Irving Fisher Committee on
Central Bank Statistics

BANK FOR INTERNATIONAL SETTLEMENTS

IFC-National Bank of Belgium Workshop on "*Data needs and Statistics compilation for macroprudential analysis*"

Brussels, Belgium, 18-19 May 2017

Interconnectedness of shadow banks in the euro area[1]

Celestino Girón and Antonio Matas,
European Central Bank

[1] This paper was prepared for the meeting. The views expressed are those of the authors and do not necessarily reflect the views of the BIS, the IFC or the central banks and other institutions represented at the meeting.

Interconnectedness of shadow banks in the euro area

Celestino Girón, Antonio Matas-Mir[1]

Abstract

The ESCB is working towards the identification of shadow banks in the framework of the sector accounts. So far, the OFI sector –which encompasses the ESA 2010 sectors other financial institutions (S125), financial auxiliaries (S126) and captive institutions and others (S127)- is the best proxy available to capture the phenomenon in the euro area, notwithstanding certain conceptual limitations. At the same time, the availability of counterpart sector information for financial assets and liabilities in sector accounts, or who-to-whom (w-t-w) data, has notably improved for euro area countries recently with the extension of the ECB data requirements in the field to debt securities, quoted shares and investment fund shares.

We use this data framework to make a comparison of shadow bank interconnectedness across the various euro area countries. We construct debt networks with the newly available w-t-w data, and characterise the linkages of the OFIs sector with the rest of the economy using eigenvector centrality, a network centrality metrics.

Keywords: sector accounts, financial accounts, shadow banking, other financial intermediaries, who-to-whom matrices, financial networks, eigenvector centrality, Euro Area Accounts (EAA)

JEL classification: C65, E16, G23

[1] Principal Economist-Statisticians, European Central Bank (Celestino.Giron@ecb.int, Antonio.Matas_Mir@ecb.int)

Contents

1. Introduction

The interconnectedness of shadow banks with the rest of the financial system and the overall economy is widely recognised as a key element in monitoring systemic risks. For instance, the Financial Stability Board (FSB) has been regularly examining interconnectedness indicators (see FSB, 2017) within the shadow banking annual monitoring exercise it conducts since 2011. Characterising and quantifying their degree of connectedness helps, inter alia, to understand potential financial distress contagion channels mediated by these entities and the ensuing propagation and amplification dynamics.

However, metrics of interconnectedness typically focus on direct linkages between economic agents whilst failing to capture indirect, more intricate connections. For instance, the FSB uses the indicator *"bank interconnectedness funding risks from OFIs"*, defined as the ratio of bank liabilities to selected financial institutions to total assets. Yet risks on bank funding stemming from funding risks faced by OFIs themselves are *not* captured by this indicator[2].

In this paper we examine macro-economic level linkages also accounting for indirect linkages by using "eigenvector centrality", an interconnectedness measure borrowed from network theory. We construct financial linkage networks using who-to-whom (w-t-w) financial accounts data newly available in the framework of the Guideline of the European Central Bank (ECB) on financial accounts[3], and characterise the degree of interconnectedness of shadow banks using the above metrics.

In line with one of the FSB's monitoring aggregates, we use a broad measure of shadow banks, namely the Other Financial Institutions (OFIs) grouping as defined in the aforementioned ECB Guideline. This grouping may encompass activities and agents that may not be usually thought as shadow banks, whilst excluding others that are. Nevertheless, data availability considerations and the lack of a universally applicable definition of shadow banking justify our choice.[4]

We apply eigenvector centrality to networks constructed for an aggregate of debt instruments capturing only credit intermediation relationships (i.e. equity linkages are excluded). We use in our analysis data on tradable debt instruments on a w-t-w basis that are available for all euro area countries only since 2016. This

[2] A prime example of this during the financial crisis was the funding crisis faced in 2007 by the UK bank Norther Rock. Its business model relied heavily on funding mortgage originations through the capital markets by way of their subsequent securitisation. The drying up of demand for securitised products, which represented liabilities of non-bank securitisation vehicles, did eventually impact the funding of the bank itself.

[3] Guideline of the European Central Bank of 25 July 2013 on the statistical reporting requirements of the European Central Bank in the field of quarterly financial accounts (recast) (ECB/2013/24) (2014/3/EU).

[4] The FSB uses the term "Other financial Intermediaries", also under the acronym OFIs, for its "broad measure" of shadow banking. The definition we use here for OFIs is different from the FSB one. For a discussion, see section 3.

paper is the first one making a comparison of sectoral financial interconnectedness in the euro area based on an (almost) complete w-t-w debt network that also incorporates tradable instruments.

Section 2 introduces the w-t-w data used. Section 3 discusses the choices made for approximating shadow banks. Section 4 presents the methodology used, eigenvector centrality, and section 5 shows and compares the results of applying this approach to the euro area as a whole and to the individual country members. Section 6 concludes.

2. Who-to-whom financial data in the euro area

W-t-w accounts extend financial accounts by tracking counterparty information for both assets and liabilities in the system. For instance, the non-financial corporations (NFC) sector may hold debt securities recorded as an asset item on their balance sheet. In addition to the amount outstanding for the item, w-t-w accounts further break it down by sector of the issuer of the debt. A similar breakdown applies to each recorded liability, so that e.g. loans received by NFCs are broken down by sector of the lender. This applies to all sectors in the system, yielding one table of creditor/debtor relationships for each financial instrument presented on a w-t-w basis.

These tables facilitate a detailed analysis of the paths followed by financial investment flows to meet the final financing needs, inter alia allowing to identify bottlenecks and sectoral dependences. When prepared for balance-sheet data, w-t-w tables provide a portrait of intersector financial exposures and financing risks. Ideally, w-t-w accounts are fully consistent with the rest of elements in the financial accounts system. With creditor sectors in rows and debtor sectors in columns, each column total coincides with total liabilities for each sector in a given instrument, while each row sum coincides with total assets. This helps analysts link different aspects of related phenomena.

W-t-w tables embed information on indirect intersector financing patterns and on indirect exposures and risks. Applying appropriate tools, the analyst can identify investment flows that go from one sector to another but are channelled through a third sector. Indirect exposures between two sectors, say A and B, resulting from A's holdings of liabilities of a third sector C which in turns holds assets on B, can be quantified. Since w-t-w data are susceptible to be represented as mathematical matrices or network graphs, tools from these fields are particularly well suited to analyse quantitatively these kinds of relationships.

In the euro area, w-t-w tables are fairly complete since the ECB adopted a new Guideline on quarterly financial accounts (ECB/2013/24, footnote 1) to align to the new national accounts standard ESA 2010. Various enhancements were also adopted with the new Guideline, among which was the extension of the scope of w-t-w breakdowns for both the euro area as well as individual EU countries. W-t-w data for stocks and transactions of loans and deposits had already been available since 2010 reaching back to Q1 1999. With the new Guideline, they were extended to debt securities, quoted shares and fund share/units, with data back to Q4 2013. Only unquoted shares, other equity, financial derivatives, insurance technical reserves and other accounts are not yet available on this basis.

For euro area countries, the national w-t-w data cover relationships between domestic sectors and links of domestic sectors with sectors resident in other members of the euro area countries. In the case of loans, debt securities, quoted shares and mutual fund shares, cross-border data refer to assets of domestic sectors broken down by foreign issuing sector, while for deposits the data refer to liabilities of domestic sectors broken down by non-resident holding sector[5].

The cross-border data described above are instrumental to complete the full picture of intra euro area sector relationships included in the euro area w-t-w tables compiled by the ECB as part of the Euro Area Accounts –EAA (see Box 1 for a discussion of all sources used for euro area w-t-w tables). For the new instruments covered by the Guideline ECB/2013/24, euro area w-t-w tables have been published for the first time in April 2016[6].

Box 1

Compilation of who-to-whom tables in Euro Area Accounts[1]

The compilation of the euro area w-t-w accounts involves the combination and confrontation of a multitude of data sources. A predetermined data hierarchy is used to resolve cases where more than one candidate source exists for the same statistical concept. At the top of the data selection hierarchy are the euro area aggregates of the monetary financial institutions (MFI) statistics and the euro area balance of payments (BOP). This is justified by their reliability relative to other competing sources, but also to respond the users' preference to minimize discrepancies with these statistics within the financial accounts. Other euro area-level statistics used include investment fund (IF) statistics and government finance (GFS) statistics. It should be noted that as regards total loan borrowing and total debt issuance by general government the highest priority is assigned to GFS sources.

Data at the level of individual euro area countries from the national quarterly financial accounts (available in ECB/2013/24) are also used as a source. The need to combine both euro area-level primary statistics and national financial accounts stems, on the one hand, from the fact that the rest of the world financial account for the euro area is not the simple summation of national rest of the world accounts. This also extends to w-t-w accounts, since they include the rest of the world as both creditor and debtor sectors. On the other hand, national financial accounts data are required to cover sectors for which euro area level statistics are either not available, are not sufficiently detailed or are difficult to align with the ESA methodological requirements. This is the case for large sections of the other financial intermediaries, non-financial corporations, pension funds, and households.

The compilation of w-t-w tables proceeds in a fairly similar fashion for all instruments. For instance, deposits are mostly compiled from the counterparty detail available in MFI and BOP statistics, with some gaps covered by national financial accounts. The loans tables are also mostly determined by MFI and BOP statistics, again with the exceptions of some gaps. Securities are compiled following a similar approach, except for two specificities. Unlike for loans and deposits, MFIs do not report on the counterpart sector to their liabilities in the form of marketable securities. This must be sourced from the national financial accounts, which in turn obtain it from the various security-by-security databases on holdings available at national central banks (NCBs) and/or from the ECB's security holdings statistics (SHS). In addition, MFI statistics do not provide stocks of security holdings at market value, so that their compilation also falls back on the national financial accounts.

1) Extract from Matas-Mir and Willeke (2017)

Mainly due their better coverage, the interconnectedness analysis in this paper is restricted to debt instruments only, using an aggregate comprising deposits,

[5] This asymmetry with respect to cross-border deposits is explained by the fact that the best quality information on this instrument can be typically collected from the issuer, rather than from the holder, of cross-border deposit liabilities.

[6] Country data and euro area data can be found in the ECB websites (ECB 2017a, 2017b)

loans and securities other than shares. In any case, a focus on debt instruments is warranted on behavioural grounds in assessing systemic risk as equity investors already expect uncertain outcomes from their holdings whilst holders of nominal claims typically expect to be repaid in full. Insofar as we look in detail to shadow banks, it is therefore the relationships between regulated and non- (bank-like) regulated channels of credit intermediation that constitutes the focus of this paper.

At the same time, we concentrate on interconnectedness as measured from balance-sheet data, as opposed to net transactions, to capture relationships akin to risk exposures and systemic impact, although our choice is also conditioned by methodological considerations favouring the use of non-negative data like those provided by balance-sheets[7] (see section 4).

3. Shadow banking and the sector Other Financial Institutions (OFIs)

In its 2015 Global Monitoring Report, the FSB describes shadow banking as "credit intermediation involving entities and activities outside of the regular banking system". Some other definitions have been used in the related literature, but they all refer one way or the other to financial intermediation activities that share certain features with traditional banking -in particular the presence of high leverage and the engaging in maturity and liquidity transformation- but do not operate under the same regulatory and supervisory framework, nor enjoy the same backstop mechanisms as banks do. These activities have been identified as major sources of systemic risk and have been pointed out as main contributors to the global financial crisis of 2007-2009[8].

While an exhaustive analysis of shadow banking activities would probably require the use of microdata to isolate specific risks depending on the specific analytical concerns, economic statistics can still serve to monitor the size, growth and interaction with the rest of the economy of such activities at a macro level. Thus, the FSB has been monitoring shadow banking trends at the global level since 2011 making use of financial accounts data inter alia. Similarly, the review of the sector accounts templates in the context of the G-20 Data Gap Initiative-2[9] is considering the inclusion of additional sector and instrument detail to facilitate shadow banking analysis.

7 An analysis of interconnectedness in relation to funding and role-over risks and financing patterns would require the use of transaction data as opposed to balance-sheets. Gross, rather than net, transaction data would still be adequate for eigenvector centrality and probably be more appropriate for the kind of analysis suggested, but they are not available in the sector accounts framework which follows a strict net approach in this respect.

8 See Bakk-Simon et al. for a description of the size and the structure of shadow banking within the euro area using the statistical data sources available to the ECB/Eurosystem.

9 Recommendations 5 and 8 of the G-20 Data Gap Initiative-2. See first progress report in IMF and FSB (2016).

In this paper we follow partially the monitoring strategy of the FSB[10], and focus on a financial accounts aggregate of non-bank institutional units where most of the shadow banking activities takes place. We thus proxy shadow banking by means of the aggregate data collected under Guideline ECB/2013/24 under the heading "Other Financial Institutions (OFIs)". The data collected inseparably groups the following sectors from the European System of Accounts (ESA, Eurostat 2013): "Other financial intermediaries, except insurance corporations and pension funds (S.125)", "Financial auxiliaries (S.126)" and "Captive financial institutions and money lenders (S.127)".

The inseparability of the OFIs data collected under the Guideline owes mainly to the lack of developed quarterly primary sources for some of the subsectors encompassed under the heading. Data from units as diverse as factoring corporations, holding companies or securities brokers and dealers are therefore indistinguishably included in the aggregate. While primary data sources and harmonised coverage exist for some of these units, like for Financial Vehicle Corporations for which ECB legislation is in place, the rest of the sector is compiled on the basis of data sources with little harmonisation, including surveys, and on the basis of counterpart information – itself often available only at the OFI grouping level - and/or residual calculation.

Like the "broad measure" in the FSB monitoring context, the OFIs data include institutions and activities that would not qualify for shadow banking under a closer examination, notwithstanding the difficulty of delineating an all-purpose, universally accepted shadow banking perimeter. Similarly, institutions and activities presenting features common to shadow banks might not be covered by the aggregate. The choice of OFIs as our shadow banking proxy is driven mainly by data availability considerations, notably the availability of sufficient w-t-w data for the euro area, which in turn derives from the aforementioned Guideline requirements.

Our OFIs aggregate differs from the corresponding FSB "broad measure of shadow banking", also by the same acronym but standing there for "Other Financial Intermediaries"[11]. The FSB measure excludes financial auxiliaries and public (non-bank) financial institutions, while OFIs include them. Financial auxiliaries cannot be currently identified separately within the financial accounts framework in most of the euro area countries. Similarly, (non-bank) public financial institutions are not generally separately available, the provision of data on that sector only being a voluntary annual requirement in the European statistical legal context (and only for all financial institutions, without a bank/non-bank distinction). While the amounts of assets and liabilities held/ issued by auxiliaries are small and are therefore not a

[10] The FSB defines three aggregates in its 2016 Monitoring Report (FSB, 2017): MUNFI (or Monitoring Universe of Non-bank Financial Intermediation) which includes all non-bank financial intermediation (except public financial institutions and financial auxiliaries), OFIs (Other Financial Intermediaries), or "broad measure", which excludes from the previous aggregate insurance corporations and pension funds, and the "narrow measure" of shadow banking constructed on the basis of the economic functions of the financial institutions. The last aggregate is largely a non-sector accounts concept and is the focus of the financial stability risk monitoring made by the FSB. In this paper we use a sector account aggregate similar, but not identical, to the FSB "broad measure".

[11] The FSB brad measure by the name OFIs is in turn different from the ESA sector "Other financial intermediaries, except insurance corporations and pension funds (S.125)". The latter is a subset of both the FSB measure and the OFIs aggregate used in this paper.

major source of discrepancy between the two measures, public non-bank financial institutions are relevant in some countries since the start of the financial crisis as a result of the setting up of "bad-bank" structures[12].

At the same time the FSB measure includes institutions not included in the OFIs aggregate used in this paper. Money Market Funds (MMFs) are considered by the FSB as part of its broad shadow banking measure as their shares are substitutes for deposits and potentially subject to runs. However, in Guideline ECB/2013/23 they are reported together with Monetary Financial Institutions (MFIs, the aggregate for banks in the ESA). Although separate financial accounts for MMFs are available or could be derived for most euro area countries using primary data, a w-t-w coverage fully consistent with ECB/2013/23 would still be difficult to come by.

A separate case is that of Investment Funds (IFs) other than MMFs (sector S.124 in ESA), which is included in the FSB broad measure, but excluded from our OFIs measure. As opposed to the cases above, IFs are treated separately in the Guideline, including for the w-t-w requirements. Nevertheless we prefer not to include them within the scope of our shadow banking proxy for two methodological choices.

First, the characterisation of the investment fund industry as "shadow banking" is dubious. In general, there is no unambiguous "credit intermediation" dimension in their activity given that their liabilities are in most cases not debt-like, but rather equity-like, as e.g. reflected in their ESA classification ("investment fund shares/ units"). Neither can maturity transformation nor high leverage be taken as a central feature of the sector, in particular if we consider their liabilities as being mainly equity. The FSB recognises these difficulties by excluding part of them from its narrower measure, focusing instead on only those that have a clearer credit intermediation flavour: fixed income funds (including mixed funds), credit hedge funds and real estate funds. Unfortunately, such breakdowns are not available within the Guideline framework.

One could still work with an aggregate that includes all investment funds even if there are justified doubts about the nature as shadow bank of a great deal of them. After all, it is recognised that many of the units included in our proposed OFIs aggregate are anyway not shadow banks, like holding companies which are part of the ESA sector S.127. However, a second methodological issue relates to our aim to isolate exclusively a debt network. The consideration of some of the investment funds as shadow banks would also require the identification of the corresponding liabilities that are of a debt nature. This endeavour is tantamount to the split of the sector into fund categories, such as those above borrowed from the FSB approach, or into alternative ones based on the closeness of the investment fund shares/units to runnable liabilities. None of these splits are however supported by data availability in the financial accounts w-t-w framework[13].

This paper will therefore not include IFs within the aggregate shadow banking proxy examined, which will therefore strictly correspond to the "Other Financial Institutions (OFIs)" grouping as defined in the ECB Guideline. The diagram in Figure 1 below shows for clarity the relation between OFIs and the FSB broad measure. In

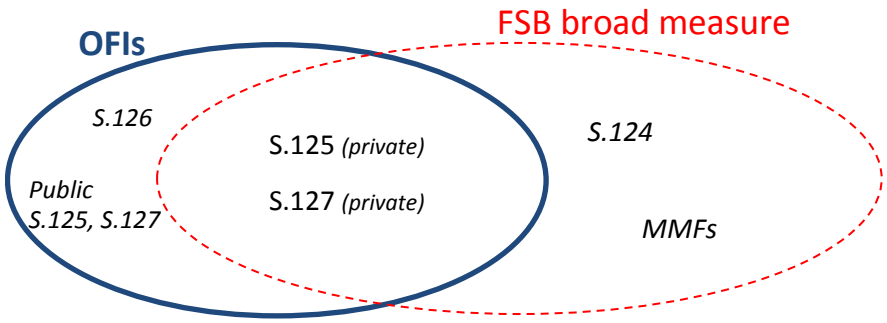
12 Examples are SAREB in Spain and NAMA in Ireland.

13 The obvious alternative of working with a total asset network, as opposed to a debt network, is not feasible given the lack of w-t-w detail in relevant equity instruments as explained in section 2.

addition to that, all investment fund shares will be characterised as equity liabilities for the purposes of the computation of centrality measures[14].

OFIs and FSB broad measure

Figure 1



MMFs: Money Market Funds; S.124: Investment Funds (other than MMFs); S.125: Other financial intermediaries, except insurance corporations and pension funds; S.126: Financial auxiliaries; S.127: Captive financial institutions and money lenders

4. Eigenvector centrality in who-to-whom networks

Measures of interconnectedness typically focus on direct links between agents. This fails to capture more complex interactions that transit through indirect links. For instance, exposures of banks to risks stemming from household mortgages financed by securitisation vehicles whose liabilities are part of bank portfolios would not be embedded in a direct interconnectedness measure; neither would the dependence of non-financial corporations on financing from the rest of the world, via domestic banks recourse to non-resident funding.

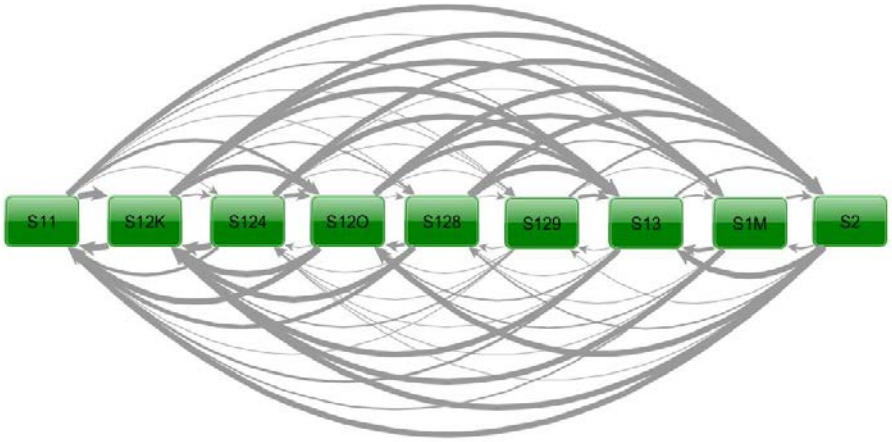
This paper proposes a measure of interconnectedness that takes into account direct and indirect linkages, of any order. To that purpose we view the w-t-w data as a network of interrelationships in which the nodes –the elements interlinked in the network- are institutional sectors and the edges –the links between nodes- are asset/liability links. The edges in the network are "weighted" by the amounts involved in every asset/liability relationship.

Figure 2 shows a directed graph representation of the network of debt instruments (see section 2 for a detailed explanation of the w-t-w data used) for the euro area at the end of 2016, with the width of the asset/liability edges being proportional to their "weight" in the network, i.e. to the corresponding amounts of credit-like claims outstanding between the different sectors.

[14] The debt centrality scores worked out in section 5 for our shadow banking proxy, the OFIs, are naturally not invariant to the definition of the sector, and in particular by the consideration of IFs as entities outside the proxy. In addition, the consideration of all investment fund shares as equity (and not as debt) also has a bearing on the results by precluding that fund share/units act as a channel of propagation of dependencies in our network. See section 4 for further details.

Debt network for the euro area

Balance-sheets. 2016 Figure 2



S11: Non-financial corporations; S12K: Monetary Financial Institutions (S.121+S.122+S.123 in ESA); S124: Investment Funds (other than MMFs); S12O: OFIs; S128: Insurance corporations; S129: Pension funds; S13: General government; S1M: Households and non-profit institutions serving households (S.14+S.15 in ESA); S2: Rest of the world

Network constructed with the sum of ESA instruments "Currency and deposits (F.2)", "Securities other than shares (F.3)" and "Loans (F.4)"

Arrow from sector SX to sector SY indicates assets of SX and liabilities of SY. Width of arrows proportional to amount of assets

In network analysis, eigenvector centrality is a measure of the influence of the various nodes in the network. It consists in an array of node scores that satisfy the principle that higher scores are assigned to nodes that are highly connected to nodes that in turn have high scores themselves[15]. It is therefore a metrics of a recursive nature capturing second, third and higher orders of influence in the network. The concept is therefore particularly well suited to our aim of emphasising also the importance of indirect links in measuring debt interconnectedness.

The score array corresponds to an algebraic property of a matrix, known as weight matrix, that represents the weights of the edges of the graph (see Box 2 for a detailed explanation). In our case the weight matrix corresponds to the matrix or table representation of the w-t-w data. Eigenvector centrality can be calculated on a weight matrix or on its transpose, representing two distinct properties of the underlying network: one represents node centrality insofar as edges outflow from the nodes and the other insofar edges inflow to the nodes.

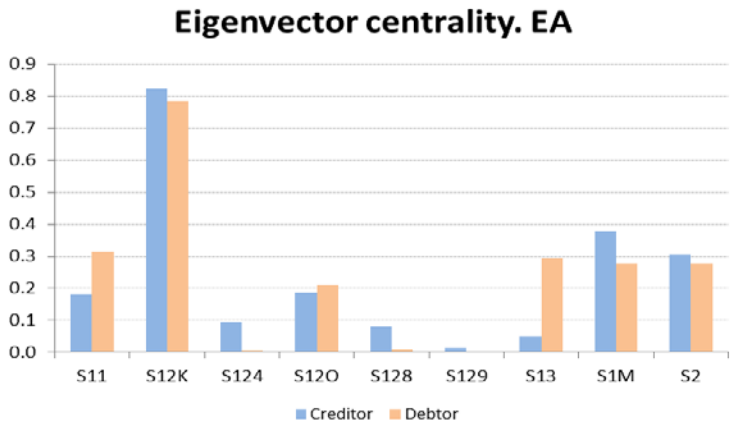
In our case, the eigenvector centrality calculated on w-t-we data tabulated as a matrix of creditor-debtor relationships represents the interconnectedness of a sector seen as a creditor, or "creditor" centrality. When calculated on the corresponding transposed matrix, i.e. on w-t-w data tabulated as a matrix of debtor-creditor relationships, it represents sector interconnectedness from the liabilities side, or "debtor" centrality[16]. The two measures are shown in Figure 3 for the euro area debt network at the end of 2016.

[15] For a reference, see for instance Newman (2010).

[16] Concepts similar to what we call "creditor centrality" and "debtor centrality" here have been identified in other contexts as "vulnerability" and "systemic risk" indices. See for instance Markose (2012).

Eigenvector centrality. Debt network. Euro area

Balance-sheets. 2016 Figure 3



S11: Non-financial corporations; S12K: Monetary Financial Institutions (S.121+S.122+S.123 in ESA); S124: Investment Funds (other than MMFs); S12O: OFIs; S128: Insurance corporations; S129: Pension funds; S13: General government; S1M: Households and non-profit institutions serving households (S.14+S.15 in ESA); S2: Rest of the world

Network constructed with the sum of ESA instruments "Currency and deposits (F.2)", "Securities other than shares (F.3)" and "Loans (F.4)

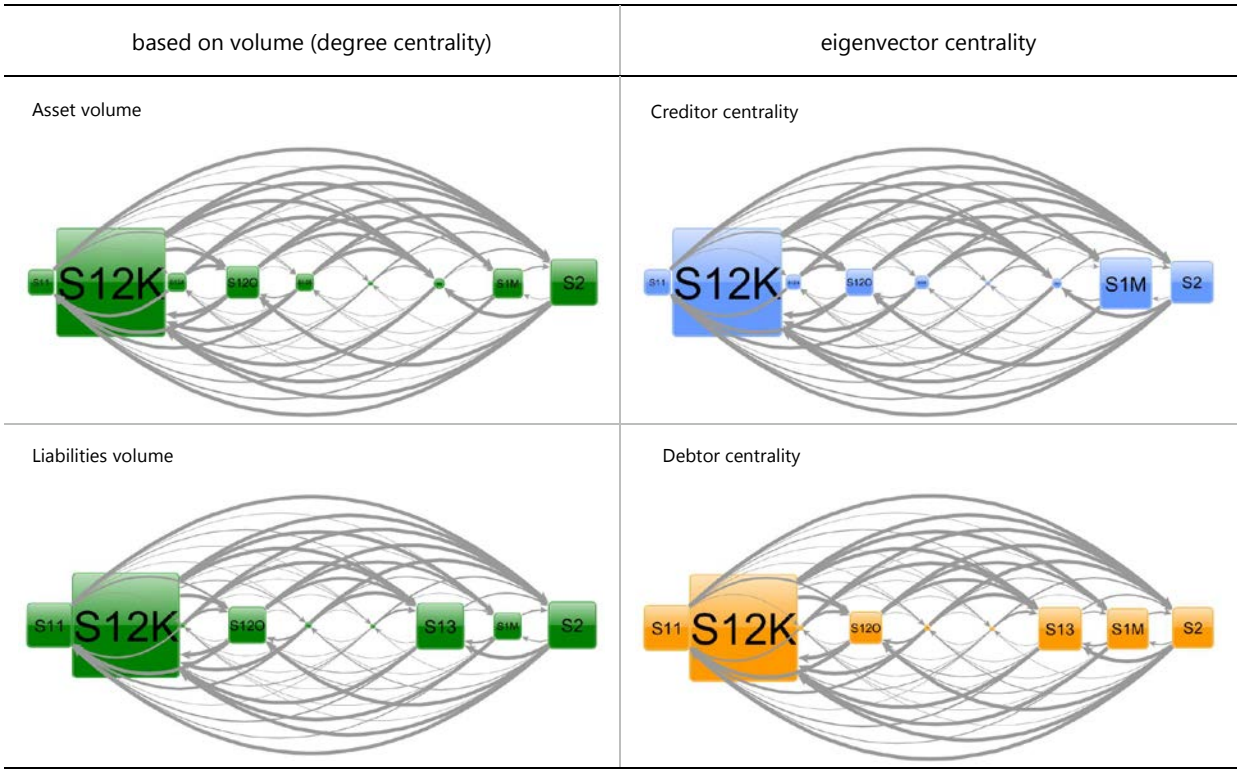
Units: components of the Perron's eigenvector (normalised) of a matrix with elements for row *i* and column *j*, a_{ij} , representing, in the case of "Creditor", assets of sector *i* and liabilities of sector *j*, and, in the case of "Debtor", assets of sector *j* and liabilities of sector *i*

Not surprisingly, MFIs (S12K) show up as the most central sector both from the creditor and the debtor perspectives. In turn, OFIs (S12O), our aggregate proxy for shadow banks, presents a much smaller degree of centrality, reflecting the fact that the euro area is an economy largely based on bank intermediation. Moreover, non-financial corporations (S11) and particularly government (S13) present much higher debtor centrality than creditor centrality, in line with their economic nature. The rest of the world also presents high centrality scores as a result of the high openness of the euro area economy to external financial flows. Thus, at least at first blush, eigenvector centrality does not appear to provide any further insight compared to simpler, direct measures such as debt volumes. Nevertheless some subtle, albeit important, differences exist, as discussed next.

Figure 4 shows graphically the centrality of the various sectors by making the size of the node representation proportional to their centrality. On the left column, rankings based on volume (ignoring indirect links and tantamount to "degree centrality" in graph theory) are shown, both for sectors as creditors (credit asset volumes) and debtors (credit liabilities volume). On the right column the corresponding eigenvector centrality measures are presented instead, again from both the creditor and debtor perspectives.

Sector centrality in the euro area debt network

Balance-sheets. 2016 Figure 4



S11: Non-financial corporations; S12K: Monetary Financial Institutions (S.121+S.122+S.123 in ESA); S124: Investment Funds (other than MMFs); S12O: OFIs; S128: Insurance corporations; S129: Pension funds; S13: General government; S1M: Households and non-profit institutions serving households (S.14+S.15 in ESA); S2: Rest of the world

Network constructed with the sum of ESA instruments "Currency and deposits (F.2)", "Securities other than shares (F.3)" and "Loans (F.4)"

Arrow from sector SX to sector SY indicates assets of SX and liabilities of SY. Width of arrows proportional to amount of assets. Size of nodes proportional to the corresponding centrality measure: volume of assets (or liabilities), eigenvector centrality for matrix representing investor/issuer (or issuer-investor)

The differences between the two measures become more apparent for the households sector (S1M). While credit assets held by non-residents (S2) are more than 160% as much as those held by resident households (upper-left-hand-side panel in Figure 4), creditor eigenvector centrality places households before the rest of the world, and only second to MFIs in creditor centrality (upper-right). This results from households holding large amounts of debt-like claims on MFIs, mainly in the form of deposits, coupled with the fact that MFIs are in turn very central (i.e., they channel the funds to all other sectors). In turn, the credit claims of non-resident are to a greater proportion liabilities of government (S13) and non-financial corporations (S11), sectors that usually do not employ any significant proportion of the proceeds for onward lending to other sectors.

Similarly, the debtor centrality of households is very similar to that of both the rest of the world and government (lower-right), in spite of having just around half the volume of debt liabilities of those two sectors (lower-left). This can be interpreted as a relatively higher systemic impact of households per unit of debt compared to e.g. government, which is explained by the fact that difficulties by households in servicing their debts would have an impact on banks mainly, which in turn would impact all other sectors in the network via bank debtor centrality. In

comparison, government has a larger share of investors other than MFIs, like the rest of the world or pension funds, which have a lesser degree of debtor centrality[17].

[17] Pension fund holdings could be viewed as buffering the systemic impact of disturbances in the credit worthiness of government owing to the long-term nature of their liabilities relative to that of banks. Centrality measures computed on our debt-only network embed this idea by excluding pension technical reserves from the definition of credit.

Box 2

A probabilistic interpretation of eigenvector centrality

The "eigenvector centrality" scores of a weighted directed graph correspond to the components of an eigenvector associated to a specific eigenvalue of the weight matrix (the matrix containing the weights of the graph edges)1. Thus, the scores v_i of a graph with weights $w_{i,j} \geq 0$ (of edge from node i to node j) i, j= 1...n , satisfy the equality:

$$\boldsymbol{W}\boldsymbol{v} = \rho\boldsymbol{v}, \qquad \boldsymbol{v} = \begin{bmatrix} v_1 \\ \vdots \\ v_n \end{bmatrix}, \qquad \boldsymbol{W} = \begin{bmatrix} w_{1,1} & \cdots & w_{1,n} \\ \vdots & \ddots & \vdots \\ w_{n,1} & \cdots & w_{n,n} \end{bmatrix}$$

The specific eigenvalue, ρ ,called Perron-Fobrenius eigenvalue, is the one of maximum module, which is real and positive for "irreducible matrices", i.e. for non-negative matrices that can be associated to strongly connected directed graphs (graphs that present direct or indirect connections between any pair of nodes). Weight matrices made of w-t-w balance-sheet data satisfy this condition.

It is guaranteed for irreducible matrices that an eigenvector can be chosen associated to the Perron-Fobrenius eigenvalue with all components v_i strictly positive[2]. Moreover, in this paper we choose eigenvectors of unit norm ($\boldsymbol{v}'\boldsymbol{v} = 1$) for the chart representations.

The specific characteristic of a Perron-Fobrenius eigenvector that makes it suitable for measuring centrality is the following property: for any vector $\boldsymbol{d}$ **,** it exists a Perron-Fobrenius eigenvector, $\alpha\boldsymbol{v}$, such as

$$\lim_{p\to\infty} \left(\frac{\boldsymbol{W}}{\rho}\right)^p \boldsymbol{d} = \alpha\boldsymbol{v}$$

In particular for $\boldsymbol{d} = \boldsymbol{1}$, the unitary vector, it results that $\alpha * v_i = \sum_{j=1}^{n} \left(\lim_{p\to\infty} \left(\frac{\boldsymbol{W}}{\rho}\right)^p\right)_{i,j}$. Somewhat less formally,

it exists an integer sufficiently large *q*, such as $\alpha * \rho^p * v_i \approx \sum_{j=1}^{n} (W^p)_{i,j}$ for any $p > q$, i.e. the components

(centrality scores) in $\boldsymbol{v}$ are approximately distributed as the row sums of the (sufficiently large) power of the weight matrix.

Our weight matrix consists in w-t-w stock data. As the eigenvectors of a matrix are invariant to its multiplication by a scalar, their eigenvector centrality scores are also those of the matrix resulting from dividing all w-t-w stocks by the total assets/ liabilities. Such matrix represent the probability distribution of the w-t-w links: each value $w_{i,j}$ is the

probability that a euro invested in the economy is invested in an asset of sector *i* on sector *j*. The sum of the elements in row *i* is the probability that a euro is invested by sector *i* (in any other sector).

Let's calculate the probability that a euro is invested *indirectly* by sector *i* in sector j via sector *k* as $\frac{w_{i,k} * w_{k,j}}{t_2}$,

$t_2 = \sum_{a,b,c} w_{a,b} * w_{b,c}$ $a, b, c = 1, \ldots, n$. Then, each of the numbers $\frac{(\boldsymbol{W^2})_{i,j}}{t_2}$ represents the probability that an indirect

investment of a euro between any two sectors via a third one takes places between sectors *i* and *j* (via any other

sector). Similarly, $\frac{(\boldsymbol{W^p})_{i,j}}{t_p}$ is the probability that an indirect investment link takes place between sector *i* in sector *j* when such indirect links involve any combination of *p-1 sectors* in-between, with $t_p = \sum_{a,b,c} \left(\boldsymbol{W^{p-1}}\right)_{a,b} * w_{b,c}$.

As seen above the eigenvector centrality scores are distributed as the row sums of $\boldsymbol{W^p}$, for *p* sufficiently large,

and therefore as the row sums of $\frac{\boldsymbol{W^p}}{t_p}$, i.e. as **the probabilities of the various sectors being the originators of**

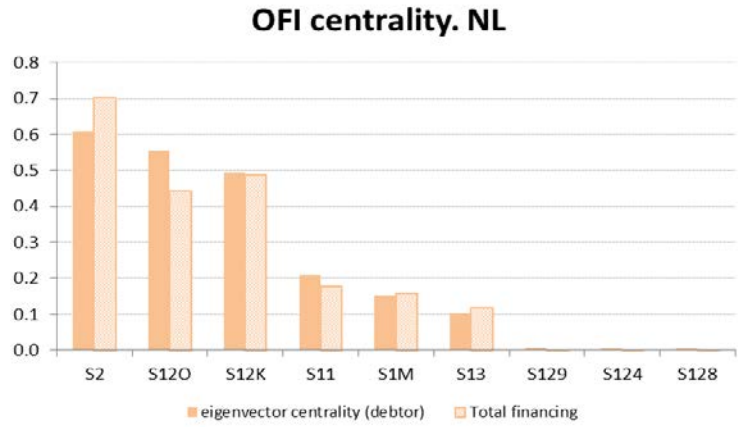
investment chains when such chains involve a large number of indirect steps.

1) For a reference to eigenvalues and eigenvectors, see for instance Herstein (1964)
2) See for instance Meyer (2000)

Our chosen aggregate to proxy shadow banks, OFIs (S12O), presents eigenvector centrality scores similar to what results from direct assets and liabilities links only. As an exception, the OFIs sector is surpassed by households in debtor centrality for the reasons explained above. However, this result for the euro area does not extend to every individual country, in particular for those where the non-bank financial industry is more developed. That is the case for instance of the Netherlands, where debtor eigenvector centrality yields a score for the OFIs sector higher than for the MFIs, even though the latter issue more liabilities than the former. This is shown in Figure 5.

Eigenvector centrality (debtor) vs Share in total liabilities. The Netherlands

Balance-sheets. 2016 Figure 5



S11: Non-financial corporations; S12K: Monetary Financial Institutions (S.121+S.122+S.123 in ESA); S124: Investment Funds (other than MMFs); S12O: OFIs; S128: Insurance corporations; S129: Pension funds; S13: General government; S1M: Households and non-profit institutions serving households (S.14+S.15 in ESA); S2: Rest of the world

Network constructed with the sum of ESA instruments "Currency and deposits (F.2)", "Securities other than shares (F.3)" and "Loans (F.4)"

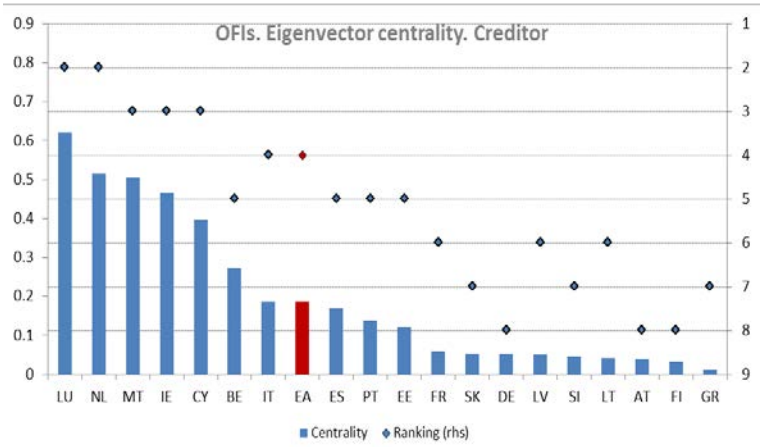
Units: for "eigenvector centrality (debtor)" components of the Perron's eigenvector (normalised) of a matrix with elements for row i and column j, a_{ij}, representing assets of sector j and liabilities of sector i; for "share in total liabilities", share of liabilities of sector i in total liabilities

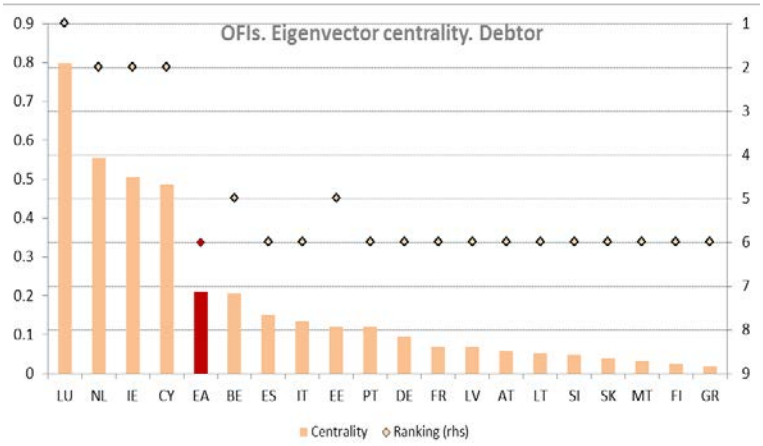
5. Interconnectedness of OFIs

Figure 6 shows the eigenvector creditor and debtor centrality scores for the OFIs sector in the 19 members of the euro area. The rank of the OFI sector resulting from ordering all sectors in each country by descending value of their centrality scores is also presented. Both creditor and debtor centrality of the OFI sector is significantly larger than for the euro area as a whole in Luxembourg, the Netherlands, Ireland and Cyprus. In all these countries, the OFI sector ranks first or second in debtor centrality, and second or third in creditor centrality. The centrality of the OFI sector in Malta, on the other hand, stems almost exclusively from its role as creditor, a feature that presumably relates to the significant presence of Special Purpose Entities (SPEs) whose main liabilities are in the form of equity.

Figure 6 - OFIs eigenvector centrality. Debt network

Balance-sheets. 2016





S11: Non-financial corporations; S12K: Monetary Financial Institutions (S.121+S.122+S.123 in ESA); S124: Investment Funds (other than MMFs); S12O: OFIs; S128: Insurance corporations; S129: Pension funds; S13: General government; S1M: Households and non-profit institutions serving households (S.14+S.15 in ESA); S2: Rest of the world

Network constructed with the sum of ESA instruments "Currency and deposits (F.2)", "Securities other than shares (F.3)" and "Loans (F.4)

Units: components of the Perron's eigenvector (normilised) of a matrix with elements for row *i* and column *j*, $a_{i,j}$, representing, in the case of "Creditor", assets of sector *i* and liabilities of sector *j*, and, in the case of "Debtor", assets of sector *j* and liabilities of sector *i*

The centrality figures obtained above are naturally sensitive to the heterogeneity implicit in our aggregate measure of the OFI sector. As a cross-check, we compute similar measures for a network where only short-term debt is included (that is, the sum of loans, debt securities and deposits with original maturity of up to one year). A debt network restricted to short maturities can function, at least in part, as a definition of shadow banking more along the lines of the "activity based measures" approach employed by the Financial Stability Board. For instance, the creation of private quasi-money, potentially runnable, liabilities outside of the banking sector, one of the hallmarks of shadow banking activity, would possibly be better captured by such a network. Non-bank maturity transformation is also more

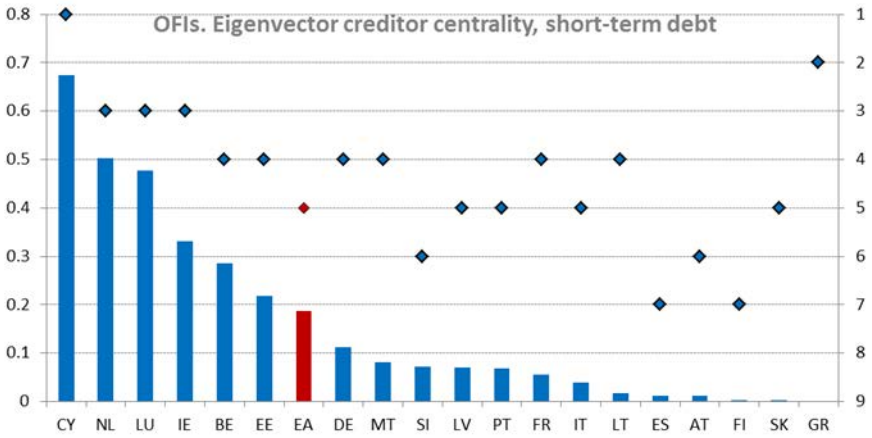
likely to take place in entities whose debt liabilities are predominantly short-term[18]. The centrality results for this short-term debt only network are presented in Figure 7.

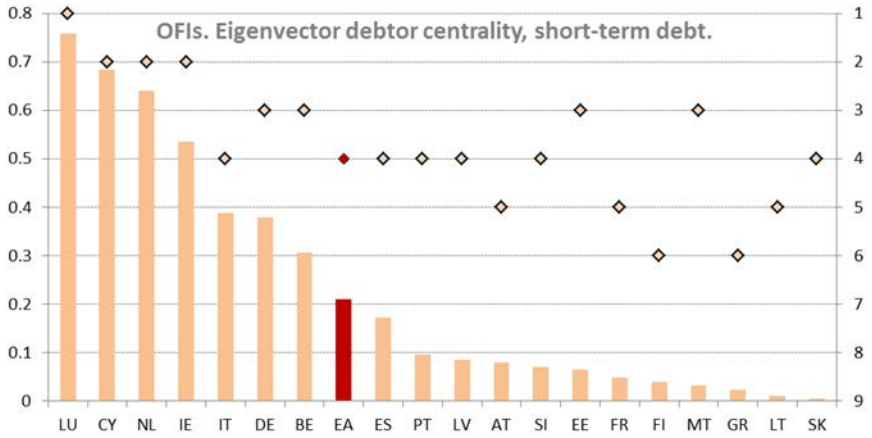
Compared to the network where all debt maturities were considered, a significant increase in OFI sector centrality can be observed in the short-term debt network for debtor measures (lower panel in Figure 7). For instance, the ranking of the OFI sector on that score is strictly higher in thirteen out of nineteen countries – in no case being lower. For the euro area as a whole, the OFI sector ranks fourth in debtor centrality, compared to sixth when all debt maturities were combined. Furthermore, Germany, Italy and Belgium show larger OFI centrality than the euro area as a whole, but did not when considering all maturities combined. For creditor centrality, in turn, considering only short-term debt within the network results overall in a similar picture in most cases. Nevertheless, we believe that debtor centrality is possibly a more significant concept in terms of characterising interconnectedness for the shadow-bank-like activities we were trying to, however imperfectly, proxy by employing only short-term debt.

[18] With respect to maturity transformation, the approach has the obvious caveat that we must restrict both assets and liabilities, not only liabilities, to be short-term debt. This is because in a debt network, or in a who-to-whom presentation, every sector asset is some other sector's liability.

Figure 7 - OFIs eigenvector centrality. Short-term debt network.

Balance-sheets. 2016





S11: Non-financial corporations; S12K: Monetary Financial Institutions (S.121+S.122+S.123 in ESA); S124: Investment Funds (other than MMFs); S12O: OFIs; S128: Insurance corporations; S129: Pension funds; S13: General government; S1M: Households and non-profit institutions serving households (S.14+S.15 in ESA); S2: Rest of the world

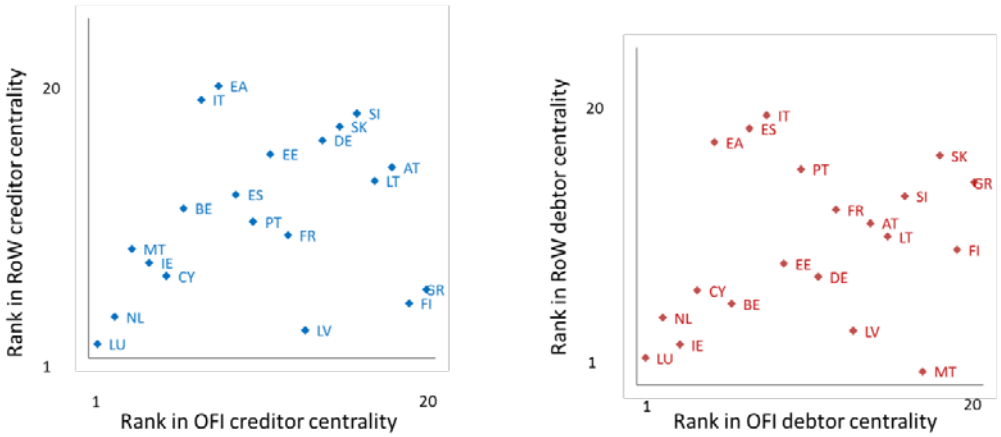
Network constructed with the sum of ESA instruments "Currency and deposits (F.2)", "Securities other than shares (F.3), of which original ʏear" and "Loans (F.4), of which original maturity up to one year". For deposits, official financial accounts data on maturity on a who-to-ҳist. To restrict deposits to those with original maturity up to one year, the proportions of short-term deposits over total deposits that can B statistics on the Monetary Financial Institutions sector (BSI statistics) were calculated and applied to their financial account counterparts.

Units: components of the Perron's eigenvector (normilised) of a matrix with elements for row *i* and column *j*, $a_{i,j}$, representing, in the case of "creditor centrality", assets of sector *i* and liabilities of sector *j*, and, in the case of "debtor centrality", assets of sector *j* and liabilities of sector *i*

Coming back to the all maturities combined debt network, countries with high creditor and debtor centrality of the OFI sector appear to also have a high interconnectedness of their domestic sectors with the rest of the world. This can be seen from Figure 8, which plots the rank obtained when ordering countries by descending value of their OFI centrality score, against the rank derived from ordering them by the centrality of their rest of the world sector. In general, a positive relationship can be observed which, to an extent, is not an unexpected. The type of activities undertaken by OFIs are in many cases driven by a favourable environment in their jurisdictions relating to specific financial activities, often

relating to tax, regulatory, statutory advantages, and/or a concentration of know-how in these areas. This may imply that a large part of the business of OFI originates beyond their jurisdiction's borders.

Figure 8 - Country ranks in OFI centrality vs. rank in rest of the world centrality



We wish to shed more light on this external dimension of OFI centrality in the four countries that present with both high OFI and rest of the world centrality in the network, namely Luxembourg, Netherlands, Ireland and Cyprus. For that purpose, we make use of data reported under the Guideline that break down claims (or liabilities in the case of deposits) by the domestic sectors on/to the rest of the world by institutional sector of the euro area counterparties[19]. This allows us to construct an extended network including 17 nodes as opposed to the 9 nodes employed thus far, as described below.

Our expanded network decomposes the rest of the world node within the original network into eight nodes, each representing positions with non-resident euro area institutional units grouped by institutional sector, plus one extra node collecting positions with non-euro area counterparties. The construction of this expanded network requires some data to be estimated, since the Guideline data only breaks down on a who-to-whom basis the claims on, but not the debts to, residents in other euro area countries[20]. The missing who-to-whom, cross-border data on debt is estimated by assuming that its structure equals that observed for the euro area as a whole.

The debtor eigenvector centrality measures relating to these cross-border relationships with other euro area countries, as well as with non-euro area institutional units, are presented in Figure 9[21]. For both Netherlands and Luxembourg non-financial corporations in other euro area countries present the highest centrality among euro area counterparties. This is consistent with a priori

19 The breakdown by institutional sector of the counterpart is not available for counterparties resident outside of the euro area, for which nevertheless an aggregate 'all sectors combined' does exist. .

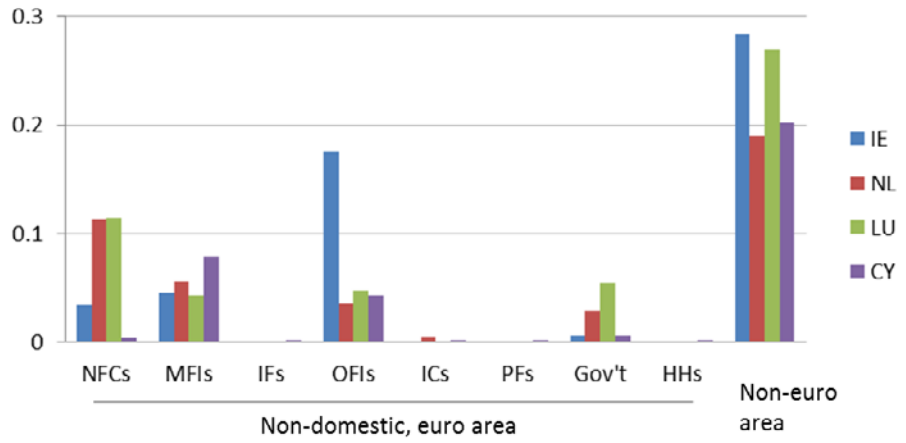
20 For deposits, the reported data take the opposite perspective, i.e. liabilities (rather than claims) of resident sector are broken-down by institutional sector of the creditor for euro area counterparties.

21 We only discuss debtor centrality, since creditor centrality would be more sensitive to the fact that who-to-whom data on non-domestic creditors was estimated.

knowledge that large euro area non-financial corporations issue significant amounts of marketable debt by way of subsidiary vehicles resident in these two jurisdictions, with the funds raised subsequently channelled to their parent companies. In Ireland, a high score for OFIs resident in other euro area countries is verified instead, possibly suggesting a more complex web of cross-border relationships.

At the same time, MFIs in other euro area member states do not seem to be driving external connectedness of the OFI sector, with the largest eigenvector score corresponding to Cyprus. Other institutional groupings of residents in other euro area countries, such as insurance corporations and pension funds, government or households, do not contribute a significant degree of debtor centrality in any of the four economies. In turn, non-euro area residents present the highest centrality scores in all four cases examined[22].

Figure 9 – OFI debtor centrality for groupings of non-residents by institutional sector



[22] This latter result is nevertheless not straightforward to interpret, since we cannot observe the scores that would obtain if non-euro area residents could be split by institutional sector. Their representation as a single node in the network, as opposed to eight distinct nodes, does have a bearing in the observed score since eigenvector centrality measures are not invariant to the level of disaggregation within a node.

6. Conclusions

The improvement in the availability of w-t-w data over the last years in Europe, but also worldwide, opens new possibilities for flow of funds analysis. Methodologies taken from matrix algebra or network theory can be used to better understand sector interlinkages, including propagation and contagion dynamics that escaped the traditional analysis of financial accounts.

In this paper we have explored the use of a network centrality concept, eigenvector centrality, to provide a euro area cross-country comparison of interconnectedness of shadow banks with the rest of the economy. By using eigenvector centrality we capture direct and indirect financial connection paths between sectors, improving alternative analysis of interconnectedness based only on direct links. We have used newly available w-t-w data supported by ECB statistical legislation, and our work constitutes the first complete comparison of euro area countries institutional sector interconnectedness.

We find a high level of centrality for our measure of shadow banks in countries where the non-bank financial industry is important, as would be also found with a poorer analysis that would not take into account indirect links. However, the results based on eigenvector centrality present relevant differences with those other simpler analysis in terms of both absolute and relative centrality as discussed in the paper.

A major drawback of our analysis is posed by the rest of the world sector. In sector accounts the rest of the world is, rather than an institutional sector proper, an analytical construct to "close" the system of accounts capturing the flows of the units resident in an economy that do not have as a counterpart units of that economy, but units resident in other economies. The flows for the rest of the world sector are not, as opposed to for the other sectors, aggregates of total flows of a certain group of economic agents: here only a subset of the flows of the agents grouped is considered -those having a resident agent as a counterpart.

In terms of eigenvector centrality, that implies that indirect links that travel via the node "rest of the world" are not captured as richly as those that travel via the nodes for the domestic sectors, where linkages between the various units grouped under the same node are taking into account as well. Moreover, the rest of the world sector/node groups together units of very different economic behaviour, not offering as a consequence enough "resolution" of interconnectedness.

We have made an attempt correct for this "rest of the world bias" to better understand OFI interconnectedness. For that we have used the more granular information on cross-border links provided by the financial accounts Guideline. However, even more detail would be needed to avoid such bias, and possibly the development of so-called Global Flow of Funds presenting full international investment-financing links.

Furthermore, our work on shadow banking centrality would benefit from increased availability of data that would allow for the construction of more relevant networks. This includes a better delineation of shadow banks, beyond the OFI aggregate here used, the full availability of equity on a w-t-w basis, including unquoted equity, and more detailed debt breakdowns. Regarding the latter, although in this paper we already make an analysis of short-term debt centrality and compare it with overall debt centrality, a more pertinent comparison would

require the use of debt broken down by residual maturity, as opposed to original maturity.

References

Bakk-Simon, K., Borgioli, S., Girón, C., Hempell, H., Maddaloni, A., Recine, F. and Rosati, S. (2012), "Shadow Banking in the Euro Area: an Overview" ECB Occasional Papers, no 133

European Central Bank (2017, a), Euro Area Accounts, Who-to-whom detail, web http://sdw.ecb.europa.eu/reports.do?node=1000002345

European Central Bank (2017, b), Financing and Investment Dynamics, Euro Are Statistics, web https://www.euro-area-statistics.org/financing-and-investment-dynamics?cr=eur&lg=en

Eurostat (2013), "European System of Accounts. ESA 2010"

Financial Stability Board (2017), "Global Shadow Banking Monitoring Report 2016"

Herstein, I. N. (1964), "Topics In Algebra", Waltham: Blaisdell Publishing Company

International Monetary Fund, Financial Stability Board (2016), "Second Phase of the G-20 Data Gaps Initiative (DGI-2). First Progress Report"

Markose, S. M. (2012), "Systemic Risk from Global Financial Derivatives: A Network Analysis of Contagion and Its Mitigation with Super-Spreader Tax", IMF Working Paper WP/12/282, International Monetary Fund

Matas-Mir, A. and Willeke, C. (2017), "Compiling financial accounts: a European perspective", 61th ISI World Statistics Congress, IFC organized sessions

Meyer, C. (2000), "Matrix analysis and applied linear algebra", SIAM

Newman, M.E.J. (2010), "Networks: An Introduction", Oxford University Press

Irving Fisher Committee on
Central Bank Statistics

BANK FOR INTERNATIONAL SETTLEMENTS

IFC-National Bank of Belgium Workshop on "*Data needs and Statistics compilation for macroprudential analysis*"

Brussels, Belgium, 18-19 May 2017

Interconnectedness of shadow banks in the euro area[1]

Celestino Girón and Antonio Matas,
European Central Bank

[1] This presentation was prepared for the meeting. The views expressed are those of the authors and do not necessarily reflect the views of the BIS, the IFC or the central banks and other institutions represented at the meeting.

EUROPEAN CENTRAL BANK

EUROSYSTEM

C Girón, A Matas

European Central Bank

Interconnectedness of shadow banks in the euro area

IFC – National Bank of Belgium Workshop on "Data needs and Statistics compilation for macroprudential analysis"

Brussels, 18-19 May

Overview

1. “Who-to-whom” financial accounts networks
2. Eigenvector centrality
3. OFI interconnectedness
4. Cross-border analysis
5. Financial integration and w2w networks

Turn traditional balance-sheet representation into a *NETWORK* of sector interlinks. Matrix representation:

Columns break down a **sector's liabilities by counterparty.**

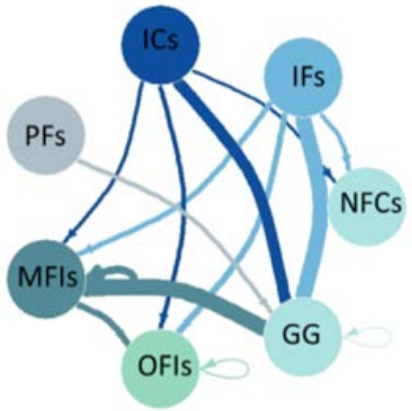
Rows break down its assets.

Government

Assets:	Liabilities :
Item 1 …	Item 1 …
Item 2 …	Item 2 …
	Debt issued : B+E+H

Banks

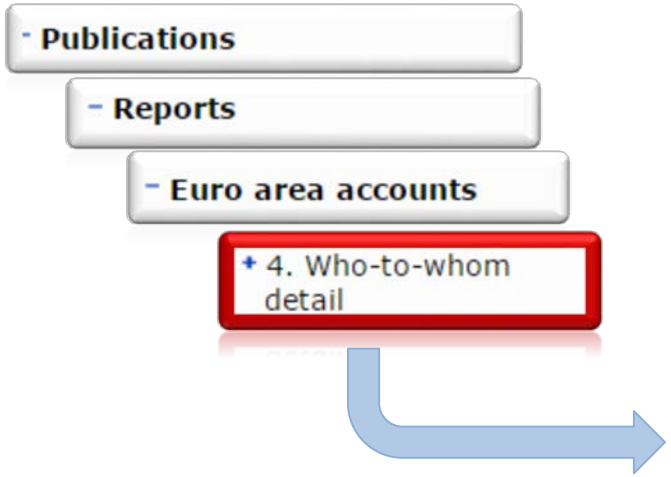
Assets:	Liabilities :
Item 1 …	Item 1 …
Item 2 …	Item 2 …
Debt held : A+B+C	

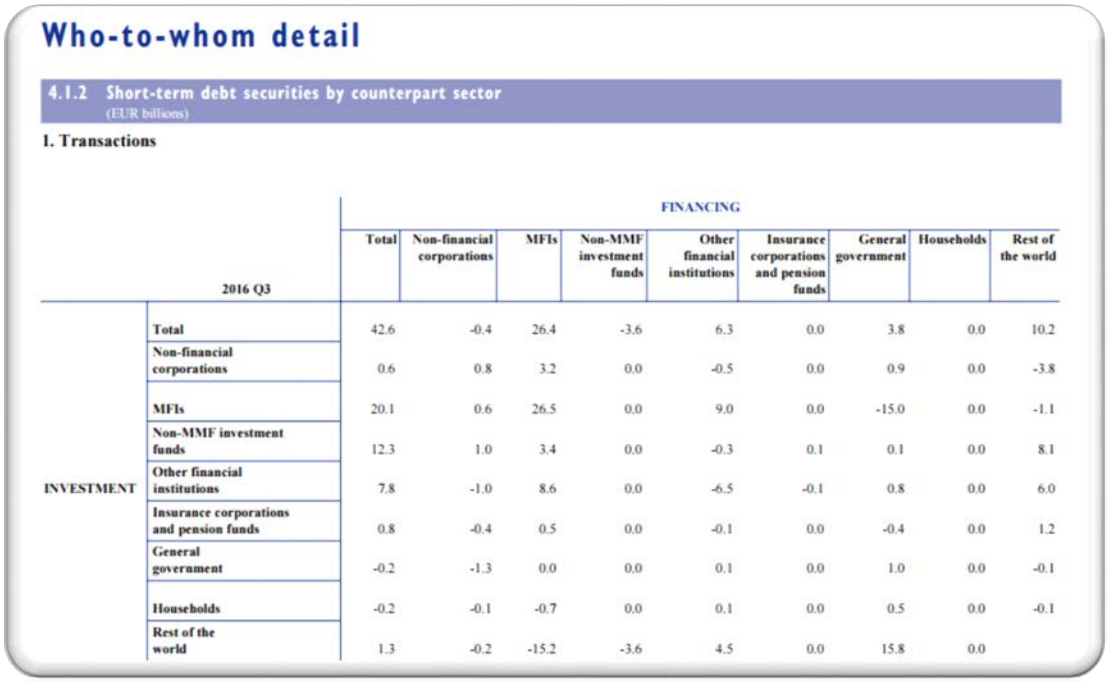


		Debtor (issuer)			
		Banks	Gov't	Corp.	**Total held**
Creditor (holder)	Banks	A	B	C	Banks: A+B+C
	Gov't	D	E	F	Gov't: D+E+F
	Corp.	G	H	I	Corp.: G+H+I
	Total issued	Banks: A+D+G	Gov't: B+E+H	Corp.: C+F+I	

The ECB provides euro area and country networks (with data from 13Q4) as data matrices…

- http://sdw.ecb.europa.eu/reports.do?node=1000005335





Who-to-whom detail

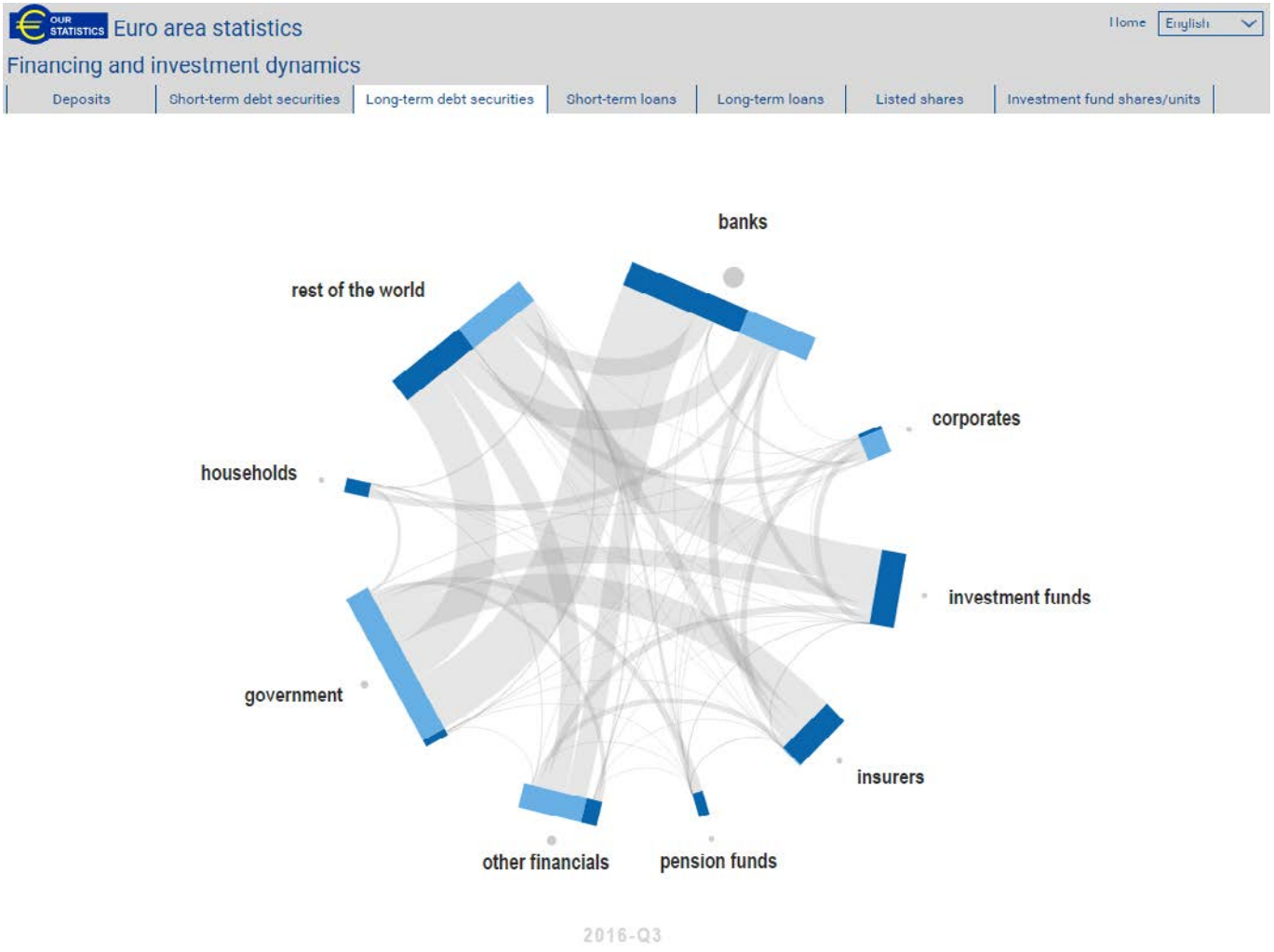
4.1.2 Short-term debt securities by counterpart sector
(EUR billions)

1. Transactions

	2016 Q3	FINANCING								
		Total	Non-financial corporations	MFIs	Non-MMF investment funds	Other financial institutions	Insurance corporations and pension funds	General government	Households	Rest of the world
INVESTMENT	Total	42.6	-0.4	26.4	-3.6	6.3	0.0	3.8	0.0	10.2
	Non-financial corporations	0.6	0.8	3.2	0.0	-0.5	0.0	0.9	0.0	-3.8
	MFIs	20.1	0.6	26.5	0.0	9.0	0.0	-15.0	0.0	-1.1
	Non-MMF investment funds	12.3	1.0	3.4	0.0	-0.3	0.1	0.1	0.0	8.1
	Other financial institutions	7.8	-1.0	8.6	0.0	-6.5	-0.1	0.8	0.0	6.0
	Insurance corporations and pension funds	0.8	-0.4	0.5	0.0	-0.1	0.0	-0.4	0.0	1.2
	General government	-0.2	-1.3	0.0	0.0	0.1	0.0	1.0	0.0	-0.1
	Households	-0.2	-0.1	-0.7	0.0	0.1	0.0	0.5	0.0	-0.1
	Rest of the world	1.3	-0.2	-15.2	-3.6	4.5	0.0	15.8	0.0	

http://www.ecb.europa.eu/press/pr/stats/ffi/html/index.en.html

… and as network graphs



OUR STATISTICS is an ECB website for journalists: www.euro-area-statistics.org

1 “Who-to-whom” financial accounts networks

2 **Eigenvector centrality**

3 OFI interconnectedness

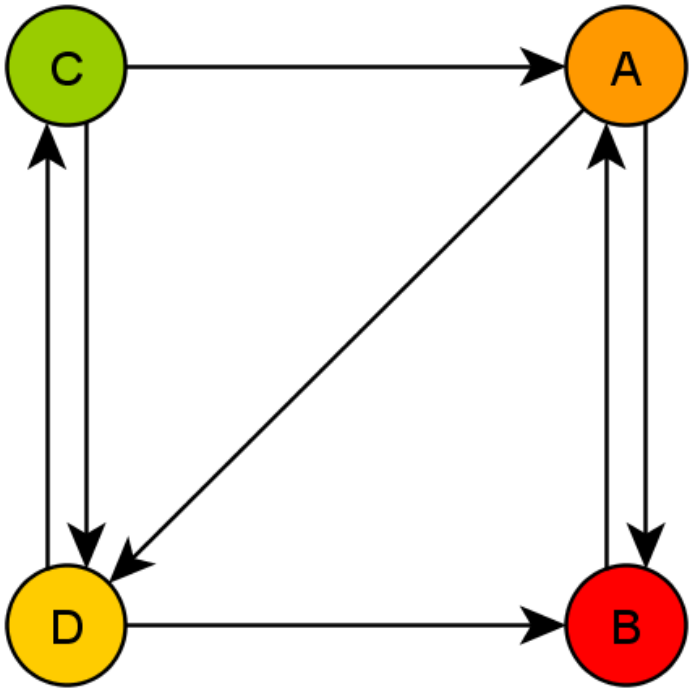
4 Cross-border analysis

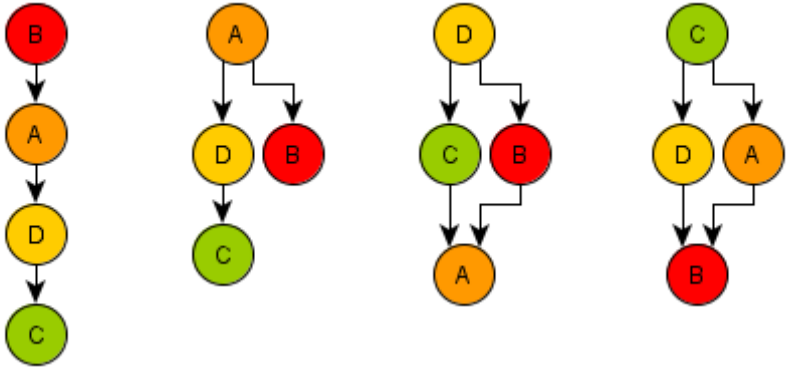
5 Financial integration and w2w networks

2. Eigenvector centrality

“The Beggars”, Pieter Bruegel (1568)

Which node is more connected?





✓interconnectedness ranking: **C-D-A-B**

✓For more complex networks (in particular weighted networks), the solution is not trivial

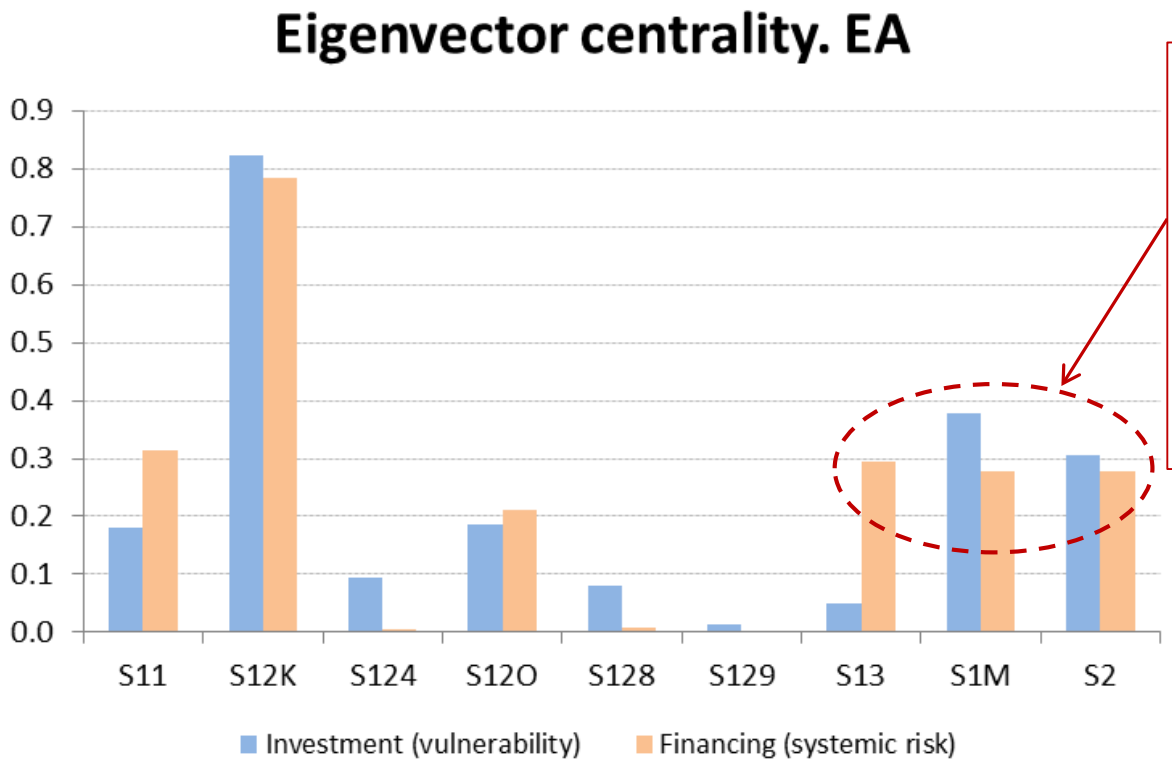
✓**Eigenvector centrality** provides "interconnectedness" scores/ rankings on the basis of the matrix representation of the network: **Perron eigenvector** (principal vector of Perron eigenvalue)

✓ here **(0.50 0.29 0.61 0.54)**

Applied to w2w networks…

- ✓ indicates sector interconnectedness via direct (first order) investment and financing links, but also indirect (second and higher order) links via financial intermediation
- ✓ Recursive interpretation: "the more a sector is linked to sectors with high score, the higher the score of the sector is"
- ✓ Perron's vector, when calculated on networks …
  - …showing **creditor-debtor** links, provides rankings of interconnectedness via investment: **vulnerability indicator**
  - …showing **debtor-creditor** links (represented by the transposed matrix of a creditor-debtor network), provides rankings of interconnectedness via financing: **systemic risk indicator**

Scores take into account indirect investment- financing links

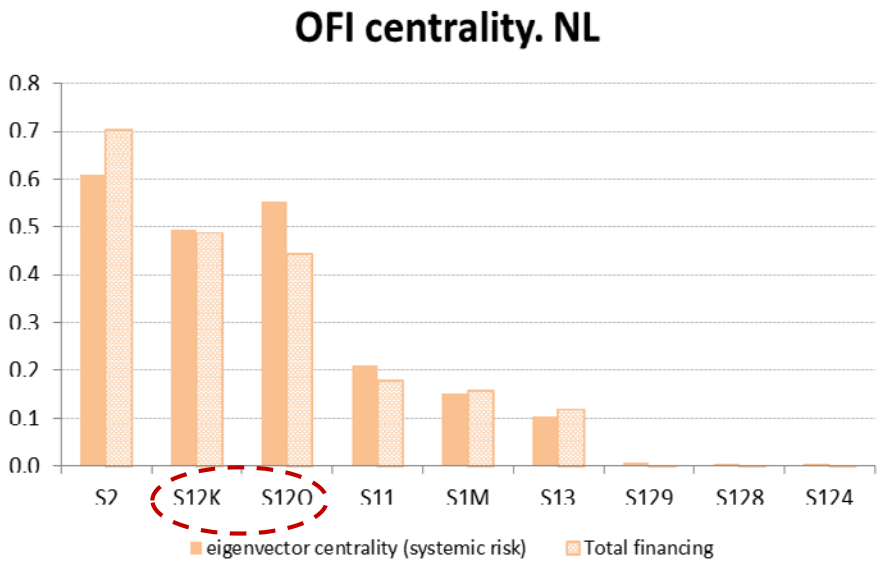


Households are as systemic as government and the rest of the world in spite of having half their liabilities!!!

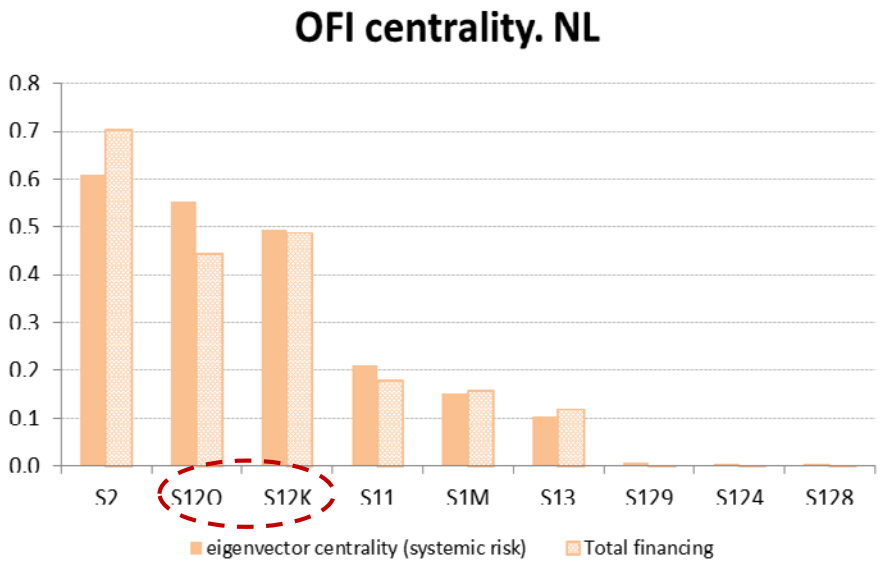
Notes:

- *Units: components of normalized Perron eigenvectors; network of debt (debt securities, loans and deposits); 16Q4*
- *S11: non-financial corporations; S12K: MFIs (S121+S122+S123); S124: investment funds; S12O: OFIs (S125+S126+S127); S128: insurance corporations; S129: pension funds; S13: general government; S1M: households and NPISHs (S14+S15); S12: rest of the world*

If complex w2w links exist, rankings might be different from plain volume rankings



Sorted by total financing



Sorted by eigenvector centrality

Note:

- *Units: S120 component in normalized Perron eigenvector (debt network, debtor-creditor links) and normialized weight of S120 financing (debt liabilitis) in total economy debt; 16Q4*

Some references for eigenvector centrality…

Elgammal, A.; Saleh, B. (2015) "Quantifying Creativity in Art Networks", Sixth International Conference on Computational Creativity (ICCC), June 29-July 2nd 2015, Park City, Utah, USA.

Markose, S. M., (2012), "Systemic Risk and Global Financial Derivatives: A Network Analysis of Contagion and Its Mitigation with Super-Spreader Tax", IMF Working Papers WP/12/282

and for w2w and network analysis…

Antoun de Almeida, L. (2015), "A Network Analysis of Sectoral Accounts: Identifying Sectoral Interlinkages in G-4 Economies" IMF Working Papers WP/15/111

Castrén, O.; Kavonius, I. K (2009), "Balance Sheet Interlinkages and Macro-Financial Risk Analysis in the Euro Area", ECB Working Papers No. 1124

Castrén, O.; Rancan, M. (2013), "Macro-Networks: an Application to Euro Area Financial Accounts", ECB Working Papers No. 1510

1 “Who-to-whom” financial accounts networks

2 Eigenvector centrality

3 OFI interconnectedness

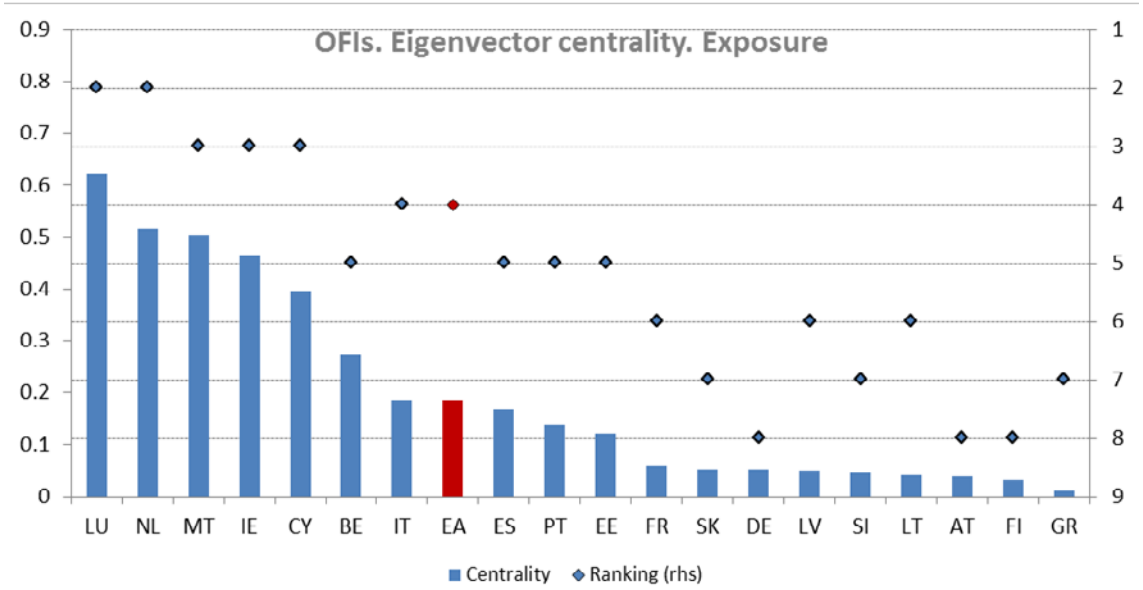
4 Cross-border analysis

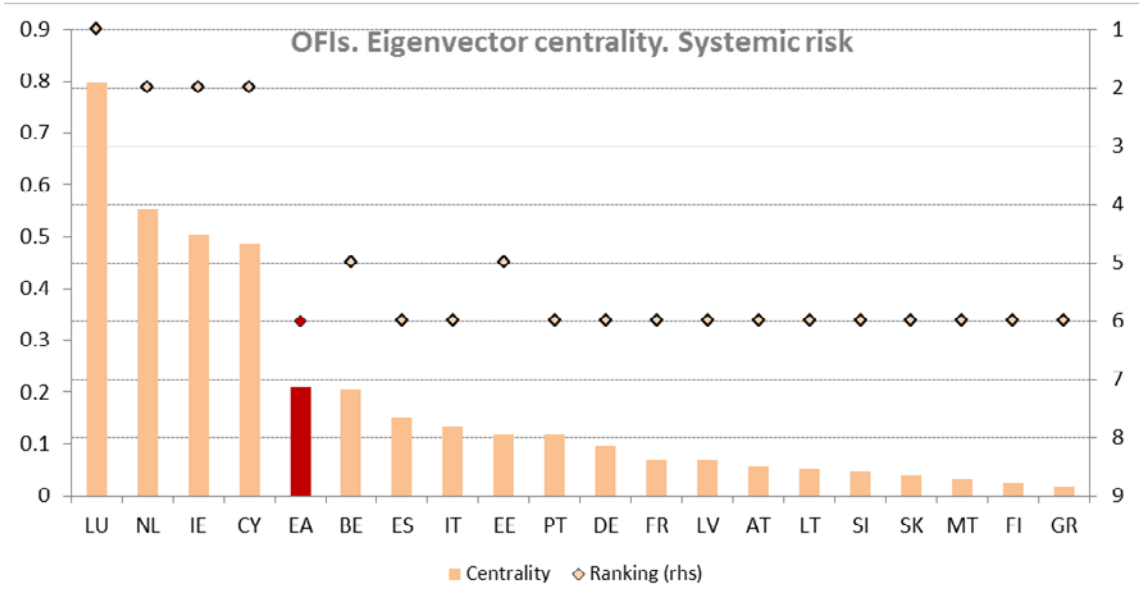
5 Financial integration and w2w networks

We examine shadow banking interconnectedness in euro area countries…

- ✓ using as a proxy for shadow banks the **OFI sector**, i.e. financial intermediaries other than MFIs and ICPFs, financial auxiliaries and captives financial institutions: roughly in line with the "broad measure" of shadow banking used in the FSB annual monitoring report, http://www.fsb.org/2017/05/global-shadow-banking-monitoring-report-2016/
- ✓ working with **w2w *debt* networks**: debt securities + loans + deposits
- ✓ looking into vulnerability and systemic risk indicators calculated from **eigenvector centrality,** with reference period 2016Q4

3. OFI interconnectedness



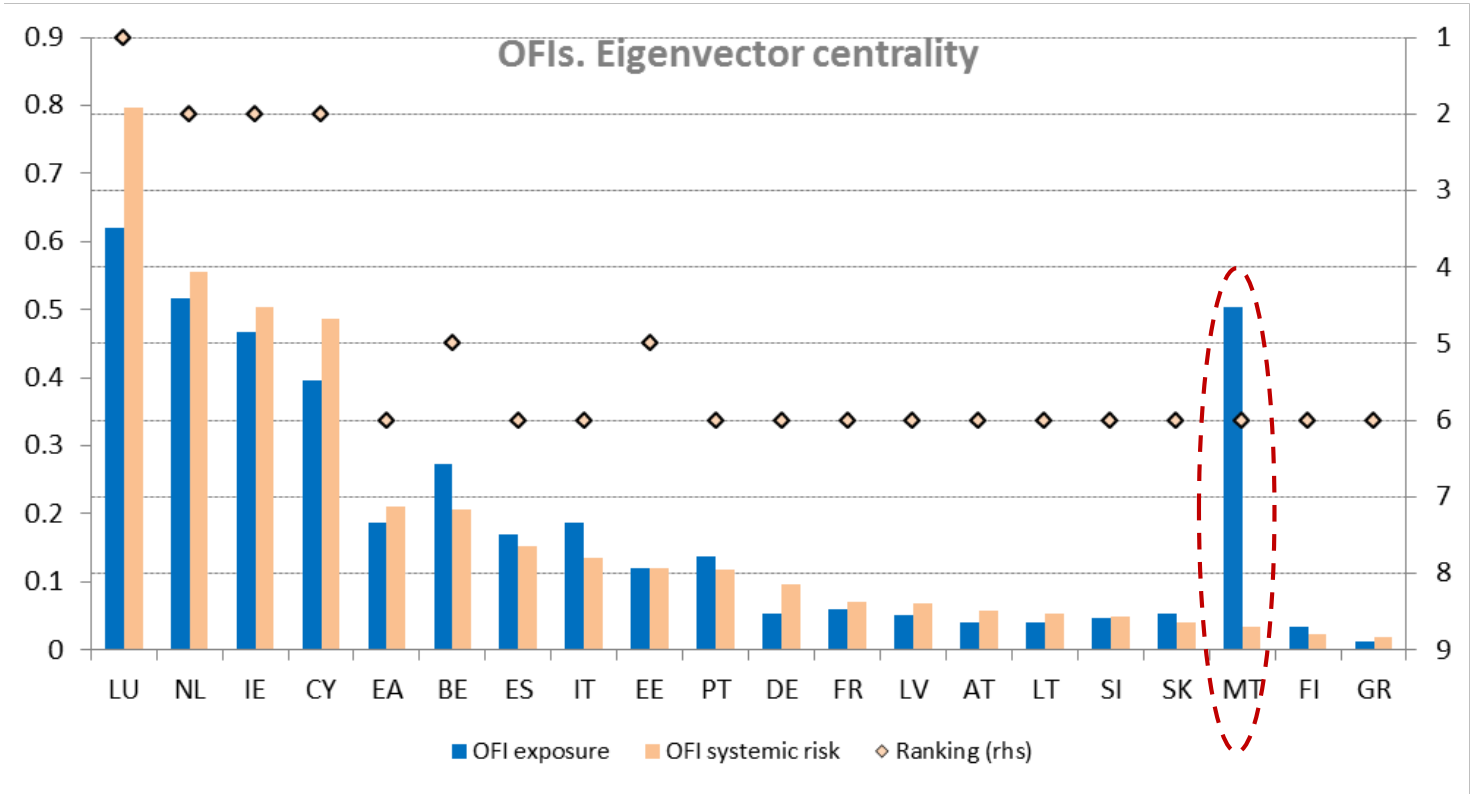


OFI in *LU, NL, IE, CY* present high vulnerability and systemic risk

Note:

- *Units: S120 component in normalized Perron eigenvectors; debt network ; 16Q4*

Vulnerability and systemic risk might present high heterogeneity



Notes:

- *Units: S120 component in normalized Perron eigenvectors; debt network; 16Q4*
- *Sorted by systemic risk*

1 “Who-to-whom” financial accounts networks

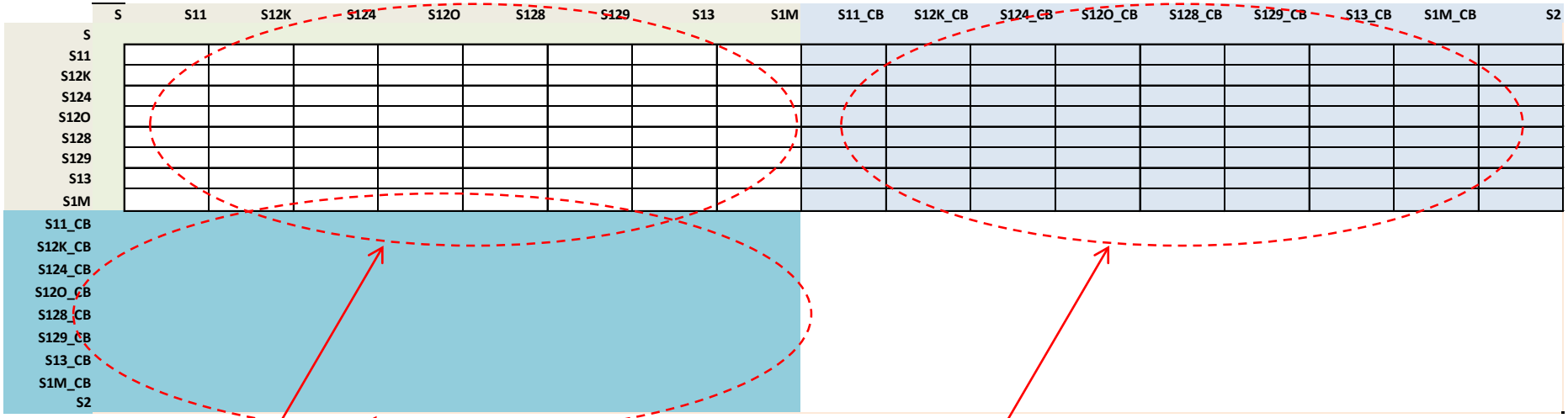
2 Eigenvector centrality

3 OFI interconnectedness

4 Cross-border analysis

5 Financial integration and w2w networks

For compiling euro area w2w, countries provide data for…



Domestic w2w

Domestic creditors vis-à-vis other euro area debtors and of the world (C_{ij})

But do not send data on "domestic debtors vis-à-vis euro area creditors and rest of the world"… **need to be estimated!!** (D_{ij})

Estimating "domestic debtors (*j*) to euro area creditors (*i*)" for country c, D_{ij}^{c}

$$D_{ij}^{c} = \sum_{d \neq c} a_{ij}^{dc}$$

a_{ij}^{dc} being assets of sector *i* in country *d*, liabilities of sector *j* in country *c*

$D_{ij}^{c} \neq \sum_{d \neq c} a_{ij}^{cd} = C_{ij}^{c}$, which is the cross-border information reported by each country *c*, but…

$$\sum_{c} D_{ij}^{c} = \sum_{c} \sum_{d \neq c} a_{ij}^{dc} \equiv \sum_{c} \sum_{d \neq c} a_{ij}^{cd} = \sum_{c} C_{ij}^{c}$$

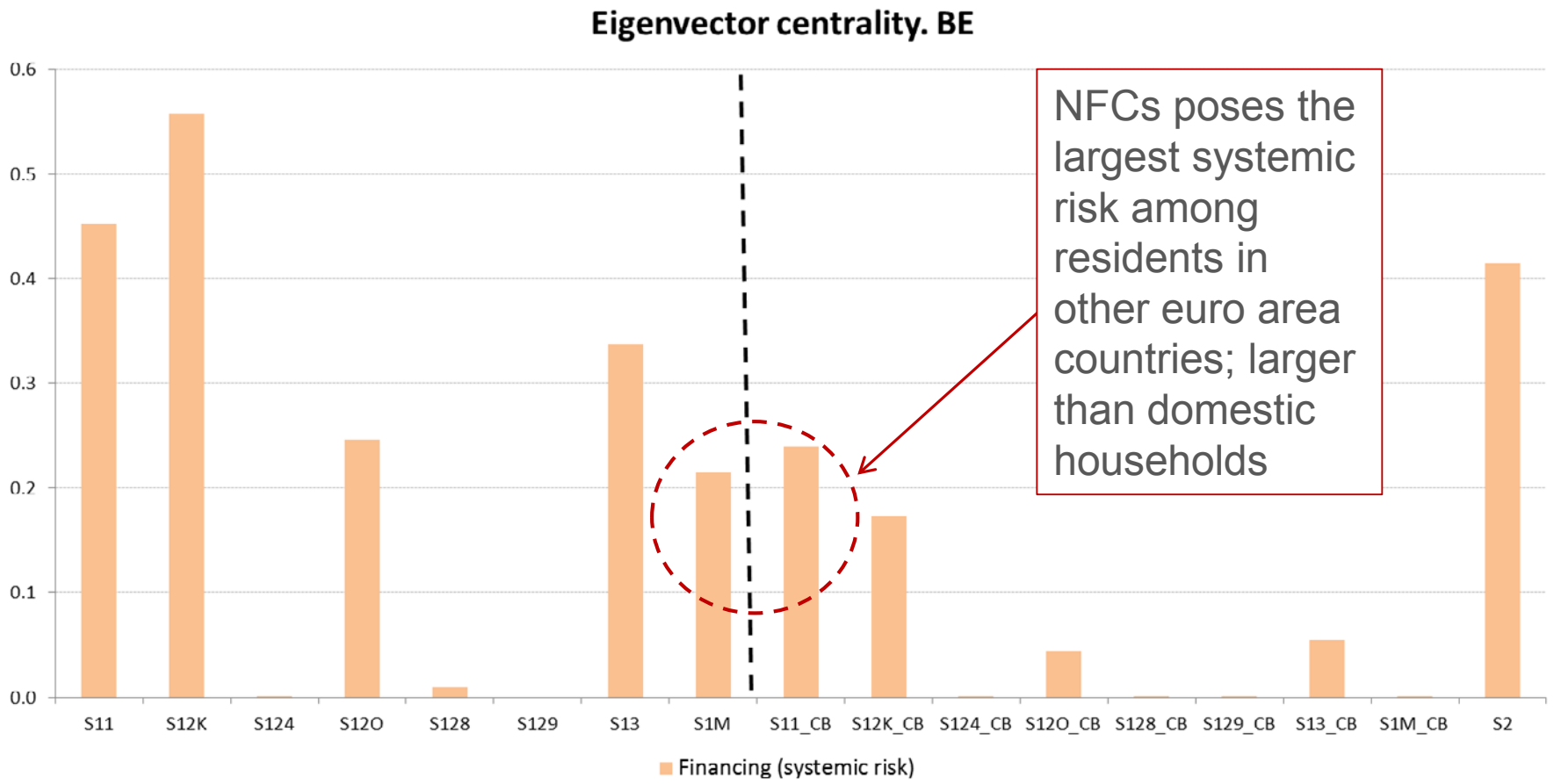
We assume that the distribution of D_{ij}^{c} across *i, j* is "similar" to that of $\sum_{c} D_{ij}^{c}$, *either by*

- *keeping identical structure, or*
- *by cross-entropy minimization (of Kullback–Leibler divergence)*

We look into…

- ✓ **enlarged country networks ,** nodes for domestic sectors and for sectors resident in other euro area countries, (17 nodes in total); **for countries with high centrality of the OFI sector**
- ✓ eigenvector **centrality for "sectors in other euro area countries"**
- ✓ Caveats:
  - "sectors in other euro area countries" only covered in so far as they present links to domestic sectors: high order **indirect exposures/ risks via links within sectors resident in other euro area countries are not covered**
  - accuracy of estimates for links of "domestic debtors to euro area creditors", D_{ij}^{c}, on the basis of euro area averages might be poor for the countries of interest: eigenvector **systemic risk better estimated** (first order exposures based on reported data)

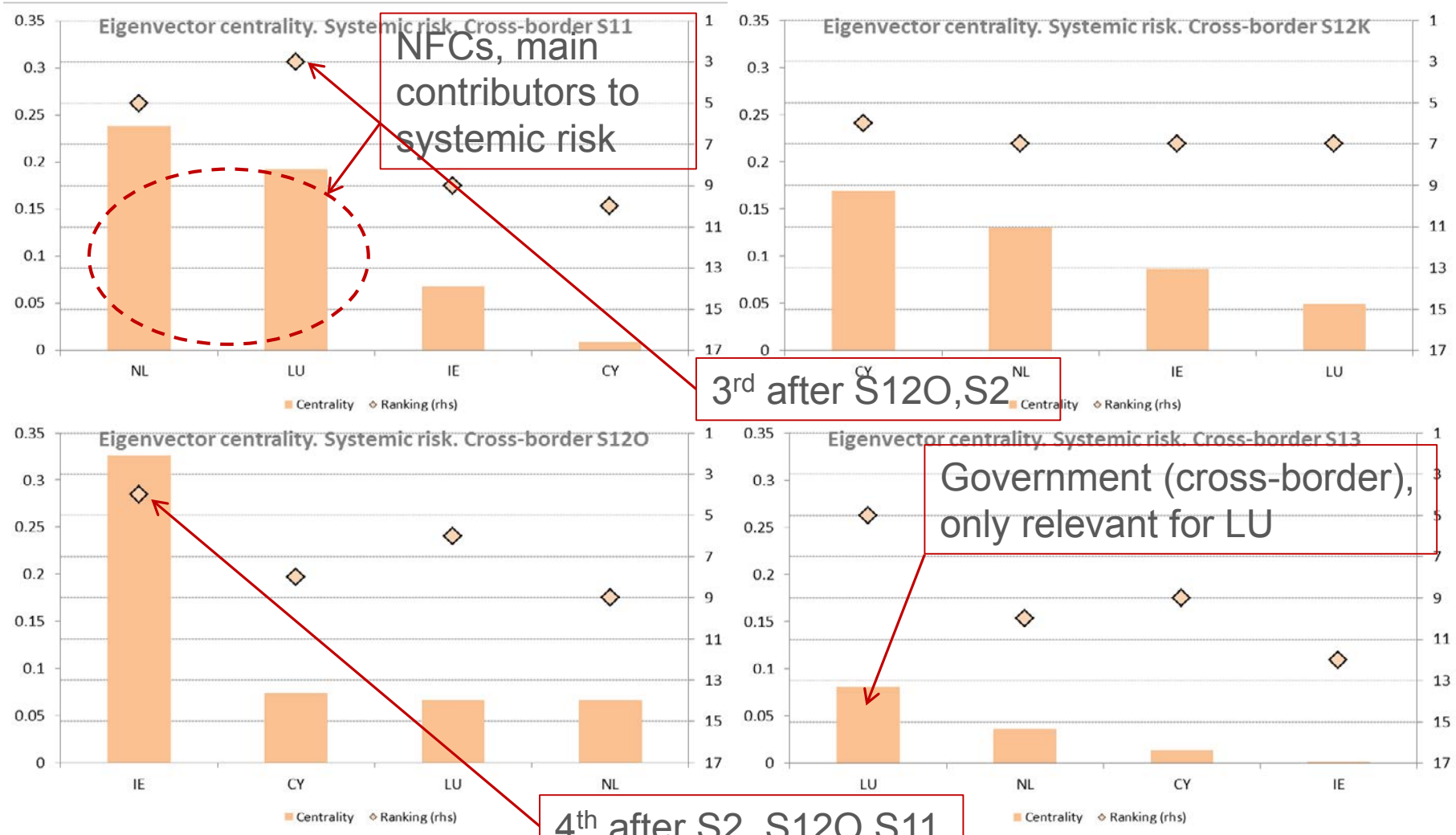
4. Cross-border analysis



Notes:

- *Units: components of normalized Perron eigenvectors; enlarged network of debt ; debtor-creditor links;16Q4*
- *Sector codes without suffix: domestic sectors; sector codes with suffix _CB: residents in other euro area countries; S2: extra euro area*

The "other euro area countries" sectors in OFI-central countries



Notes:

- *Units: components of normalized Perron eigenvectors; enlarged debt network ; 16Q4*
- *Sorted by centrality*

1 “Who-to-whom” financial accounts networks

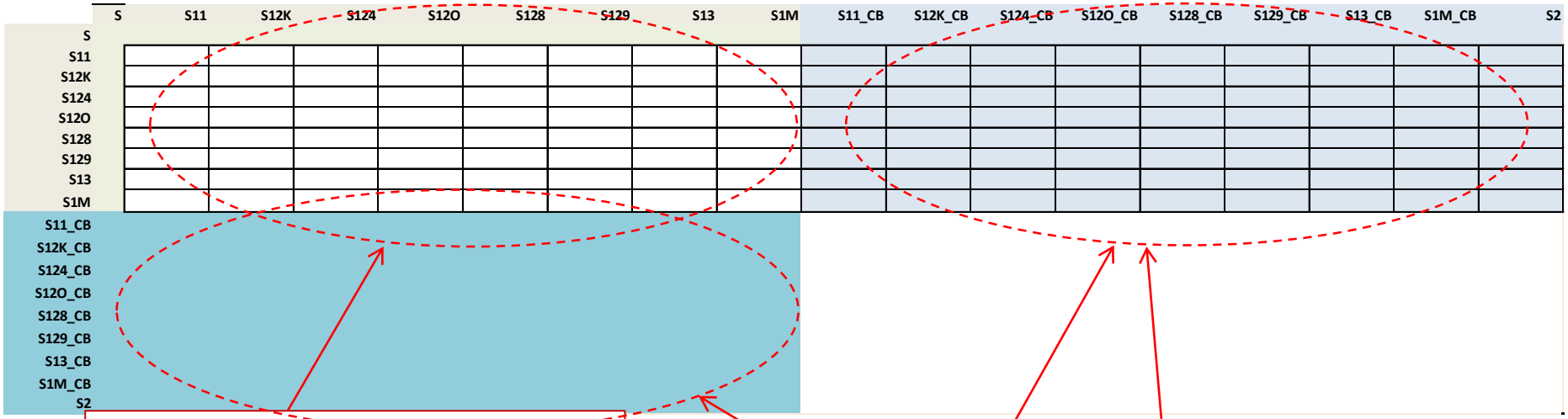
2 Eigenvector centrality

3 OFI interconnectedness

4 Cross-border analysis

5 Financial integration and w2w networks

For the euro area, an "enlarged network" can also be compiled, but having a different interpretation



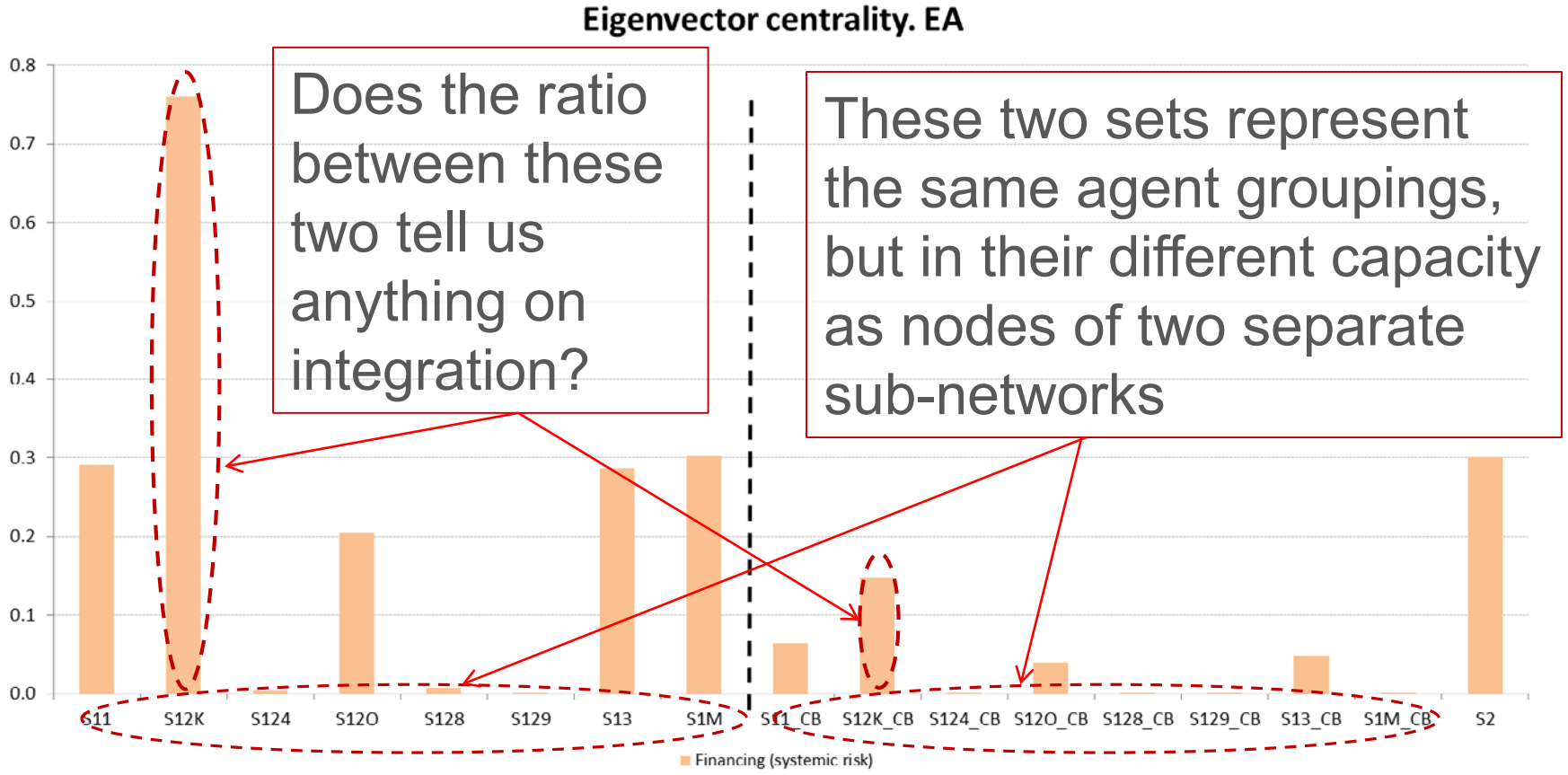
Domestic (only within borders) intra euro area links

$\sum_c C_{ij}^c$ cross border intra euro area links

$\sum_c D_{ij}^c$ cross border intra euro area links

These two matrices are identical. **No estimation needed!!**

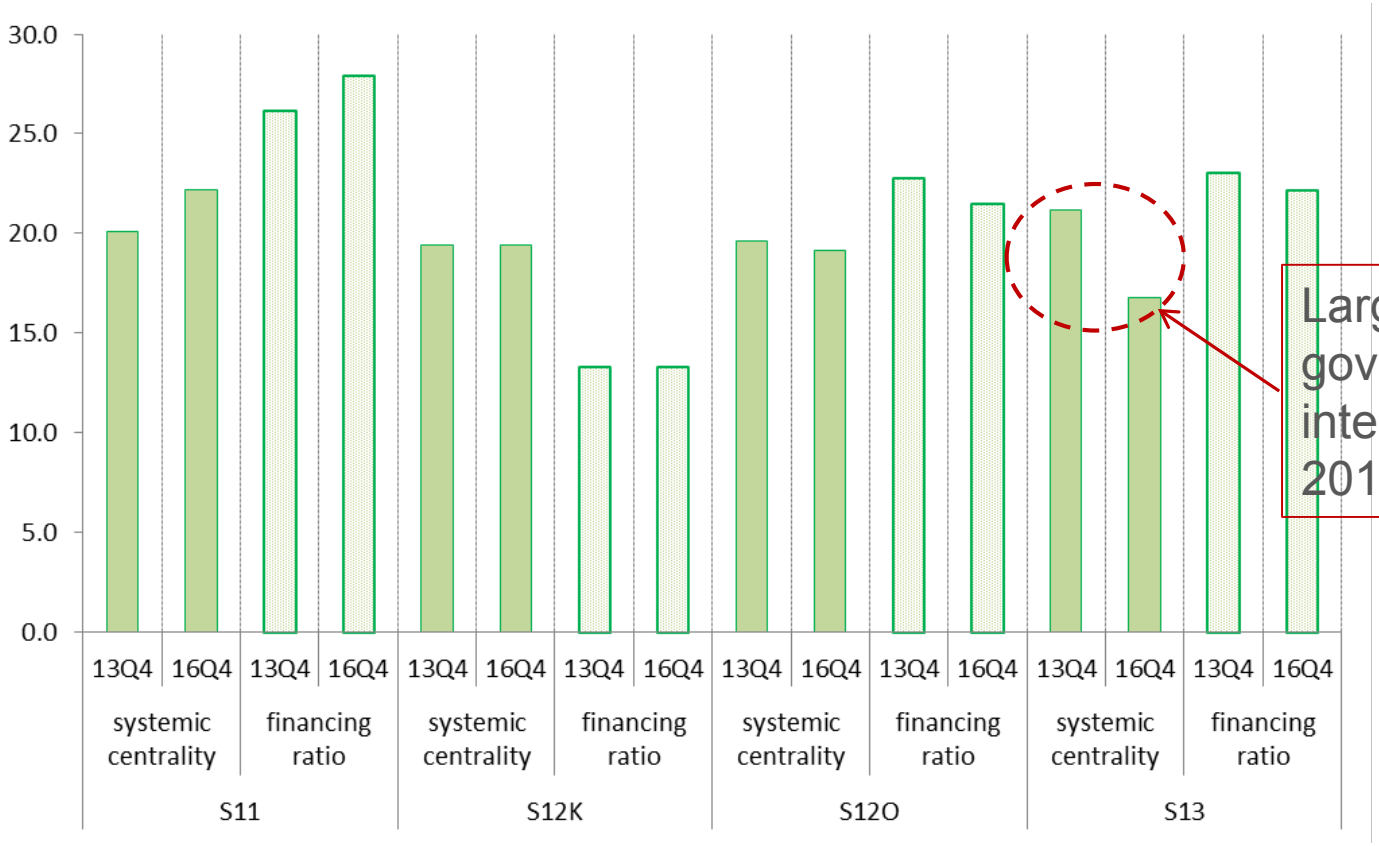
Difficult interpretation of Perron eigenvector



Notes:

- *Units: components of normalized Perron eigenvectors; enlarged network of debt; debtor-creditor links; 16Q4*
- *Sector codes without suffix: domestic sectors; sector codes with suffix _CB: residents in other euro area countries; S2: extra euro area*

More uniformity in sector integration if measured on Perron's eigenvector components (as opposed to volume ratios)



Notes:

- *Units: ratios in percentages of components of normalized Perron eigenvectors of debtor-creditor enlarged network (for systemic centrality), and of total debt liabilities (for financing ratio); for each sector, cross-border component (or cross-border financing) to domestic component (domestic financing)*

Conclusions

- ✓ Eigenvector centrality calculated on w2w financial accounts networks provides a convenient way to measure interconnectedness that accounts for indirect, second and higher order sector links
- ✓ NL, LU, IE, CY present high centrality scores for the OFI sector, both for the vulnerability and systemic risk metrics, surpassing sectors with higher total investment and financing
- ✓ For those countries, systemic risks posed by residents in other euro area countries are mainly coming from NFCs
- ✓ Ratios of eigenvector components for a euro area enlarged w2w financial accounts network might be used to measure financial integration: sectors present uniform integration levels, and the government shows a dramatic fall in integration since 2013

Thank you for your attention !

EUROPEAN CENTRAL BANK

EUROSYSTEM