggregated view always yields additional information which bolsters the case for a multilayer perspective on interbank networks.

We find that the network layers have very different link structures and there is strong heterogeneity in the significance of banks in the different layers. For a multilayer network comprising exposures due to listed shares, unsecured and secured debt securities, we find that - unsurprisingly perhaps - global systemically important banks (G-SIBs) are active in all layers and display an interconnectedness above the mean in all layers. Such a descriptive statistic is useful for financial stability analysis, since it allows to gauge which bank's distress might lead to disruptions across several markets. More interestingly perhaps, we find that some banks not classified as G-SIBs exhibit similarly high interconnectedness than G-SIBs. This finding might point to the need to monitor the linkages of large non-GSIBs too.

Since we know the issuer and the holder of each security within the network, it is possible to build networks with directed links. We can therefore distinguish a funding network and an exposure network. This is the first paper to provide such an analysis for euro area banks. Liquidity risk in the funding network and credit risk in the exposures network affect banks differently for different instrument categories which underlines the importance of having a disaggregated view of the interbank network.

Then we take a wider perspective and build a network where the euro area banking sector is connected to other euro area sectors via securities exposures. We split the euro area banking sector into the 26 largest banking groups and other, smaller euro area banks to analyze differences in funding by and lending to euro area sectors. This is the first paper to investigate the different sectoral funding and exposure patterns of euro area banks with such granularity. There are marked differences between sectors that fund banks and sectors that banks are exposed to. Banks mostly invest in government bonds and are mostly funded by the banking sector, households and the financial sector. The shares of the different sectors differ markedly by the maturity of the debt security and whether we consider the 26 largest or the remaining euro area banks.

A network representation of sectoral linkages can also be useful for contagion analysis. For that purpose we build a multilayer macro-financial network of euro area banking sectors where the different layers correspond to the 19 euro area countries. Each network layer represents the exposures of the national euro area banking sector to other euro area sectors, out of the holding banking sector's aggregate CET1 capital, which we collected from the ECB Consolidated Banking Database (CBD). That way, we assess the exposure of national banking sectors to other sectors and can quantify in an intuitive way the vulnerability of national banking sectors, should there be distress or defaults in the sectors banks invest into.

We find that there is a strong heterogeneity in terms of exposures of euro area banking sectors to euro area economic and financial sectors. Some banking sectors have very large exposures across several instrument categories and sectors, such as Italy and Greece, and some exposures are more concentrated. Since exposures based on securities are only one aspect of the overall exposures of banks, it is possible that certain banking sectors are more heavily exposed in other asset categories, such as loans or derivative products. Similarly, we restrict our analysis to the euro area on both the holder and issuer side, exposures to other large financial sectors and economies such as the United Kingdom or the United States are therefore not covered here.

This level of granularity is crucial for macroprudential policy. If systemic importance of banks vary with instrument and maturity and certain banks might spread disruptions across several markets, it becomes key for the regulator to have a multilayer view of the interbank network and of the macro-financial network.

Introduction

In the recent financial crisis, regulators had very limited information about exposures to specific securities. Most official statistics contained only aggregate information, which made it very difficult to single out exposures of banks or sectors to individual issuers and to thereby assess credit risk, market risk or funding risk of financial institutions. In the European System of Central Banks (ESCB) detailed securities holdings statistics by sectors and for the largest euro area banking groups have become available since. This is the first paper to combine the European Central Bank (ECB) Securities Holdings Statistics by Group (SHSG) with the ECB Securities Holdings Statistics by Sector (SHSS) as well as the Centralised Securities Database (CSDB) to build an interbank network of large euro area banking groups and then extending it to a macro-financial network including sectoral exposures of banks, further broken down by euro area country.

First we focus on the 26 largest euro area banking groups, for which we have the exact network of securities cross-holdings. Typically in the financial networks literature bilateral exposures are estimated due to a lack of detailed counterparty data. Thanks to the availability of detailed characteristics of the securities in the CSDB, we can build three different multilayer networks according to three different splits of the dataset.[1] The first multilayer network has four layers split by seniority (equity, subordinated debt, senior unsecured debt, secured debt), the second multilayer network splits the exposures according to maturity into two layers (short- and long-term debt) and the third multilayer network has also two layers distinguished by whether the debt instrument is covered or securitized. For each multilayer network, we additionally build a layer which aggregates up all the other layers in order to assess whether the disaggregated layers yield additional information. We find that for the three multilayer networks, the disaggregated view always yields additional information which bolsters the case for a multilayer perspective on interbank networks.

We find that the network layers are very different according to topological measures and there is strong heterogeneity in the significance of banks in the different layers. For a multilayer network comprising exposures due to listed shares, unsecured and secured debt securities, we find that - unsurprisingly perhaps - G-SIBs are uniformly active in all layers and display an interconnectedness above the mean in all layers. More interestingly, we find that some banks not classified as G-SIBs exhibit similarly high interconnectedness. Such a descriptive statistic is useful for financial stability analysis, since it allows to gauge which bank's distress might lead to disruptions across several markets.

Since we know the issuer and the holder of each security within the network, it is possible to build networks with directed links. We can therefore distinguish a funding network and an exposure network. This is the first paper to provide such an analysis for euro area banks. Liquidity risk in the funding network and credit risk in the exposures network affect banks differently for

[1] In our specific application, a multilayer network is constituted of several network layers, where each layer represents the financial exposures of the 26 banks in one specific instrument category.

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A network representation of sectoral linkages can also be useful for contagion analysis. For that purpose we build a multilayer macro-financial network of euro area banking sectors where the different layers correspond to the 19 euro area countries. Each network layer represents the exposures of the national euro area banking sector to other euro area sectors, out of the holding banking sector's aggregate CET1 capital, which we collected from the ECB Consolidated Banking Database (CBD). That way, we assess the exposure of national banking sectors to other sectors and can quantify in an intuitive way the vulnerability of national banking sectors, should there be distress or defaults in the sectors banks invest into. Keeping track of exposures of national banking sectors to other banking sectors is useful to quantify potential losses due to possible banking crises or due to the bail-in of a large bank. Similarly, the bank-sovereign doom loop has been a big concern during the past crisis and it is equally important to monitor exposures of national banking sectors to euro area sovereigns. Finally, the so-called shadow banking sector is a growing component of the financial sector and it is important for banking supervisors to keep track of the exposures traditional banks face to those sectors as well.

We find that there is a strong heterogeneity in terms of exposures of euro area banking sectors to euro area economic and financial sectors. Some banking sectors have very large exposures across several instrument categories and sectors, such as Italy and Greece, and some exposures are more concentrated. Since exposures based on securities are only one aspect of the overall exposures of banks, it is possible that certain banking sectors are more heavily exposed in other asset categories, such as loans or derivative products.[2] Similarly, we restrict our analysis to the euro area on both the holder and issuer side, exposures to other large financial sectors and economies such as the United Kingdom or the United States are therefore not covered here.

Network analysis is widely used to study interconnections within financial sectors.[3] Most empir-ical studies however face the limitation that interconnections need to be estimated, since detailed

[2]For a recent study of interconnectedness in derivatives markets, see Abad et al. (2016).

[3]Surveys of this rapidly growing field include Cabrales et al. (2015), Glasserman and Young (2015), Hüser (2015) and Upper (2011).

counterparty data is rarely available (Degryse and Nguyen, 2007; Mistrulli, 2011; Upper and Worms, 2004; Wells, 2004). This paper is able to overcome these data limitations since we use the ESCB securities holdings statistics by banking groups, which is a proprietary dataset that contains all the security-by-security exposures of the 26 largest euro area banking groups. The dataset also contains details on the characteristics of the individual securities, such that we can construct three multilayer networks, where the layers are broken down by maturity, seniority and the secured nature of the instrument. We thereby also contribute to the emerging multilayer network literature (Aldasoro and Alves, 2018; Bargigli et al., 2014; Hüser et al., 2018; Langfield et al., 2014; Montagna and Kok, 2016).[4] The main takeaway at this stage is that it is important to differentiate the layers of the network, since both topology and contagion processes can be different between layers. Our analysis of the securities exposures broken down by layers confirms that finding.

Very few papers however study the linkages of the financial sector with other sectors of the economy. This is mainly due to the fact that a network representation requires detailed sectoral counterparty data, which is scarce. To deal with this limitation, previous empirical studies have estimated sectoral linkages based on sectoral accounts and flow of funds data (Castrén and Kavonius, 2009; Castrén and Rancan, 2014; De Almeida, 2015). This paper is able to overcome these data limitations since we use the ESCB securities holdings statistics by sectors, which is a proprietary dataset that contains all the security-by-security cross-holdings of euro area sectors.

This level of granularity is crucial for macroprudential policy. If systemic importance of banks vary with instrument and maturity and certain banks might spread disruptions across several markets, it becomes key for the regulator to have a multilayer view of the interbank network and of the macro-financial network.

The paper is structured as follows. Section 1 describes the data. Section 2 presents the multilayer network model of large euro area banks and descriptive statistics on the topology of the network layers. Section 3 provides a detailed analysis of the funding and exposure network of large euro area banks. Section 4 introduces the euro area macro-financial network and provides an analysis of funding and exposures within that network. Section 5 analyzes the potential for contagion in the macro-financial network. The final section concludes.

1 Data

We make use of two micro-financial ESCB datasets namely the Securities Holdings Statistics (SHS) and the Centralised Securities Database (CSDB). SHS data have been collected quarterly since the fourth quarter of 2013 and cover the two main types of security: debt securities and equity securities (including investment fund shares). The main feature of these data is that holding information is collected on the level of each individual security. The SHS dataset contains two data

[4]See the survey by Hüser (2015) for an overview of the multilayer financial networks literature.

modules: the SHS Sector (SHSS) and the SHS Group (SHSG). The two modules differ on account of the granularity of the information on the holder's side. The SHSS module provides aggregate information on the holdings of institutional sectors resident in individual euro area countries. The data provide us with security-by-security data with general coverage greater than 90 percent for various holder sectors. The SHSG module contains holder-by-holder information for the 26 largest (by total assets) banking groups headquartered in the euro area.[5] The outstanding volume of securities held by the 26 largest banking groups amounted to 3.2 trillion euro in Q4 2015. This compares to 5.1 trillion euro for the wider euro area banking (MFI) sector. i.e. a coverage of approx. 64%. For the securities holdings of the 26 largest euro area banking groups, 82% consist of long-term debt securities, 5% of short-term debt securities, 11% of shares, and 2% of investment funds. For the euro area MFI holdings, 85% consist of long-term debt securities, 5% of short-term debt securities and 9% of shares.

We construct the network of securities cross-holdings among the 26 banks in the following way. From the SHSG data we can identify all the cross-holdings of debt securities and quoted shares among the sample of banking groups comprising this dataset. The individual security holdings are reported at a non-consolidated level but intra-group holdings are flagged in the dataset. We utilize precisely this intra-group holdings flag to identify all the individual entities belonging to a group. Thus, we derive the group structure from this flag assuming a cross-holding of instruments between entities belonging to the same group. In case there are no cross-holdings of securities between two entities belonging to the same group or this relationship is not flagged in the dataset we might not be able to identify all entities belonging to a banking group.

We use the International Security Identification Number (ISIN) to merge the SHSG data with the CSDB. In so doing we obtain information on the type of debt[6] and the seniority[7] which, in turn, permits us to accurately assess the exposure[8] of the banking groups. We also have information on the maturity and whether the bond is covered or securitised. Based on these datasets, we can build three multilayer networks: (i) a multilayer network differentiated by the seniority of the securities where the layers are equity, subordinated debt, senior unsecured debt and secured debt;

[5]The selection of the banking groups included in SHSG is subject to the Governing Council decision, which is taken at least once a year (the groups are then called reporting banking groups, or shortly RBGs). The SHS Regulation indicates the use of a quantitative threshold (0.5% of consolidated balance sheet of the EU banking Groups), combined with other quantitative and/or qualitative criteria (e.g. to keep certain groups in the sample even if they fell below the threshold over time), to identify banking groups of particular relevance for monetary policy, financial stability or other ESCB t asks. Banking Groups are (parent) credit institutions and all their financial subsidiaries or branches, other than insurance undertakings which have received official authorisation in accordance with Art. 6 of Directive 73/239/EEC or Art. 4 of Directive 2002/83/EC.

[6]This attribute provides a broad range of categories in which debt securities are classified in e.g. straight bond, medium term note, commercial paper, asset backed security, hybrid instrument etc.

[7]This attribute classifies debt instruments into senior/subordinated, secured/unsecured and guaranteed/unguaranteed.

[8]We do not have information in SHS with respect to which part of the bank's portfolio these instruments are allocated in (i.e. available-for-sale, trading or held-to-maturity). Thus, we consider the holdings of debt and equity recorded at book value as we are interested in assessing the nominal cross-holding exposure.

(ii) a multilayer network differentiated by the maturity of the securities where the layers are short term debt and long term debt; (iii) a multilayer network differentiated by the secured nature of the transaction where the layers are covered bonds and securitised debt (such as asset-backed securities).[9]

Using the SHSS data, we then build a star network, where the euro area banking sector is connected to other euro area sectors via securities cross-held. We split the euro area banking sector into the 26 largest banking groups and other, smaller euro area banks to analyze differences in funding and lending patterns between large and small banks. Finally, we build a multilayer macro-financial network of euro area banking sectors where the different layers correspond to the 19 euro area countries.

For all the results displayed below we use data in nominal values for the fourth quarter of 2015.

2 The multilayer network of large euro area banks

In this section, we focus on the 26 largest euro area banking groups, for which we have the exact network of securities cross-holdings.

Due to the availability of detailed characteristics of the securities in the CSDB, we build three different multilayer networks according to three different splits of the dataset. In our specific application, a multilayer network is constituted of several network layers, where each layer represents the financial exposures of the 26 banks in one specific instrument category. The first multilayer network has four layers split by seniority (equity, subordinated debt, senior unsecured debt, secured debt), the second multilayer network splits the exposures according to maturity into two layers (short- and long-term debt) and the third multilayer network has also two layers distinguished by whether the debt instrument is covered or securitized. For each multilayer network, we additionally build a layer which aggregates up all the other layers in order to assess whether the disaggregated layers yield additional information. Figures 1, 2, 3 and 4 visualize the equity, unsecured, secured and aggregated network layers, respectively. Just from the visual inspection it becomes clear that the exposures in the different instrument categories are very heterogeneous and warrant a detailed analysis of each layer individually.

2.1 Topological properties of the individual layers

Network measures consist of centrality and connectivity measures. Centrality measures refer to nodes' importance in the system, while connectivity measures refer to interconnectedness. Table

[9] Covered bonds are debt securities issued by a bank and secured against a pool of assets that, in case of failure of the issuer, can cover claims. Unlike securitised debt, covered bonds continue as obligations of the issuer, meaning that the investor has recourse against the issuer and the collateral, which is known as "dual recourse."

Figure 1: Structure of the equity network layer

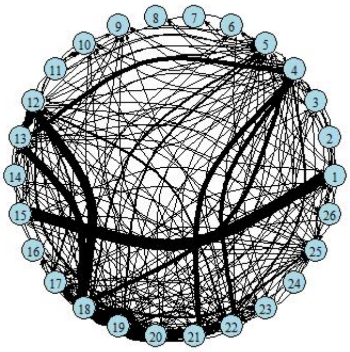


Figure 2: Structure of the unsecured debt network layer

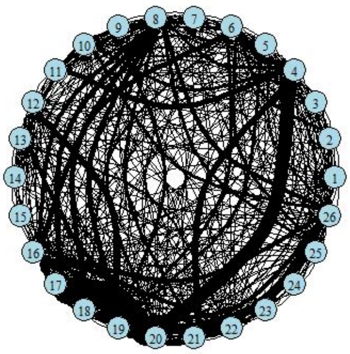


Figure 3: Structure of the secured debt network layer

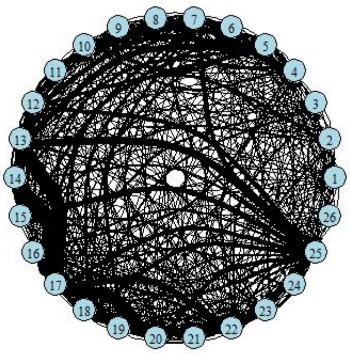
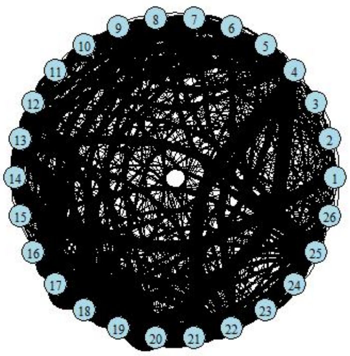


Figure 4: Structure of the aggregated multilayer network



Note: Each arc-link represents an exposure and the orientation of the arc defines the direction of the exposure. The size of the links is proportional to the size of the exposure. The aggregated multilayer network represents the sum of all the financial links across all instrument categories in the dataset.

1 presents the following connectivity measures: average degree[10] and density.[11] The aggregated

[10]The degree of a node in a network is the number of links the node has to other nodes. The network built here is directed, meaning that links point in one direction from one node to another node. For, example bank 1 might hold

multilayer network is a highly dense network where 75% of the possible links are present (see Figure 4 for a visualization of the aggregated network).

Table 1: Network topology measures for each network layer

	Density	Average Degree
Equity	0.32	16.30
Subordinated debt	0.29	14.61
Senior unsecured debt	0.56	28.30
Secured debt	0.65	32.53
Aggregated multilayer network	0.75	37.53
Short-term debt	0.05	2.92
Long-term debt	0.73	36.92
Total debt	0.74	37
Securitised debt	0.52	26.30
Covered debt	0.10	5.38
Total sec. and cov. debt	0.63	31.69

Note: The aggregated multilayer network represents the sum of all the financial links across all instrument categories in the dataset. Covered bonds are debt securities issued by a bank and secured against a pool of assets that, in case of failure of the issuer, can cover claims. Unlike securitised debt, covered bonds continue as obligations of the issuer, meaning that the investor has recourse against the issuer and the collateral, which is known as "dual recourse."

Table 2 presents four centrality measures: closeness centrality[12], betweenness centrality[13], eigenvector centrality[14] and clustering coefficient[15]. These four measures are averaged across the 26 nodes to give a general overview. Figures 19, 20, 21 and 22 in the appendix show the distribution of the individual node-level results for each measure by layer.

The same three layers have the highest average closeness centrality, average eigenvector centrality and average clustering coefficients: the long term debt layer, the total debt layer and the total securitised and covered bond layer. The average closeness centrality for most layers is very high and Figure 19 shows that individual closeness centrality measures for the nodes are high. In some cases closeness centrality is equal to zero - this is due to layers where at least one node does not have any links to other nodes in the network, there the average distance is set to infinity and therefore

a security of bank 2, but not vice versa. In that case, nodes have two different degrees, the in-degree, which is the number of incoming links, and the out-degree, which is the number of outgoing links. The average degree computed here is the average of the total degree, which is the sum of the in-degree and the out-degree.

[11] The density of the network is the number of existing edges over the number of possible edges.

[12] Closeness centrality how close a given node is to any other node. Here we use the inverse of the average distance between a given node and any other node.

[13] Betweenness captures the absolute position of the node in a network. It measures the extent to which a particular node lies "between" the other nodes in the network.

[14] Eigenvector centrality assigns relative scores to all nodes in the network based on the concept that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes.

[15] The clustering coefficient is the ratio of the number of edges between a node's neighbours to the total possible number of edges between a node's neighbours.

the denominator in the closeness centrality measure is infinity and the resulting measure is zero. Betweenness centrality measures are low. This is due to the fact that in very dense networks not one particular node stands out as intermediary. Noteworthy is the subordinated debt layer, since it has the highest average betweenness centrality and Figure 20 also shows that this layer has the highest interquartile range and the biggest outlier for this measure. In addition, Table 1 shows that the subordinated debt layer is not very dense. Taken together, this points to the fact that the subordinated debt layer has some central intermediaries that stand out compared to other banks.

Table 2: Average centrality measures for each network layer

	Close. centr.	**Betw. centr.**	**Eigenv. centr.**	**Clust. coeff.**
Equity	0.00	0.01	0.15	0.64
Subordinated debt	0.00	0.02	0.17	0.56
Senior unsecured debt	0.68	0.01	0.18	0.75
Secured debt	0.73	0.00	0.18	0.73
Aggregated multilayer network	0.81	0.00	0.19	0.82
Short-term debt	0.00	0.01	0.13	0.16
Long-term debt	0.79	0.00	0.19	0.81
Total debt	0.79	0.00	0.19	0.81
Securitised debt	0.62	0.01	0.18	0.67
Covered debt	0.00	0.00	0.11	0.12
Total sec. and cov. debt	0.73	0.00	0.18	0.72

Note: The aggregated multilayer network represents the sum of all the financial links across all instrument categories in the dataset. Covered bonds are debt securities issued by a bank and secured against a pool of assets that, in case of failure of the issuer, can cover claims. Unlike securitised debt, covered bonds continue as obligations of the issuer, meaning that the investor has recourse against the issuer and the collateral, which is known as "dual recourse."

2.2 Descriptive statistics of the multilayer network

To plot structural measures for multiplex networks, let us first introduce some notation and concepts.[16] The overlapping degree of node i is defined as:

$$o_i = \sum_{\alpha=1}^{M} k_i^{[\alpha]}, \tag{1}$$

where $k_i^{[\alpha]}$ is the degree of node i on a given layer α. Instead of the overlapping degree we consider the associated Z-score, which allows to compare multiplex networks of different size:

$$z(o_i) = \frac{o_i - \langle o \rangle}{\sigma_o}, \tag{2}$$

[16] For more background on structural measures for multiplex networks, see Battiston et al. (2014).

where $\langle o \rangle$ is equal to the average overlapping degree of the nodes of the system and σ_o is the corresponding standard deviation. The Z-score of the overlapping degree is the signed number of standard deviations by which the overlapping degree is above the mean.

We also compute the multiplex participation coefficient of node i, which is defined as:

$$P_i = \frac{M}{M-1}\left[1 - \sum_{\alpha=1}^{M}\left(\frac{k_i^{[\alpha]}}{o_i}\right)^2\right], \tag{3}$$

where M is the total number of layers in the multiplex network. P_i takes values in [0,1] and measures whether the links of node i are uniformly distributed among the M layers or are instead primarily concentrated in just one or a few layers. More precisely, the coefficient P_i is equal to 0 when all the edges of i lie in one layer, while $P_i = 1$ only when node i has exactly the same number of edges on each of the M layers. In general, the larger the value of P_i, the more equally distributed is the participation of node i accross the M layers.

Figure 5 shows a scatter plot of the Z-score of the overlapping degree and the multiplex participation coefficient for the 26 largest euro area banks. The Z-score and the multiplex participation coefficient were computed for a multiplex network with three layers (equity, unsecured debt and secured debt). The size of the bubbles in the scatter plot are proportional to the total assets of the respective bank. The colors of the bubbles correspond to the business models of the respective banks.

The bank business models[17] are defined in the following way:

- a *universal bank* is a bank that engages in both commercial and investment banking activities;
- a *G-SIB* is a global systemically important bank (G-SIB) according to the classification methodology of the Basel Committee on Banking Supervision (BCBS);
- a *G-SIB universal bank* is a universal bank that also qualifies as G-SIB;
- *sectoral lenders* are specialized lenders such as auto and shipping financing companies and *wholesale lenders* provide wholesale funding to large customers and financial institutions;
- a *diversified lender* is a bank that lends significantly across borders and to both retail and corporate clients.[18]

[17]The business model classification used in the paper follows the definition regularly employed in ECB publications (see e.g. Special Feature C entitled “Adapting bank business models: financial stability implications of greater use of fees and commissions” in the November 2016 Financial Stability Review) and in ECB Banking Supervision. The classification is based on a non-published indicator-based approach. It is broadly consistent with but not strictly comparable to the Lucas et al. (2018) approach.

[18]Diversified lenders refer to banks not classified as GSIBs (by the FSB) but operating with a relatively broad range of loan products (as compared to similar sized sectoral lenders which tend to specialize in one or few business lines; say, mortgage lending, consumer credit, shipping loans, etc.).

Figure 5 shows that there is a range of levels for the multiplex participation coefficient, which indicates that there is heterogeneous behavior regarding the participation of banks in each of the three layers - here equity, unsecured debt and secured debt. G-SIBs have a multiplex participation coefficient of 1 or close to 1. It is equal to 1 only when the node has exactly the same number of edges on each of the equity, unsecured debt and secured debt layers. This implies the participation of G-SIBs is uniformly distributed across the different layers. The lower the multiplex participation coefficient, the more banks' links are concentrated in one network layer and hence they are more specialized in one type of security. Furthermore, the larger the bank by total assets, the higher its multiplex participation coefficient, which implies that larger banks seem to be active in all three network layers. Such a descriptive statistic is useful for financial stability analysis, since it allows to gauge which bank's distress might lead to disruptions across several markets.

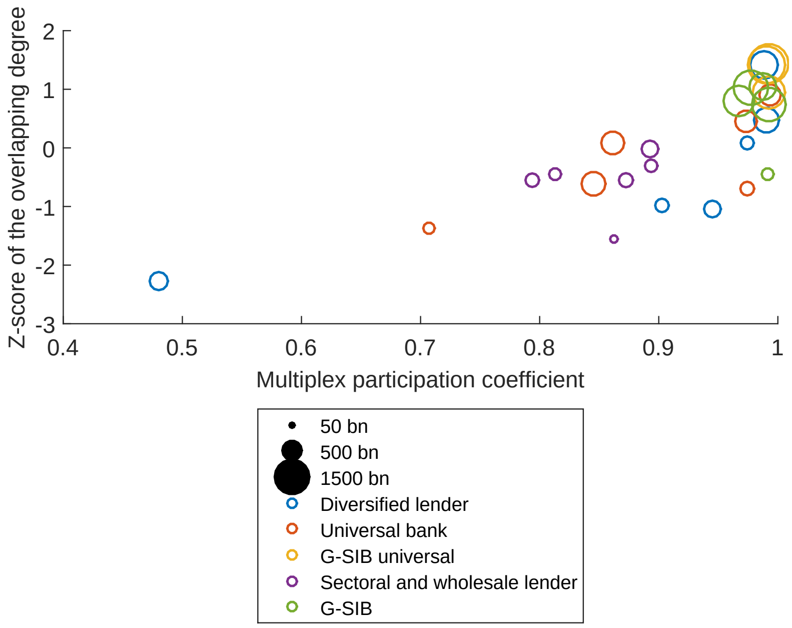
The Z-score of the overlapping degree shows that there is also heterogeneity with respect to the overlapping degree. While the large banks (mostly G-SIBs) have a high Z-score, indicating that their overlapping degree is between one and two standard deviations above the mean, some smaller banks exhibit the opposite pattern.

To sum up, we find that - unsurprisingly perhaps - G-SIBs are uniformly active in all layers and display an interconnectedness above the mean in all layers. More interestingly, we find that some banks not classified as G-SIBs exhibit similarly high interconnectedness across layers. This finding might point to the need to monitor the linkages of large non-GSIBs too.

As noted by Bargigli et al. (2014) and Aldasoro and Alves (2018), when describing multilayer networks it is important to distinguish between topological similarity and point-wise similarity. It is possible that network layers are very similar in terms of topological measures such as density or degree, but these measures do not uniquely identify a network. Indeed, the link patterns between the nodes can still differ. In the following point-wise similarity analysis we test to what extent a layer is representative of the other. Similarity analysis can be a useful tool for financial stability analysis. Shock propagation and contagion in a multiplex network do also depend on the similarity between the layers. Indeed, if the same counterparties are linked in different layers, it means they are exposed to each other in different markets and distress of one counterparty will affect the other one in different markets.

An appropriate metric for similarity analysis of network layers is the Jaccard similarity index J. It is a measure designed for binary networks. A binary network is represented by a matrix with entries of only 1 and 0, where a 1 represents the existence of a link between two nodes and 0 the absence of a link. The index captures the probability of observing a given connection in a network conditional on observing the same link in the other network. For a given pair of vectors x and y, the index is computed as the quotient between the size of the intersection and size of the union of the two ordered vectors:

Figure 5: Scatter plot of the Z-score of the overlapping degree and the multiplex participation coefficient for the 26 largest euro area banks



Note. Bubble sizes are proportional to total assets. The Z-score and the multiplex participation coefficient were computed for a multiplex network with three layers (equity, unsecured debt and secured debt).

$$J(x, y) = \frac{x \cap y}{x \cup y} \tag{4}$$

According to the Jaccard similarity index presented in Table 3, there is a wide heterogeneity in terms of similarity between network layers. A similarity of between 97 to 99% is achieved for layers that constitute subsets of each other, such as the long-term debt layer and the total debt layer. For layers where the instruments are mutually exclusive, we can also find high overlaps. For example the secured and the unsecured debt layer have a similarity of 67%, implying complementarity between the two instrument types. On the other hand the mutually exclusive short- and long-term debt network layers only have a similarity of 7%, which shows a lack of complementarity among instruments of different maturity. In between that range we find the mutually exclusive equity, subordinated and senior unsecured debt layers to have a similarity of between 44% and 46% for the different pairs.

Table 3: Jaccard similarity index for each network layer

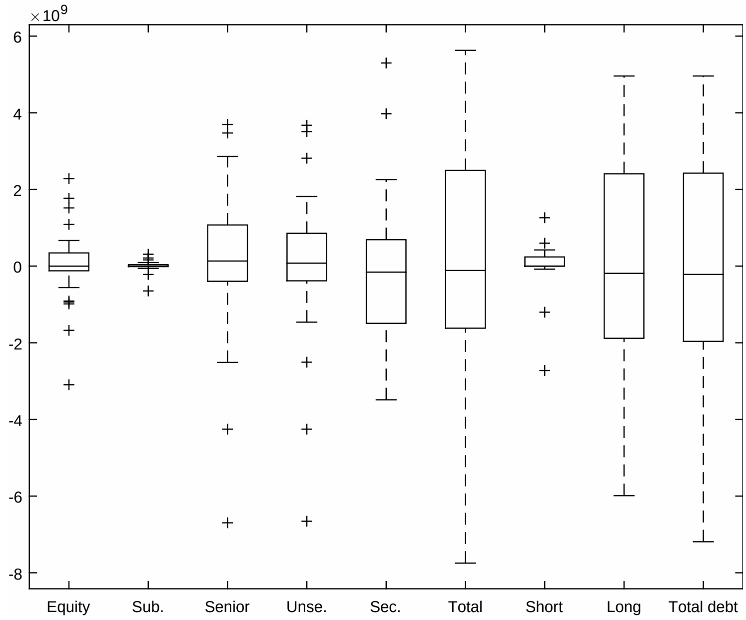
	Equity	**Sub.**	**Senior**	**Unsec.**	**Sec.**	**Total sen.**	**Short**	**Long**	**Total debt**	**Securit.**	**Cov.**	**Total sec.**
Equity	1	0.45	0.46	0.47	0.42	0.43	0.07	0.42	0.42	0.38	0.11	0.41
Sub.	0.45	1	0.44	0.49	0.37	0.38	0.13	0.39	0.39	0.34	0.10	0.36
Senior	0.46	0.44	1	0.95	0.66	0.75	0.10	0.76	0.76	0.58	0.10	0.63
Unsec.	0.47	0.49	0.95	1	0.67	0.78	0.09	0.79	0.80	0.59	0.10	0.65
Sec.	0.42	0.37	0.66	0.67	1	0.86	0.074	0.88	0.87	0.80	0.16	0.97
Total sen.	0.43	0.38	0.75	0.78	0.86	1	0.07	0.98	0.98	0.70	0.14	0.84
Short	0.07	0.13	0.10	0.09	0.07	0.07	1	0.07	0.07	0.07	0.02	0.07
Long	0.42	0.39	0.76	0.79	0.88	0.98	0.07	1	0.99	0.71	0.14	0.85
Total debt	0.42	0.39	0.76	0.80	0.87	0.98	0.07	0.99	1	0.71	0.14	0.85
Securit.	0.38	0.34	0.58	0.59	0.80	0.70	0.07	0.71	0.71	1	0.00	0.83
Cov.	0.11	0.10	0.10	0.10	0.16	0.14	0.02	0.14	0.14	0.00	1	0.16
Total sec.	0.41	0.36	0.63	0.65	0.97	0.84	0.07	0.85	0.85	0.83	0.16	1

Note. Sec. refers to secured debt; Total sen. refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Securit. refers to securitised debt, Cov. refers to covered debt; Total sec. refers to the aggregated securitised and covered debt layers.

3 Funding and exposures in the multilayer network of large euro area banks

Since the granularity of the data allows us to build a network with directed links, we know the issuer and the holder of each security within the network. We can therefore distinguish funding from exposures in the network. Figure 6 shows the difference between exposures and funding of the 26 largest euro area banks amongst each other. Overall, we see that the negative outliers (where banks borrow more from the network than they invest into the network) are larger than the positive outliers (where banks hold more securities of the network than they issue to the network). If we look at the total position, funding from the network can outweigh exposures to the network by 8 billion euro and the reverse position can go up to 6 billion euro. If we look at individual layers, especially the senior unsecured, secured and the long-term debt layers show large differences, which are also the categories with the largest volume of securities outstanding.

Figure 6: Difference between exposures and funding of the 26 largest euro area banks



Note: Difference between exposures and funding computed as difference between the weighted out-degree and weighted in-degree of the aggregated network of the 26 largest euro area banks, in nominal values. Sub. refers to subordinated debt; Senior refers to senior unsecured debt; Unse. refers to unsecured debt (the sum of subordinated and senior unsecured debt); Sec. refers to secured debt; Total refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Total debt. refers to the aggregated short- and long-term debt layers. The top and bottom of each "box" are the 25th and 75th percentiles of the samples, respectively. The line in the middle of each box is the sample median. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box. Outliers are displayed with a + sign.

We also compute the out-degree of the network (the number of banks a given bank is exposed to) against the in-degree of the network (the number of banks providing funding to a given bank). Figures 7, 9, 11 and 13 visualize the results for the total network and for the equity, secured and unsecured network layers respectively. Furthermore, we compute the weighted out(in)-degree as the sum of nominal values of the links from (to) a given node to (from) all other nodes. Figures 8, 10, 12 and 14 visualize the results for the total network and for the equity, secured and unsecured network layers respectively. Both the unweighted and the weighted degree are very useful measures for financial stability analysis, especially when in direct comparison. The unweighted degree provides information on the interconnectedness of the bank in the network. Many links do not necessarily constitute a risk to financial stability, since strong interconnectedness can also allow for risk sharing, they do however imply that shocks can affect many banks very quickly. The weighted degree allows to gauge the overall monetary size of the linkages and provides information on the exposure of the banks in the network to default from banks they are exposed to - in other words their exposure to credit risk - and their exposure to funding withdrawals from banks in the network, meaning their exposure to liquidity or rollover risk. The scatterplots additionally allow to assess whether there is an asymmetry between the in- and the out-going links.

Figure 7 shows a scatterplot of the in- and out-degree for the aggregated network of 26 largest euro area banks. The largest banks by total assets are also the most interconnected in the network, both in terms of funding links and exposure links. The picture changes substantially when we account for the weights of links between banks, as shown in Figure 8. Large banks do not stand out as recipients of funds from the network out of their total securities issuance. Especially the diversified lenders seem to get a larger share of funds from the network compared to other banks in the network, over 10% for one bank.

Figure 9 shows a scatterplot of the in- and out-degree for the equity network layer of the 26 largest euro area banks. Some banks do not rely on equity funding from the network, but are exposed to it. Again the largest banks are in the top right corner of the chart. Looking at the weighted version in Figure 10, we see that two banks rely on the network for 6% and 9% of their equity funding respectively.

Figure 11 shows the scatterplot of the in- and out-degree for the unsecured debt network layer of the 26 largest euro area banks. Again, the largest banks are the most interconnected. But the weighted version in Figure 12 shows a much more heterogeneous picture. The share of unsecured funding out of debt securities funding from the network overall is very small and there is no clustering in terms of large or small banks.

Figure 13 shows the scatterplot of the in- and out-degree for the secured debt network layer of the 26 largest euro area banks. Again, the largest banks are the most interconnected. The weighted version in Figure 14 shows the completely opposite picture, where the largest banks receive the lowest share of secured funding out of total debt securities funding from the network.

Figure 7: Scatterplot of the in- and out-degree for the aggregated network of 26 largest euro area banks

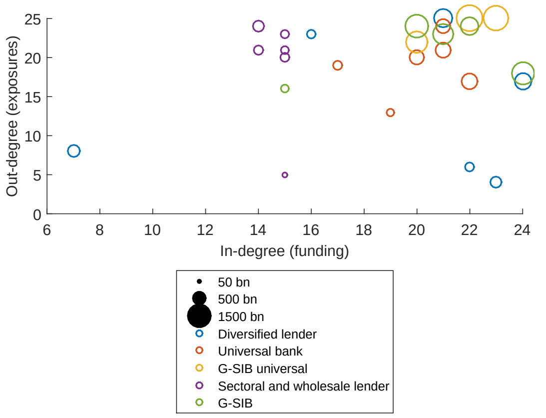
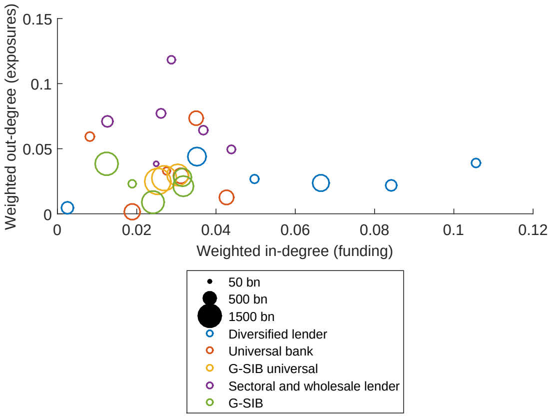


Figure 8: Scatterplot of the weighted in- and out-degree for the aggregated network of 26 largest euro area banks



Note: Bubble sizes are proportional to total assets. Bank business models are defined in Section 2.2. The weighted degree of each bank is normalised by the total nominal amount of securities issued by the bank. Figures 24 and 25 in the appendix represent the exact same information except that the bubble sizes are proportional the CET1 ratios of the banks.

Figure 9: Scatterplot of the in- and out-degree for the equity network layer of the 26 largest euro area banks

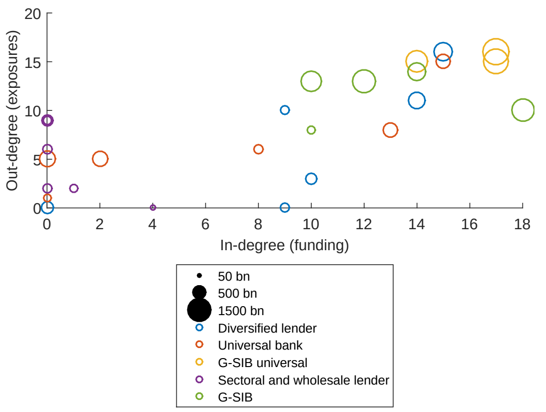
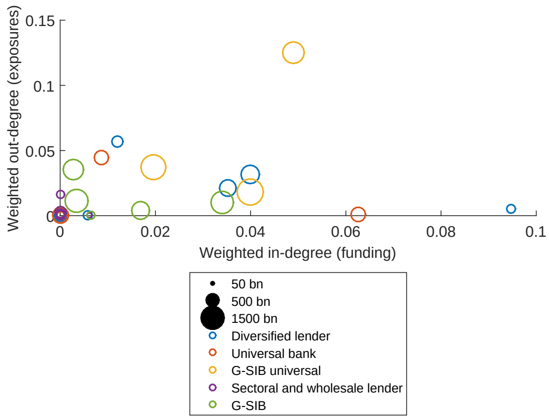


Figure 10: Scatterplot of the weighted in- and out-degree for the equity network layer of the 26 largest euro area banks



Note: Bubble sizes are proportional to total assets. Bank business models are defined in Section 2.2. The weighted degree of each bank is normalised by the total nominal amount of shares issued by the bank.

The diversified lenders are again outliers, one of them receiving 15% of its secured debt securities funding from the network.

From the analysis of the scatterplots, we can see that for the network of the 26 largest euro

Figure 11: Scatterplot of the in- and out-degree for the unsecured debt network layer of the 26 largest euro area banks

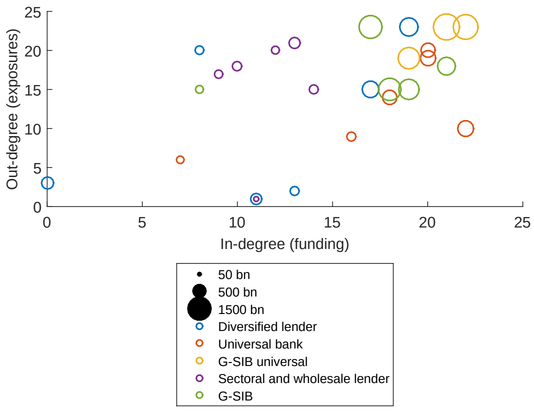
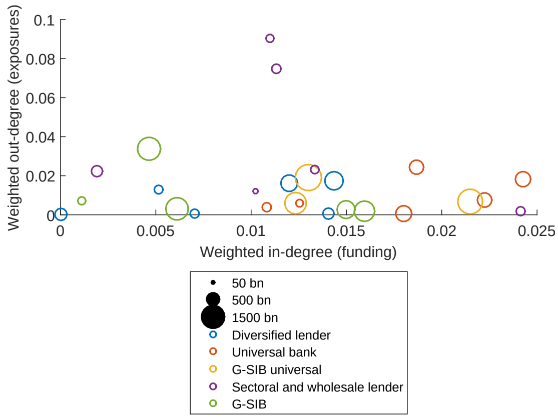


Figure 12: Scatterplot of the weighted in- and out-degree for the unsecured debt network layer of the 26 largest euro area banks



Note: Bubble sizes are proportional to total assets. Bank business models are defined in Section 2.2. The weighted degree of each bank is normalised by the total nominal amount of debt securities issued by the bank.

Figure 13: Scatterplot of the in- and out-degree for the secured debt network layer of the 26 largest euro area banks

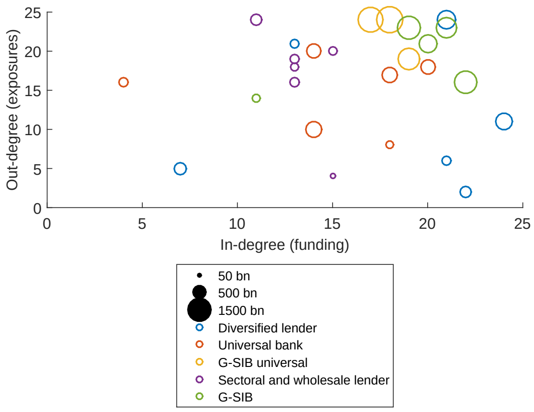
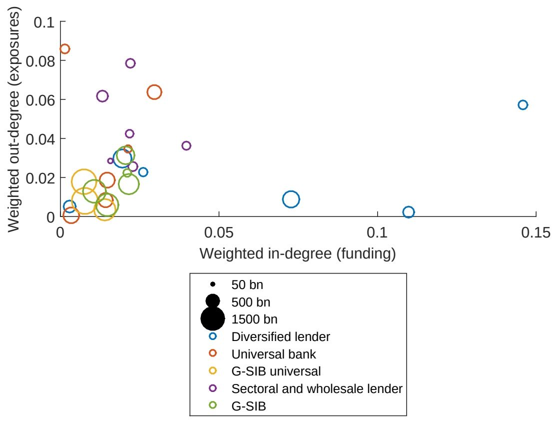


Figure 14: Scatterplot of the weighted in- and out-degree for the secured debt network layer of the 26 largest euro area banks



Note: Bubble sizes are proportional to total assets. Bank business models are defined in Section 2.2. The weighted degree of each bank is normalised by the total nominal amount of debt securities issued by the bank.

area banks, the most interconnected banks as given by the degree are not the most exposed ones in terms of monetary amounts as given by the weighted degree. To sum up, liquidity risk and credit risk affect banks differently in different markets and do call for a disaggregated view of the interbank network. Regarding contagion risk as proxied by the unweighted degree, it seems that the largest banks in the sample are invariably the most interconnected in the network, but there is more heterogeneity in the connectedness of the smaller banks, which also warrants a disaggregated view of the interbank network.

4 Euro area banks' funding and exposures by sector

The analysis is now extended to include other financial and economic sectors by combining the ECB Securities Holdings Statistics by Group (SHSG) with the ECB Securities Holdings Statistics by Sector (SHSS) as well as the Centralised Securities Database (CSDB). That way, we can build a macro-financial network, where we can distinguish the sectoral exposures of the 26 largest euro area banks as well as the funding they get from different sectors. In addition, we can compute the same descriptive statistics for the remaining euro area banks. The sectoral data is restricted to the euro area. The 26 largest euro area banking groups represent around 60% of euro area banking sector assets.

4.1 Exposures: euro area banks' securities holdings by sector

Figures 15 and 16 show the 26 largest euro area banks' and other euro area banks' sectoral security holdings, respectively. Security holdings comprise investment in listed shares, investment fund shares and debt securities. For the holdings of the 26 largest euro area banking groups we take the nominal securities holdings of the 26 banking groups that have been issued by euro area resident sectors. The holdings are those of the parent company plus the subsidiaries resident in the euro area. Subsidiaries resident outside the euro area have been excluded. We do not have institution-level data for other banks besides the 26 largest banking groups. To compute the holdings of the residual euro area banks, we take the nominal securities holdings of the euro area banking sector and subtract on a security-by-security level the holdings of the 26 largest euro area banking groups. The sectoral classification follows the 2010 European System of Accounts (ESA).[19]

The largest exposures in Figures 15 and 16 are to securities issued by government. Apart from government bond holdings, the largest banks predominantly invest in other financial institutions (OFIs) and banks (MFIs), whereas for the other euro area banks it is the other way around. A small share of the banks' investment goes to non-financial corporations (NFCs). Smaller euro area banks are also exposed to investment funds (IVFs) to a bigger extent than the large banks. Investment funds cover investment schemes whose investment fund shares or units are not seen as close substitutes for deposits, as this would be the case for money market funds. However, the large banks' exposure to other financial corporations are much larger. These comprise for example

[19] For detailed definitions of the sectors, see the note below Table 4.

financial vehicle corporations engaged in securitisation transactions, security and derivative dealers and loan and securities brokers. A possible explanation as to why the other, smaller banks might hold more securities issued by investment funds is that to construct the large banking groups we only include subsidiaries that belong to the banking sector and exclude any that belong to the investment fund or other financial institution sectors. Possibly in large and complex banking groups, these non-bank subsidiaries are more likely to hold investment fund securities, since these carry a high risk weight in the computation of regulatory capital requirements. Smaller banks might have no subsidiaries to shift these types of investment off their balance sheet.

Figure 15: Twenty-six largest euro area banks' total security holdings, by sector

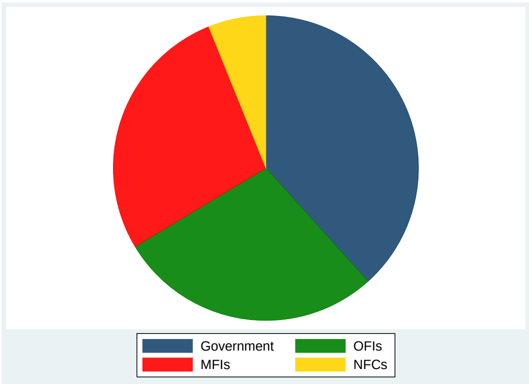
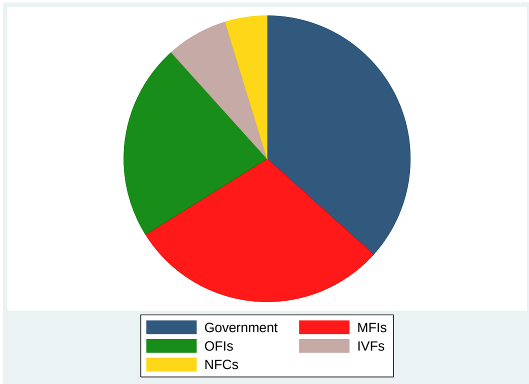


Figure 16: Other euro area banks' total security holdings, by sector



Note: Only holdings larger than 2 percent of the total holdings are displayed. For definitions of the sectors, see note below Table 4.

Table 4 shows the sectoral portfolio weights by maturity of the debt security for the 26 largest as well as other euro area banks. The long-term debt portfolio is similar for the two categories of banks. The short-term debt portfolio shows significant differences in holdings of government debt and bank debt. Large banks hold 26 percentage points more short-term government debt than the other euro area banks, but hold 36 percentage points less short-term bank debt securities.

4.2 Funding: sector holdings of euro area bank securities

In order to analyze the funding of euro area banks, we use the sector-level securities holdings data and split the issuers by whether they belong to the 26 banking groups or not. That way we can distinguish which euro area sectors fund the 26 largest banks and the other banks. In Figures 17 and 18 we display the sector-level holdings of securities issued by the 26 largest and other euro area banks. Securities comprise debt securities and shares. Figure 17 shows that nearly half the funding of the largest euro area banks comes from other banks. We use the unconsolidated version

Table 4: Sectoral portfolio weights by maturity of the debt security for the 26 largest euro area banks and other euro area banks, in percent

Instrument class	Sector name	Large banks	Other banks
Short-term debt	Government	59.53	33.57
	IVFs	0.00	1.13
	Banks	12.88	49.92
	NFCs	7.70	5.02
	OFIs	19.90	10.35
Long-term debt	Government	40.04	40.63
	ICs	0.10	0.10
	IVFs	0.00	0.25
	Banks	26.95	31.12
	NFCs	2.81	2.76
	OFIs	30.09	25.13

Note: Sectors are classified according to the European System of Accounts (ESA 2010). Banks (S.122): the deposit-taking corporations except the central bank subsector includes all financial corporations and quasi-corporations, except those classified in the central bank and in the MMF subsectors, which are principally engaged in financial intermediation and whose business is to receive deposits and/or close substitutes for deposits from institutional units, hence not only from MFIs, and, for their own account, to grant loans and/or to make investments in securities; NFC (non-financial corporation) (S.11): A corporation or quasi-corporation that is not engaged in financial intermediation but is active primarily in the production of market goods and non-financial services; IVFs (investment funds) (S.124): the non-MMF investment funds subsector consists of all collective investment schemes, except those classified in the MMF subsector, which are principally engaged in financial intermediation. Their business is to issue investment fund shares or units which are not close substitutes for deposits, and, on their own account, to make investments primarily in financial assets other than short-term financial assets and in nonfinancial assets (usually real estate); OFI (Other financial corporation): S.215-127; IC (insurance corporation) (S.128): the insurance corporations subsector consists of all financial corporations and quasi-corporations which are principally engaged in financial intermediation as a consequence of the pooling of risks mainly in the form of direct insurance or reinsurance.

of the SHSG data, therefore a substantial part of this funding might be due to cross-investments of parents and subsidiaries, since the SHSG covers the 26 largest banking groups. This might also explain why the residual euro area banks seem to receive much less funding from banks, since these will be smaller and less complex banks and have less cross-investment structures. Households, investment funds and insurance companies each make up roughly an eighth of total funding via securities issued for the 26 large banks. For the other euro area banks, the largest share of funding comes from households, who provide a quarter of the securities-based funding. Investment funds, insurance companies and banks each provide roughly a fifth of the funding via securities to smaller banks.

Large household sector holdings of bank securities may raise concerns on the feasibility of bail-in strategies due to political economy considerations. In a related analysis of the evolution of sectoral holdings of unsecured bank debt securities, ECB (2016) finds that from the last quarter of 2013 to the first quarter of 2016, euro area households have increased their share of holdings of subordinated debt securities issued by banks to 20% out of their total nominal bank debt securities holdings, which makes households more vulnerable to losses due to resolution strategies such as bail-in. In absolute terms, the euro area household sector has however reduced its debt securities holdings during that period. Another piece of evidence on the vulnerability of households to bail-in is provided by Pigrum et al. (2016), who find that euro area households hold 24% of the unsecured debt securities issued by euro area banks. These findings suggest that close monitoring of holdings of bailin-able bank liabilities might be warranted to ensure a smooth resolution process.

Figure 17: Sector-level holdings of securities issued by the 26 largest euro area banks

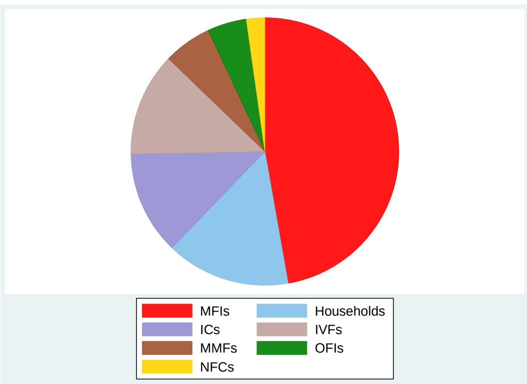
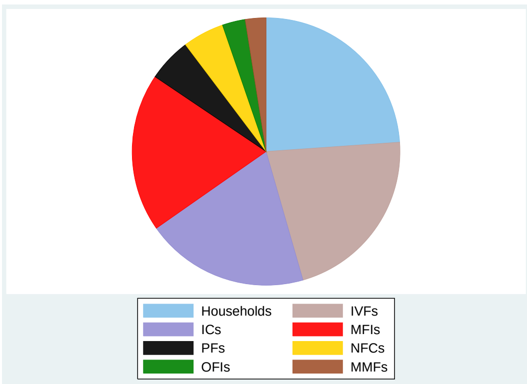


Figure 18: Sector-level holdings of securities issued by other euro area banks



Note: Only holdings larger than 2 percent of the total holdings are displayed. For definitions of the sectors, see note below Table 5.

Table 5 displays the sectoral holdings of debt securities issued by the 26 largest euro area banks and other euro area banks. Nearly half of the short-term debt securities issued by large and other euro area banks are bought by money market funds (MMFs), whereas at the long maturity it is mostly banks investing into other banks. A quarter of short-term debt securities of large banks are bought by the banking sector while this goes up to a third for the short-term debt securities issued by the other banks. Insurance companies seem to invest more into large banks at the short maturity, whereas in the long maturity the difference is much smaller.

5 Potential for contagion in the euro area macro-financial network

A network representation of sectoral linkages can also be useful for contagion analysis. For that purpose we build a multi-layer macro-financial network of euro area banking sectors where the different layers correspond to the 19 euro area countries. Results for some countries have to be jointly displayed for data confidentiality reasons. Each network layer represents the exposures of the national euro area banking sector to other euro area sectors, out of the holding banking sector's aggregate CET1 capital, which we collected from the ECB Consolidated Banking Database (CBD). That way, we assess the exposure of national banking sectors to other sectors and can quantify in an intuitive way the vulnerability of national banking sectors, should there be distress or defaults in the sectors banks invest into. Since banks invest into other banks, such metrics can be useful to get intuition on the exposure due to possible banking crises or due to bail-in of a large bank. Similarly, the bank-sovereign doom loop has been a big concern during the past crisis and in the following tables one can easily gauge exposures of national banking sectors to euro area sovereigns. Home bias is still large in the euro area, in March 2017 euro area banks held 3.8% of their total assets in domestic sovereign bonds as opposed to 1.5% in other euro area sovereign bonds (ECB, 2017). Finally, the so-called shadow banking sector is a growing component of the financial sector and it is important for banking supervisors to keep track of the exposures traditional banks face to those sectors. In our sectoral classification, these shadow banks would be other financial institutions or investment funds.

Table 6 shows the euro area national banking sector holdings of securities issued by euro area sectors in percent of the holding banking sector's CET1 capital. It is striking that euro area banks' securities holdings are dominated by securities issued by general governments, banks and other financial corporations, whereas holdings of securities issued by the non-financial private sector are in general relatively small. This primarily reflects the still largely bank-based financial system prevalent in the euro area with most of the external financing of households and firms consisting mainly of bank loans while capital market-based financing remains limited.

We find that the Italian banking sector's exposure to euro area government securities is twice the size of its CET1 capital, which is the largest ratio overall. Slovakia, Slovenia and Spain also

Table 5: Sectoral holdings of debt securities issued by the 26 largest euro area banks and other euro area banks, in percent and by maturity

Instrument class	Sector name	Large banks	Other banks
Short-term debt	**Government**	0.23	0.37
	Households	1.40	1.21
	ICs	11.77	3.28
	IVFs	7.42	5.70
	Banks	24.72	33.11
	MMFs	48.45	49.35
	NFCs	3.89	4.17
	OFIs	2.07	2.51
	PFs	0.05	0.29
Long-term debt	**Government**	0.93	1.26
	Households	13.77	10.60
	ICs	13.84	16.28
	IVFs	9.94	19.54
	Banks	53.40	43.74
	MMFs	2.93	1.37
	NFCs	1.87	1.89
	OFIs	2.53	3.67
	PFs	0.77	1.60

Note: Sectors are classified according to the European System of Accounts (ESA 2010). Banks/MFIs (S.122): the deposit-taking corporations except the central bank subsector includes all financial corporations, except those classified in the central bank and in the MMF subsectors, which are principally engaged in financial intermediation and whose business is to receive deposits, and, for their own account, to grant loans and/or to make investments in securities; NFC (non-financial corporation) (S.11): A corporation or quasi-corporation that is not engaged in financial intermediation but is active primarily in the production of market goods and non-financial services; IVFs (investment funds) (S.124) : the non-MMF investment funds subsector consists of all collective investment schemes, except those classified in the MMF subsector, which are principally engaged in financial intermediation; OFI (Other financial corporation): S.215-127; IC (insurance corporation) (S.128): the insurance corporations subsector consists of all financial corporations which are principally engaged in financial intermediation as a consequence of the pooling of risks mainly in the form of direct insurance or reinsurance; PF (pension funds) (S.129): the pension funds subsector consists of all financial corporations which are principally engaged in financial intermediation as the consequence of the pooling of social risks and needs of the insured persons (social insurance); MMF (money market fund) (S.123): the MMF subsector consists of all financial corporations, except those classified in the central bank and in the credit institutions subsectors, which are principally engaged in financial intermediation. Their business is to issue investment fund shares or units as close substitutes for deposits from institutional units. For more information on the evolution and a breakdown of sectoral holdings of unsecured bank debt securities, we refer the reader to ECB (2016).

have ratios above 1. The Greek banking sector is much less exposed to government securities, but it has the highest ratio in terms of exposures to euro area banks (159 percent) and to other financial institutions (146 percent). The German and French banking sectors provide the most funding to non-financial corporations relative to their added CET1 capital (14 percent) as well as to investment funds (22 percent).

Table 6: Euro area national banking sector holdings of securities issued by euro area sectors, ratio out of holding banking sector's CET1 capital

	Government	ICPFs	IVFs	Banks	NFCs	OFIs
AT	0.52	0.01	0.02	0.38	0.06	0.07
CY	0.42	0.00	0.01	0.27	0.02	0.02
EE	0.03	0.00	0.00	0.05	0.00	0.00
ES	1.04	0.00	0.01	0.57	0.10	0.77
FI	0.42	0.00	0.01	0.33	0.09	0.09
GR	0.48	0.00	0.01	1.59	0.02	1.46
IE	0.72	0.00	0.00	0.44	0.02	0.68
IT	2.00	0.03	0.01	1.15	0.10	0.59
LT	0.67	0.00	0.00	0.05	0.02	0.02
LV	0.36	0.00	0.02	0.24	0.03	0.15
MT	0.90	0.00	0.05	0.40	0.12	0.13
SI	1.52	0.00	0.00	0.22	0.06	0.02
SK	1.96	0.00	0.00	0.15	0.07	0.02
DE; FR	0.70	0.01	0.22	0.70	0.14	0.42
BE; NL; LU; PT	0.79	0.00	0.04	0.31	0.06	0.95

Note: For definitions of the sectors, see note below Table 5. Securities include listed shares, investment fund shares and debt securities. We include sectors where at least one entry is equal to or above 0.01. Results for some countries have to be jointly displayed for data confidentiality reasons.

Table 7 shows the euro area national banking sector holdings of listed shares issued by euro area sectors in percent of the holding banking sector's CET1 capital. Bearing in mind that these are relative numbers, overall investments in euro area bank equity is rather low, especially when compared to the much larger ratios for debt securities presented in Tables 8 and 9. Noteworthy is that the Spanish, Italian and French-German banking sectors invest into non-financial corporations in the order of 8 percent of their CET1 capital.

Table 8 shows euro area national banking sector holdings of short-term debt securities issued by euro area sectors in percent of the holding banking sector's CET1 capital. The Greek banking sector invests into the short-term debt securities of the euro area banking sector in the order of 121 percent of its CET1 capital. Noteworthy is also that the Portuguese banking sector has by far the largest share of investment into euro area non-financial corporations' short-term debt securities relative to its CET1 capital (25 percent), compared to the 1 percent invested by France, who is ranked second.

Table 7: Euro area national banking sector holdings of listed shares issued by euro area sectors, ratio out of holding banking sector's CET1 capital

	ICPFs	Banks	NFCs
ES	0.00	0.02	0.08
FI	0.00	0.00	0.03
GR	0.00	0.01	0.01
IE	0.00	0.00	0.01
IT	0.02	0.02	0.08
MT	0.00	0.00	0.01
DE; FR	0.00	0.04	0.08
BE; NL; LU; PT	0.00	0.00	0.01

Note: For definitions of the sectors, see note below Table 5. We include sectors where at least one entry is equal to or above 0.01. We exclude investment fund shares in this table. Results for some countries have to be jointly displayed for data confidentiality reasons.

While in absolute terms that would imply that France might invest more, since it has a much larger banking sector and therefore more CET1 capital, in relative terms that is a significant difference in investment patterns compared to other euro area banking sectors. Furthermore, the Irish banking sector has by far the largest share of short-term investment into other financial institutions relative to its CET1 capital (14 percent), which is 10 percentage points more than the second ranked banking sectors of Portugal and Spain.

Table 9 presents the euro area national banking sector holdings of long-term debt securities issued by euro area sectors in percent of the holding banking sector's CET1 capital. The Greek banking sector invests into the long-term debt securities of the euro area banking sector in the order of only 38 percent of its CET1 capital, compared to 121 percent for its investment in short-term bank debt (see Table 8). Both the Italian and Portuguese banking sectors have exposures to euro area banking sectors that exceed their CET1 capital. Slovakia and Italy have exposures to long-term government debt close to twice their CET1 capital and Greece is exposed to long-term debt of other financial institutions in the order of 146 percent of its CET1 capital. Noteworthy is also that the Portuguese banking sector again ranks first in terms of investment share into long-term debt of non-financial corporations, as it already did for short-term debt of that sector, though there seems to be a preference for investment into short-term debt (25 percent) rather than long-term debt (14 percent).

To sum up, there is a strong heterogeneity in terms of exposures of euro area banking sectors to euro area economic and financial sectors. Some banking sectors have very large exposures across different instrument categories and sectors, such as Italy and Greece. Since exposures based on securities are only one aspect of the overall exposures of banks, it is possible that certain banking sectors are more heavily exposed in other instrument categories. Similarly, we restrict our analysis

Table 8: Euro area national banking sector holdings of short-term debt securities issued by euro area sectors, ratio out of holding banking sector's CET1 capital

	Government	Banks	NFCs	OFIs
AT	0.01	0.01	0.00	0.00
CY	0.04	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.01
ES	0.09	0.01	0.00	0.04
FI	0.02	0.01	0.00	0.00
FR	0.07	0.10	0.01	0.03
GR	0.27	1.21	0.00	0.00
IE	0.03	0.02	0.00	0.14
IT	0.09	0.00	0.00	0.00
LT	0.07	0.00	0.00	0.00
LV	0.02	0.00	0.00	0.00
MT	0.09	0.00	0.00	0.01
PT	0.31	0.00	0.25	0.04
SI	0.07	0.05	0.00	0.00
BE; NL; LU	0.04	0.02	0.00	0.00

Note: For definitions of the sectors, see note below Table 5. We include sectors where at least one entry is equal to or above 0.01. Results for some countries have to be jointly displayed for data confidentiality reasons.

to the euro area on both the holder and issuer side, exposures to other large financial sectors such as the United Kingdom or the United States are therefore not covered here.

6 Conclusion

Banks are interlinked across many different instrument categories. In order to monitor and assess contagion risk among banks and the wider macro-financial system, granular information about the individual exposures is crucial. This paper utilizes a unique dataset of banking sector cross-holdings of securities to map these exposures among banks and economic and financial sectors. The analytical approach presented here could be useful for both micro- and macroprudential supervisors in identifying counterparty risk, concentration risk and funding risk. Such information is highly relevant for the design of appropriate prudential measures, such as for example large exposure limits.

Table 9: Euro area national banking sector holdings of long-term debt securities issued by euro area sectors, ratio out of holding banking sector's CET1 capital

	Government	ICPFs	Banks	NFCs	OFIs
AT	0.51	0.01	0.37	0.06	0.07
CY	0.38	0.00	0.27	0.02	0.02
DE	0.74	0.00	0.87	0.06	0.28
EE	0.03	0.00	0.05	0.00	0.00
ES	0.95	0.00	0.54	0.02	0.73
FI	0.41	0.00	0.33	0.06	0.08
FR	0.57	0.00	0.30	0.05	0.56
GR	0.22	0.00	0.38	0.00	1.46
IE	0.70	0.00	0.42	0.02	0.54
IT	1.92	0.01	1.13	0.02	0.58
LT	0.60	0.00	0.05	0.02	0.02
LV	0.34	0.00	0.23	0.03	0.15
MT	0.81	0.00	0.39	0.12	0.12
PT	0.93	0.00	1.08	0.14	0.87
SI	1.45	0.00	0.17	0.05	0.02
SK	1.96	0.00	0.15	0.07	0.02
BE; NL; LU	0.70	0.00	0.20	0.02	0.95

Note: For definitions of the sectors, see note below Table 5. We include sectors where at least one entry is equal to or above 0.01. Results for some countries have to be jointly displayed for data confidentiality reasons.

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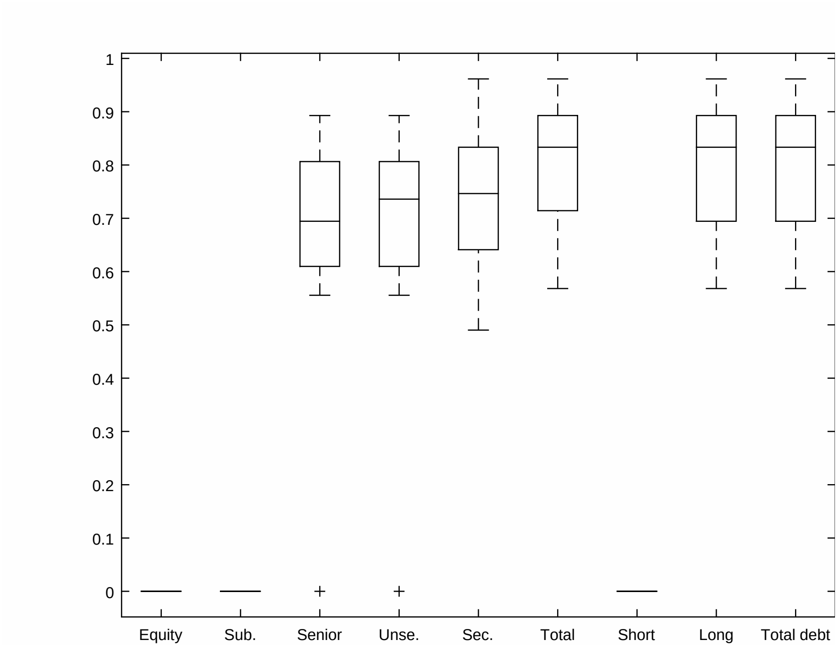
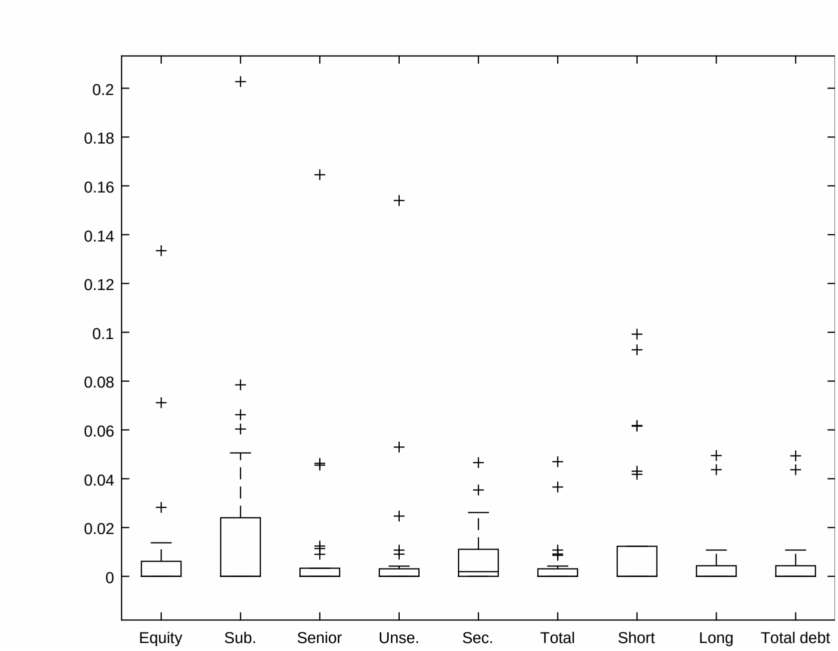
Appendix

Figure 19: Distribution of the closeness centrality measure for the 26 largest euro area banks, by network layer



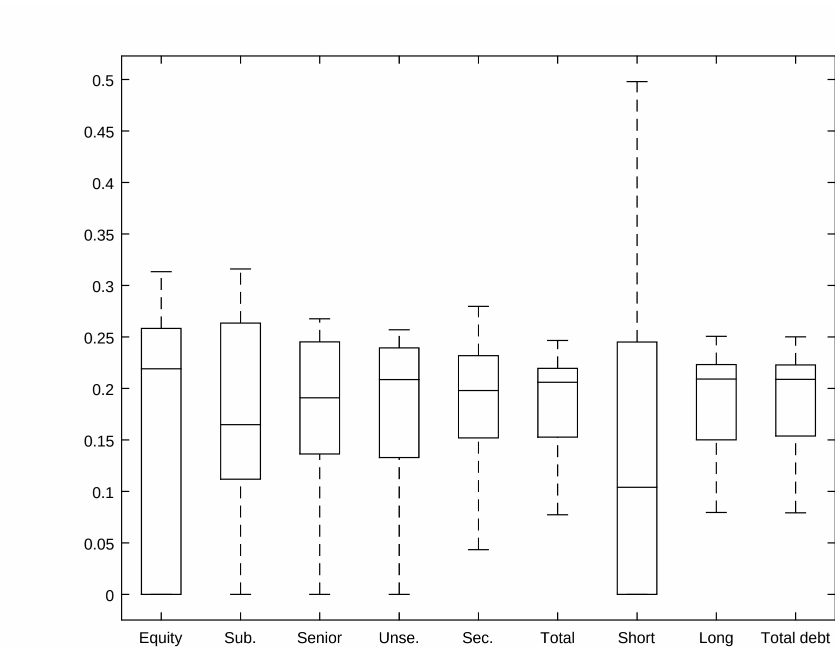
Note. Sub. refers to subordinated debt; Senior refers to senior unsecured debt; Unse. refers to unsecured debt (the sum of subordinated and senior unsecured debt); Sec. refers to secured debt; Total refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Total debt. refers to the aggregated short- and long-term debt layers. The top and bottom of each "box" are the 25th and 75th percentiles of the samples, respectively. The line in the middle of each box is the sample median. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box. Outliers are displayed with a + sign.

Figure 20: Distribution of the betweenness centrality measure for the 26 largest euro area banks, by network layer



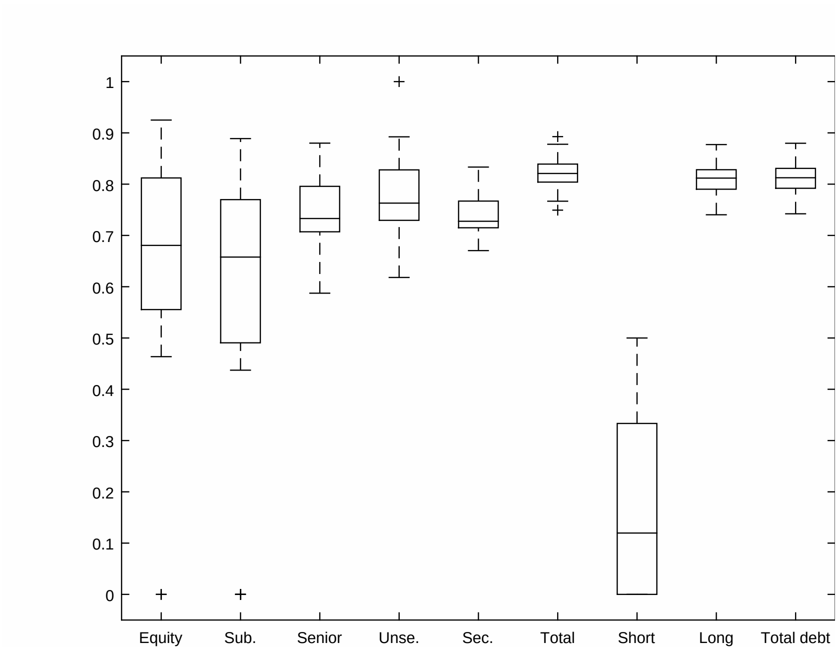
Note. Sub. refers to subordinated debt; Senior refers to senior unsecured debt; Unse. refers to unsecured debt (the sum of subordinated and senior unsecured debt); Sec. refers to secured debt; Total refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Total debt. refers to the aggregated short- and long-term debt layers. The top and bottom of each "box" are the 25th and 75th percentiles of the samples, respectively. The line in the middle of each box is the sample median. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box. Outliers are displayed with a + sign.

Figure 21: Distribution of the Eigenvector centrality measure for the 26 largest euro area banks, by network layer



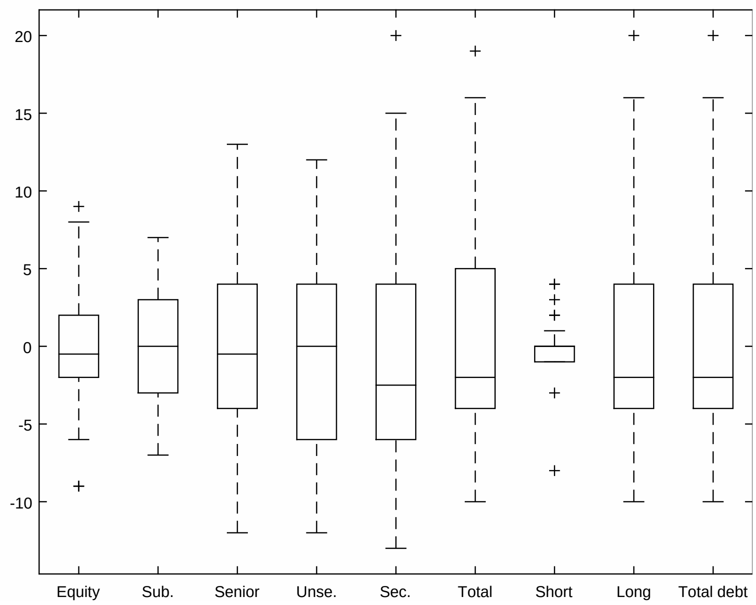
Note. Sub. refers to subordinated debt; Senior refers to senior unsecured debt; Unse. refers to unsecured debt (the sum of subordinated and senior unsecured debt); Sec. refers to secured debt; Total refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Total debt. refers to the aggregated short- and long-term debt layers. The top and bottom of each "box" are the 25th and 75th percentiles of the samples, respectively. The line in the middle of each box is the sample median. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box. Outliers are displayed with a + sign.

Figure 22: Distribution of clustering coefficients for the 26 largest euro area banks, by network layer



Note. Sub. refers to subordinated debt; Senior refers to senior unsecured debt; Unse. refers to unsecured debt (the sum of subordinated and senior unsecured debt); Sec. refers to secured debt; Total refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Total debt. refers to the aggregated short- and long-term debt layers. The top and bottom of each "box" are the 25th and 75th percentiles of the samples, respectively. The line in the middle of each box is the sample median. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box. Outliers are displayed with a + sign.

Figure 23: Difference in degrees in the aggregated network of the 26 largest euro area banks



Note. Sub. refers to subordinated debt; Senior refers to senior unsecured debt; Unse. refers to unsecured debt (the sum of subordinated and senior unsecured debt); Sec. refers to secured debt; Total refers to all the layers aggregated across seniorities; Short and Long refer to short- and long-term debt respectively; Total debt. refers to the aggregated short- and long-term debt layers. Difference computed as difference between the in-degree and out-degree of the aggregated network of the 26 largest euro area banks. The top and bottom of each "box" are the 25th and 75th percentiles of the samples, respectively. The line in the middle of each box is the sample median. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box. Outliers are displayed with a red + sign.

Figure 24: Scatterplot of the in- and out-degree for the aggregated network of 26 largest euro area banks

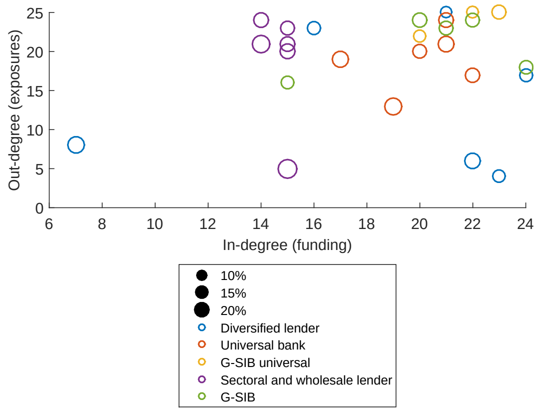
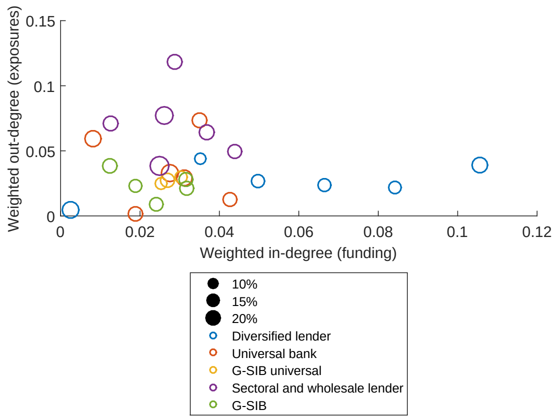


Figure 25: Scatterplot of the weighted in- and out-degree for the aggregated network of 26 largest euro area banks



Note: Bubble sizes are proportional to CET1 ratio. Bank business models are defined in Section 2.2. The weighted degree of each bank is normalised by the total nominal amount of debt securities issued by the bank.

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