FINANCIAL INTERCONNECTEDNESS IN EUROPE

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Abstract

The recent economic crisis and its aftermath have led to in-depth research on the sources of systemic risks and potential determinants of the vulnerabilities of the European financial system. The harmonization of financial supervision and regulation at European level plays a key role in ensuring financial stability and in setting the basis for recovery and growth in Europe. The banking sector plays a central role in intermediating the flow of funds to the real economy in the European countries, especially since the introduction of the single currency framework, which has notably increased not only the European financial integration but also the potential cross-border spillover effects and risk-sharing among euro area countries. The main objectives of this paper are threefold: (i) to assess the risks stemming from lending activities (credit risks); (ii) to present in a network framework the countries' vulnerabilities and cross-border exposures; and (iii) to shed light on further potential financial stability risks. In order to achieve these objectives, we use network techniques to spot financial vulnerabilities and potential for spillovers at an early stage. Our results are relevant for policy makers in their search for harmonized financial supervision and sustained financial stability in Europe.

Key words: cross-border spillovers, financial stability, financial interconnectedness, network analysis, credit risk

JEL Code: G21, F20

Introduction

The global financial crisis has underlined the necessity for a more comprehensive analysis of the connectedness between the financial systems across European Union Member States. A well-integrated financial system assures European countries of a good risk-sharing system and permanent access to credit. By using network analysis, this paper presents the intensity of the connectedness between monetary financial institutions (MFIs) across countries. Financial interlinkages presented in a network framework facilitate a better understanding of the movements of financial flows and of the benefits and risks shared between financial sectors across countries. A higher connectedness level carries, at the same time, advantages and

disadvantages. For instance, it can improve risk sharing through good shock absorption inside the network, or, it can lead to higher contagion across sectors, as shocks may be easily transferred from one node to the others inside the network.

By using network techniques, the main goal of the paper resides in assessing risks stemming from lending activities, which sheds light on further potential financial stability risks. The remainder of the paper is structured as follows. Section 1 presents briefly the literature review, section 2 describes the data and methodology used to construct the network and section 3 presents the results, while the paper ends with brief conclusions.

1 Literature review

The banking system has played a central role in the expansion of the recent crisis across borders and has been one of the main channels of shock transmissions. Network techniques have recently been used to assess, in a more comprehensive framework, the domestic linkages across sectors and the cross-border interconnectedness of the international financial systems. Researchers have adopted this technique applied before in biology and epidemiology and extended it by using mathematical methods, to study networks of national interbank payment systems (Minstrulli, 2011), resilience to systemic risk and contagious defaults (Nier, 2007) and international trade flows (Fagiolo, 2009). Given the efficiency of the technique, it has been extended and applied to other contexts as well, such as cross-border exposures by asset classes such as foreign direct investments, portfolio equity, debt levels (Kulebec, 2010), financial contagion (Kali and Reyes, 2010), generation of systemic risk (Allen, 2011), financial propagation effects (Battiston, 2012) and global banking interconnectedness (Castrén and Rancan, 2013, 2014; Minoiu and Reyes, 2013; Peltonen, Rancan and Sarlin, 2015).

Castrén and Rancan (2013, 2014) performed quarterly simulations for the period 2003-2011 for 11 euro area countries using sector balance sheet information data at country level. Their results show a general increase in the volume of bilateral linkages between 2003 and 2007, while, after the start of the crisis, a generally sharp reduction in the cross-border exposures was observed. Minoiu and Reyes (2013) show that the dynamics of cross-border financial linkages are key to understanding how the globally interconnected financial system works and the extent of its resilience to potential shocks stemming from systemic risks. They perform a global analysis for 184 countries between 1978 and 2010 using cross-border financial flows data confidentially provided by the Bank of International Settlements. Their results suggest a general increase in cross-country connectedness prior to the financial and debt crises and a general decrease during

and post-crises. The results also mark the 2008 – 2009 period as unique in their sample, indicating a massive global drop in network density, reaching the lowest levels in their analysis. Peltonen, Rancan and Sarlin (2015), build their macro-network using loans, deposits, securities and equity shares as main financial instruments for 14 euro area countries for the period 2000 - 2012. They assess different categories of risks such as credit risk, funding and liquidity risks, and market risk. Their goal resides in detecting the potential determinants of a banking crisis by measuring in a network architecture framework both the direct and indirect exposures of each country's banking sector to the whole European financial system.

The current research contributes to the existing literature on networks of financial systems by extending the analysis to an increased EU number of countries (28) and a different time frame (2007–2016). The paper complements existing literature with an in-depth analysis of the financial instrument category "loans" and a comparison of interconnectedness dynamics during crisis times (2008) and most recent period (2016). This approach may be considered a step forward towards a better understanding of the current European banking system challenges and a more comprehensive analysis on financial stability vulnerabilities and risk-sharing across EU countries.

2 Data and methodology

The paper presents via a visualization tool the lending activities for the 28 European Union Member States for the period 2007 - 2016. Loan data is a major source of information on flow of funds directions and helps to better understand the past and current levels of interconnectedness of the European financial systems. The BSI statistics from the Statistical Data Warehouse of the European Central Bank provide aggregated balance sheet data for the MFI sector broken down by country and helps to identify each country's foreign exposure by reporting from-whom-to-whom information on MFI counterparties. Data on loans is available quarterly and is expressed as outstanding amounts at the end of the period (stocks) in millions of euro. The constructed network contains 30 nodes (28 UE Member States, *"non-euro area countries*" and "*other euro area countries"*) and shows a maximum of 900 potential linkages among the countries' MFI sectors across Europe.

The quarterly stocks of loans are transformed into quarterly flows, providing information regarding the euro volumes of loans moving from one country to another on a quarterly basis. The flows are estimated as changes in stocks and are taken into consideration in the analysis if they are positive; in case the resulting flows are negative (net repayments), they are ignored.

Therefore, the matrices of cross-border lending activities are constructed based on the estimations of positive loan flows. A full set of indicators providing information on the level of interconnectedness is constructed based on the matrices data. Matrices *Mt*, where the rows represent the lenders and the columns represent the borrowers, and $Mt^{(-1)}$, the transposed form of *Mt*, where rows represent the borrowers and columns represent the lenders, are built for every time period "*t*" during 2007 – 2016. The matrices contain all possible financial linkages ($Linkij^t$, where *i* represents country *A*, *j* represents country *B* and *t* represents the time period) between any two different countries, and, where applicable, the extra two categories introduced in the network "*other euro area countries*" and "*non-euro area countries*".

The assessment of how much a country lends *("funds-out")* and how much it borrows *("funds-in")* is given by the node strength calculations. Node strength represents the sum of flows originating or terminating in a node in a given period of time. The intensity of financial linkages between two countries is captured in the node strength indicator. Therefore, for each country, the *"In-strength"* (total amount of cross-border flows it borrows) and the *"Out-strength"* (total amount of cross-border flows it lends) are calculated:

$$(\text{In-strength } i)^t = \Sigma j \neq i \ (\text{flows } ji)^t \quad (1)$$

$$(\text{Out-strength } i)^t = \Sigma \ j \neq i \ (\text{flows } ij)^t, \quad (2)$$

where *i* represents country *A*, *j* represents all the rest of the countries (the remaining 27 and the extra two categories) and *t* represents the time period.

The node degree is calculated based on the incoming links for borrowers *("in-degree")* and outgoing links for lenders *("out-degree")* and represents the number of linkages for each node in the network. If any direct flow between every two countries is positive, then the number of either *"in-degree"* or *"out-degree"* increases:

$$Nij^t = 1, \text{ if } (Link ij)^t > 0 \quad (3)$$

$$(\text{Out-degree } i)^t = (\Sigma j \neq i \ Nij)^t = (Mi1)^t \quad (4)$$

$$(\text{In-degree } i)^t = (\Sigma j \neq i \ Nij)^t = [(Mi)^{(-1)}1]^t \ , \quad (5)$$

where *N* represents the number of links of positive flows, *i* represents country *A*, *j* represents all the rest of the countries (the remaining 27 and the extra two categories), *t* represents the time period and $(Mi1)^t$ *and* $((Mi)^{(-1)}1)^t$ the two constructed matrices.

Network density is assessed by calculating the network connectivity, which represents the number of links of positive flows per each country divided by the total possible number of links (the remaining 27 countries):

$$(\text{Network connectivity } i)^t = (\text{N}i/\ 27)^t\ , \quad (6)$$

where *i* represents each country, *Ni* represents the number of links calculated for *"in-degree"* and *"out-degree"* and *t* represents the time period.

Another indicator used in the analysis is the Herfindahl-Hirschman Index *(HHI)* (Minoiu and Reyes, 2013), which measures the share concentration or diversification of each country's lending or borrowing activities. The *"Out-HHI"* is calculated for lenders as the sum of squared borrowers' shares in each lender's total outflows. The *"In-HHI"* is calculated for borrowers as the sum of squared lenders' shares in each borrower's total inflows. The values of HHI are within a range of 0 to 1.

The above presented methodology is implemented in the following steps. First, total outflows and total inflows for each period are calculated for all countries:

$$\text{Total outflows}_A = \Sigma\ (\text{flow}_{A\text{-}B} + \text{flow}_{A\text{-}C} + \text{flow}_{A\text{-}D} + \ldots + \text{flow}_{A\text{-}X}) \quad (7)$$

$$\text{Total inflows}_A = \Sigma\ (\text{flow}_{B\text{-}A} + \text{flow}_{C\text{-}A} + \text{flow}_{D\text{-}A} + \ldots + \text{flow}_{X\text{-}A}), \quad (8)$$

Next, *"out-HHI"* and *"in-HHI"* are calculated as follows:

$$\text{Out-HHI}_{A\text{-}B} = \text{outflow}_{A\text{-}B} / \text{Total outflows}_A \quad (9)$$

$$\text{In-HHI}_{A\text{-}B} = \text{inflows}_{B\text{-}A} / \text{Total inflows}_A \quad (10)$$

The total *"out-HHI"* and *"in-HHI"* are calculated as follows:

$$\text{Total Out-HHI}_A = \Sigma\ (\text{In-HHI}_{A\text{-}B})^2 + (\text{In-HHI}_{A\text{-}C})^2 + (\text{In-HHI}_{A\text{-}D})^2 + \ldots + (\text{In-HHI}_{A\text{-}X})^2) \quad (11)$$

$$\text{Total In-HHI}_A = \Sigma\ (\text{In-HHI}_{A\text{-}B})^2 + (\text{In-HHI}_{A\text{-}C})^2 + (\text{In-HHI}_{A\text{-}D})^2 + \ldots + (\text{In-HHI}_{A\text{-}X})^2) \quad (12),$$

where *A* is the lending country in (7, 9, 11) and borrowing country in (8, 10, 12), and *B,C,D..X* represent the remaining countries as borrowing countries in (7, 9, 11) and lending countries in (8, 10, 12).

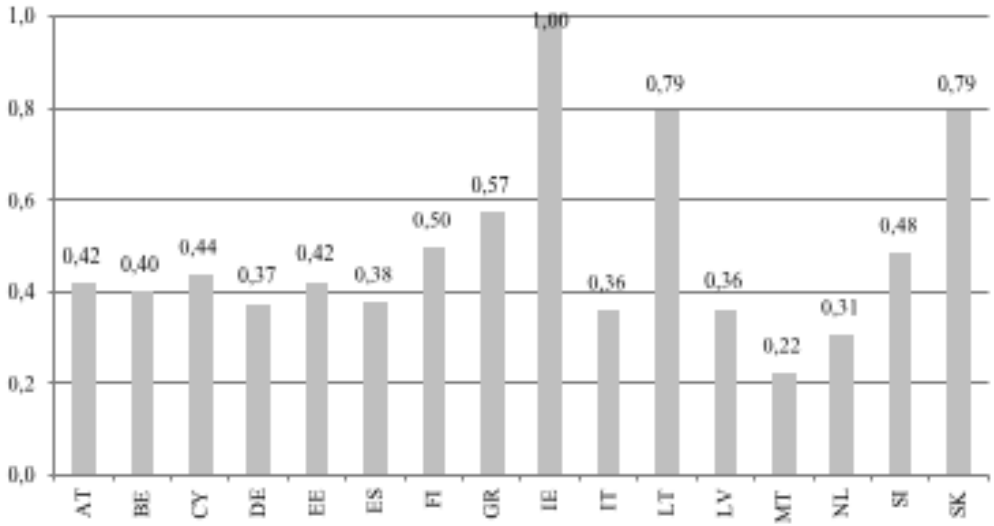
3 Results

The occurrence of the financial crisis triggered countries' tendency to tighten their international lending activities. In the post-crisis period, the countries reduced the number of the granted cross-border loans. In general, euro area countries lend more across borders than they borrow as new foreign loans on their balance sheets. Italy is a special case, as it borrowed more than

lent in 2016 Q2. Germany is the strongest lender in Europe, its' "*OUT-Strength*" exceeds 20 million euro in 2016 Q2. Belgium, Spain and the Netherlands are also important lenders to the remaining countries. Due to data availability restrictions, the non-euro area countries act only as borrowers. International funds are granted to non-euro area Member States, but to different extents. For instance, Czech Republic is the most important borrower, receiving in 2016 Q2 almost 2 million euro from abroad. On the opposite side, Bulgaria, Hungary, Croatia and Romania borrowed less than a quarter million euro.

The probability of a lending connection between every two different EU Member States is measured by the "connectivity" indicator. Measuring the network density for the *"flows-out"* for euro area countries, Germany and Italy have lent, on average, to other 15 countries of the remaining EU countries. The Netherlands is the country accessing most foreign funds in 2016 Q2, while Slovakia, Malta, Latvia, Lithuania and Estonia borrowed the least in 2016 Q2. The assessment of the network density for non-euro area countries for *"flows-in"* shows that the Czech Republic, Denmark and Sweden not only borrowed the most in terms of amounts of EUR millions, but also in terms of countries they borrowed from. Romania, Hungary and Croatia accessed foreign funds from a limited number of countries in 2016 Q2.

Fig. 1: Concentration for lenders

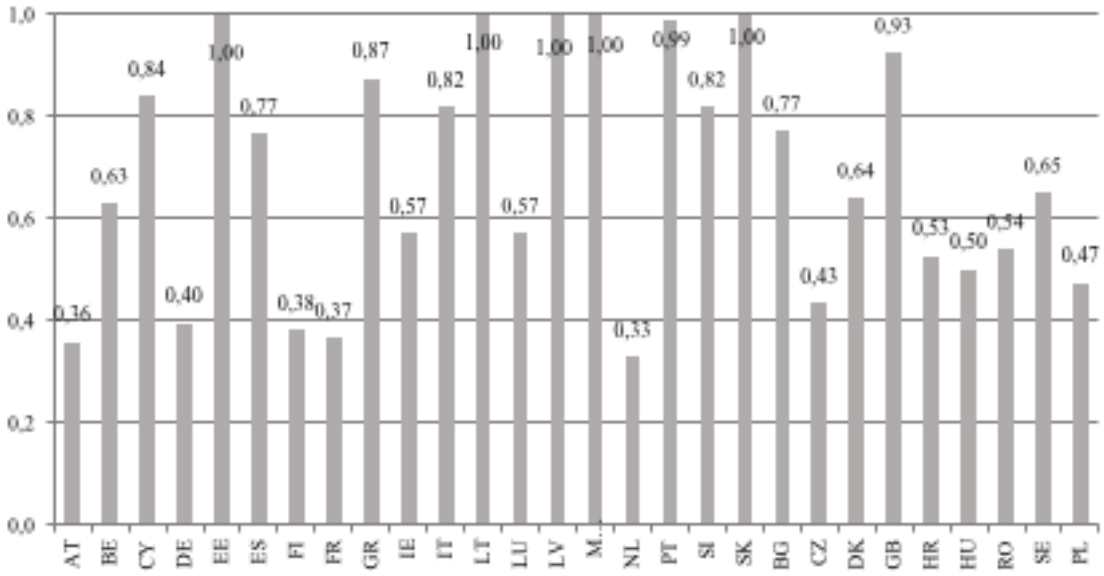


Source: ECB, BSI, authors' calculations.

When one considers the HHI, which measures the share concentration in the network, the riskiest lenders in 2016 Q2 were Greece, Latvia and Slovakia, while the least risky were Germany, Italy, Spain and the Netherlands (Fig.1). The borrowing countries presenting higher risks in 2016 Q2 were Cyprus, Estonia, Greece, Lithuania, Latvia, Malta, Slovenia, Slovakia

and Portugal for the euro area, and Bulgaria, Sweden and United Kingdom for the non-euro area (Fig. 2). The least risky borrowers in 2016 Q2 were Austria, Germany, Finland, France and the Netherlands.

Fig. 2: Concentration for borrowers



Source: ECB, BSI, authors' calculations.

Tab. 1: Summary statistics

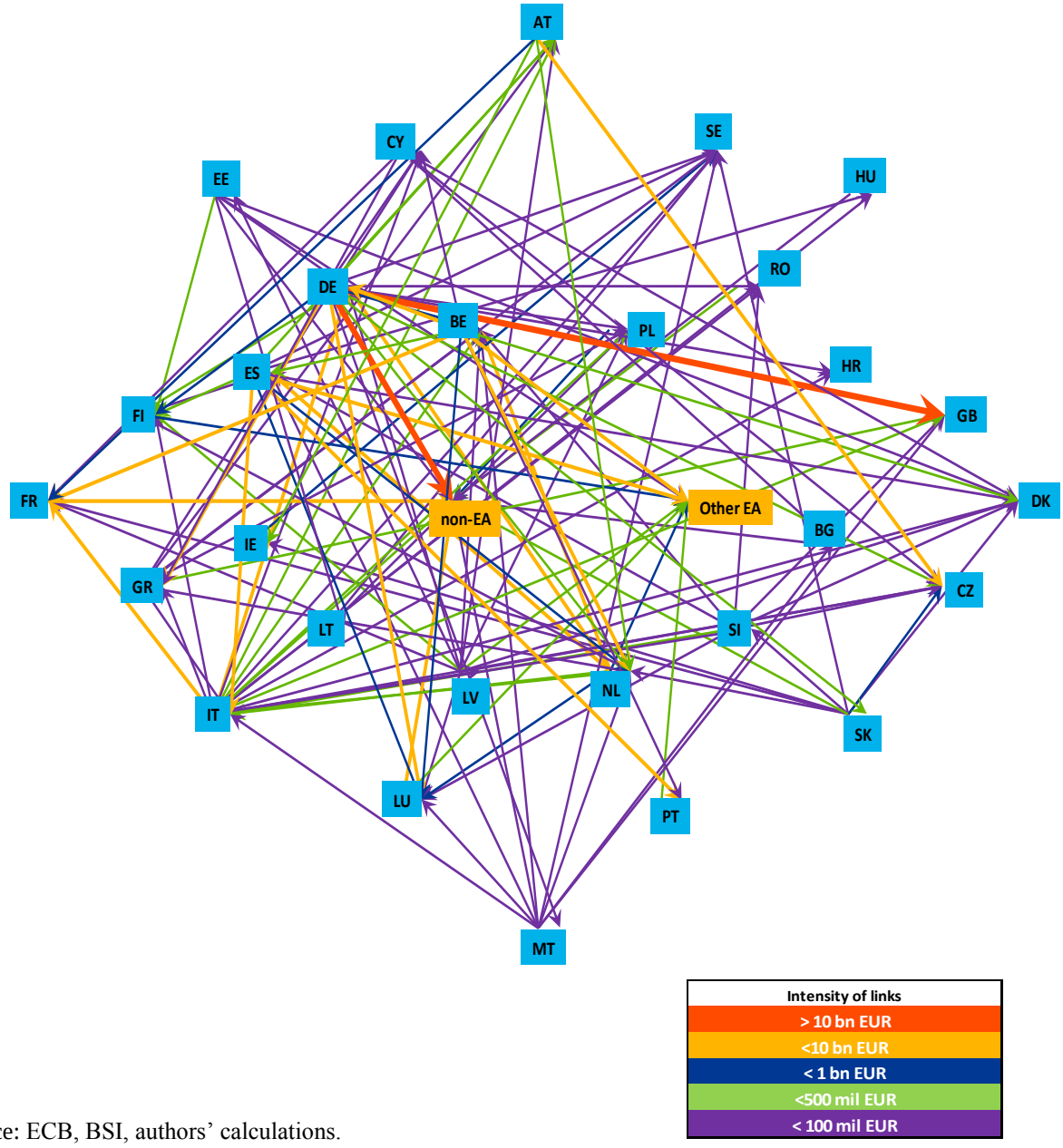
Indicator	2008 Q2					2016 Q2				
	Mean	Median	Standard deviation	Min	Max	Mean	Median	Standard deviation	Min	Max
In-degree (EU) (number of links)	5	5	2	0	10	4	5	2	1	9
Out-degree (EA) (number of links)	7	8	6	0	21	6	5	5	0	18
In-strenght (EU) (millions EUR)	3,333	1,232	4,753	0	22,716	2,239	687	3,431	2	12,711
Out-strenght (EA) (millions EUR)	4,911	938	8,116	0	26,255	3,299	372	5,604	0	21,245
In-HHI (EU) [0,1]	0.53	0.47	0.24	0	1	0.69	0.65	0.23	0.33	1
Out-HHI (EA) [0,1]	0.31	0.24	0.31	0	1	0.41	0.40	0.26	0	1

Source: ECB, BSI, authors' calculations.

Table 1 provides the summary statistics for the selected indicators for 2008 Q2 and 2016 Q2. The ones concerning *"flows-in"* are available for all selected countries, while those for *"flows-out"* are available for euro area countries only. Compared to 2008, the indicators shown in the table suggest a general reduction in cross-border lending across EU countriesin 2016. However,

the European financial systems are still highly interconnected and present high vulnerabilities and exposures to risks (Fig. 3). The network is constructed at European level, the banking sector (MFI) acting as the connecting element in the network.

Fig. 3: Cross-border linkages for EU Member States in 2016 Q2 *(flows, millions of EUR)*



Source: ECB, BSI, authors' calculations.

The network includes 30 nodes (EU Member States, "*other euro area countries*" and "*non-euro area countries*"). Two different nodes are connected to each other if there is a positive linkage stemming from lending or borrowing activities. Figure 3 presents the movements of positive international flows in 2016 Q2 (net repayments of loans were smaller than the new granted

loans). The intensity of the links is given by the colours used in the chart (see chart legend). Second quarter of 2016 is mostly characterized by transactions lower than 1 billion euro, with few exceptions, most of which were directed to the aggregated non-euro area. By selecting the second quarter of 2008 in the visualization tool, the situation looks different. The second quarter of 2008 is mainly characterized by transactions higher than 1 billion euro and in some cases, even higher than 20 billion euro. The comparison between 2008 and 2016 shows the high reduction of MFI granted cross-border loans between 2008 and most recent period. We have also looked at the stocks of total loans in 2016, which include both old loans (non-performing loans or open loans) and the new loans. In this case, the European financial system as a whole presents a higher interconnectivity, as, even though the flows of new granted loans have decreased in the post-crisis period, the stocks of total loans still record high levels, as, either the loans did not reach full maturity or the borrowing countries might have faced financial constraints in repaying back the loans according to the initial contract terms.

Conclusions

The harmonization of teh financial supervision and regulation at European level plays a key role in ensuring financial stability and in setting the basis for recovery and growth across the European countries. Our paper focuses on cross-border financial linkages for EU Member States. We present the financial interlinkages in a network framework, constructed via a visualization tool which facilitates the quarterly representation of the cross-border financial flows for time frame 2007 – 2016. The results show that the European financial systems are strongly interconnected, which means that the banking system in any country can be affected, to different extents, by shocks stemming from any banking system in any other country in the network. Notwithstanding, there is a large variability in terms of intensity in the propagation of shocks across EU countries, depending on the level of connectedness between any two different countries. In conclusion, we use network techniques to spot financial vulnerabilities and potential for spillovers at an early stage. Our results confirm the importance of understanding the implications of the from-whom-to-whom flow of funds movements and cross-border exposures and are relevant for financial stability and supervision policy makers.

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