How to Measure Interconnectedness between Banks, Insurers and Financial Conglomerates?*

Gaël Hauton[†] Jean-Cyprien Héam[‡]

Preliminary Version
(October 2014)
All comments are welcome.

Abstract

Financial institutions' interconnectedness is a key component of systemicity. However there is still no consensus on its measurement. Using a unique dataset of network of exposures of French financial institutions, we compare three strategies to measure interconnectedness that are the statistical closeness of exposure distributions, the identification of topological structures and thte measures derived from contagion models. These alternative methods are able to account for different characteristics of institutions' interconnectedness such as substituability and integration, systemic importance and systemic fragility. First, we show that contagion-based methods are the most suited to capture systemic fragility, emphasizing their importance as a supervisory tool. Then, applying these methods to the French network, financial conglomerates appear to deal with large volumes of assets. But once size is accounted for, their pivotal role can no longer be detected. This result calls for a supervisory assessment of interconnectedness immune to size considerations.

Key words: Interconnectedness; Financial Institutions; Insurers; Conglomerate; Systemic Risk.
JEL Code: G22, G28.

The opinions expressed in the paper are only those of the authors and do not necessarily reflect those of the Autorité de Contrôle Prudentiel et de Résolution (ACPR).

*We thank Olivier de Bandt, Monica Billio, Serges Darolles, Dominique Durant, Laure Frey, Henri Fraisse, Sarah Gandolphe, Christian Gouriéroux, Anne-Laure Kaminski and participants to ESRB-ATC Workshop on Stress-Test (Frankfurt, 2014) and 7^{th} Risk Forum (Paris, 2014), 14^{th} CREDIT Conference (Venise, 2014) for their helpful comments. This paper has also benefited from the excellent research assistance of Farida Azzi.

[†] Autorité de Contrôle Prudentiel et de Résolution (ACPR). gael.hauton@acpr.banque-france.fr

[‡] Autorité de Contrôle Prudentiel et de Résolution (ACPR) and CREST. *Corresponding Author.* jean-cyprien.heam@acpr.banque-france.fr

Résumé long :

L'interconnexion ("interconnectedness" en anglais, parfois traduit "interconnectivité") des institutions financières est considérée comme une composante fondamentale de leur systémicité, en particulier par les régulateurs. Cette dimension intervient explicitement dans les méthodologies d'identification des Institutions Financières Systématiquement Importantes (SIFIs en anglais). Néanmoins, aucun consensus sur la manière de mesurer l'interconnexion n'a emmergé. En analysant une base de données unique sur les expositions bilatérales bilancielles entre 21 banques, compagnies d'assurances et conglomérats français, nous comparons trois stratégies de mesure de l'interconnexion : la proximité statistique des distributions des expositions, l'identification de structures sous-jacentes au réseau financier et l'utilisation de modèles de contagion. Ces méthodes permettent d'identifier différentes composantes de l'interconnexion d'une institution financière : la *substituabilité* qui rend compte du caractère spécifique du profil des expositions, l'*intégration* qui représente la participation d'une institution au réseau, l'*importance systémique* qui indique le risque de contagion généré par l'institution et la *fragilité systémique* qui mesure l'exposition de l'institution au risque de contagion. Premièrement, nous montrons que les modèles de contagion sont les seules techniques capables d'identifier les institutions systémiquement fragiles. Ces techniques sont donc un outil irremplaçable de supervision. Ensuite, nous utilisons ces techniques pour analyser les spécificités du réseau financier français. Les trois méthodes indiquent toutes que les conglomérats financiers sont des institutions très particulières, intervenant dans le réseau financier via d'importants volumes d'actifs. Cependant, leur rôle de pivot entre le secteur bancaire et le secteur des assurances s'atténue lorsque nous contrôlons ces techniques par la taille des établissements. En termes de supervision, nos résultats soulignent l'importance d'une distinction nette entre le facteur taille et le facteur d'interconnexion dans l'identification d'institutions systémiques.

Mots-clefs: interconnexions, institutions financières, assureurs, conglomérats, systémique.
Code JEL: G22, G28.

Les opinions exprimées dans cet article sont celles de l'auteur et ne réflètent pas nécessairement celles de l'Autorité de Contrôle Prudentiel et de Résolution (ACPR).

1 Introduction

The danger stemming from interconnections between financial institutions has been highlighted during the last financial crisis with the defaults of AIG, Lehman-Brothers or Bear Stearns... Interconnectedness between financial institutions has nowadays become a major concern for supervisors and regulatory authorities. With the support of the G-20, Financial Stability Board FSB (2009) propose a general framework to identify Systematically Important Financial Institutions (SIFIs). The three key criteria are the size (the volume of financial services provided by the individual component of the financial system), the substituability (the extent to which other components of the system can provide the same services in the event of a failure) and the interconnectedness (i.e. linkages with other components of the system). These three criteria cannot be assessed separately for each institution. They require a system-wide analysis.

This general framework to identify SIFIs has been specified separately for banks and for insurance companies. For Global Systematically Important Banks (G-SIBs), the Basel Committee [see BCBS (2013a)] uses a score based on the average of 5 indicators: the cross-jurisdictional activity (20%), the size (20%), the interconnectedness (20%), the substituability (20%) and the complexity (20%). Considering interconnectedness is motivated by the fact that "financial distress of one institution can materially increase the likelihood of distress at other institutions given the network of contractual obligations in which these firms operate". For Global Systematically Important Insurers (G-SIIs), the International Association of Insurance Supervisors [see IAIS (2013)] uses 5 indicators that are the size (5%), the global activity (5%), the interconnectedness (40%), the non-traditional and non-insurance activity (45%), the substituability (5%). For G-SIBs, the regulation of interconnectedness is currently under debate. Basel Committe [see BCBS (2013b)] proposes to limit interbank exposures between G-SIBs to 10% and 15% of capital whereas the current limit is 25%.

The identification of G-SIBs and G-SIIs puts a premium on interconnectedness that counts for 20% (respectively, 40%) of the whole systemic score for banks (resp. insurance companies). Interconnectedness is in particular measured by the "intra-financial system assets" and "intra-financial system liabilities". Measuring these indicators as well as the limiting exposures between G-SIBs require to be able to chart the network between financial institutions. The first challenge is to identify all financial counterparts in the balance sheets. An official identification of all institutions is under progress at a global level [see FSB (2012)]. At a given date, an international financial group is usually composed of several hundreds of subsidiaries. The number of subsidiaries, their names and their structures evolve overtime. The second challenge is to run an accurate analysis. Exposures between financial institutions are manifold: through the on-balance sheet (loans, debt securities, share securities...), through the off-balance sheet (guarantee, credit line, derivatives...), through commercial partnerships... Understanding how complex groups organize their different activities provides sound arguments for debates on universal banking and financial conglomerates [Fanto (2011)]. The intra-group organization is connected to industrial organization theory or corporate finance as well as to supervisory concerns [Van Lelyveld and Schilder (2003)].

In addition to the SIFIs regulation, the interconnections between banks and insurance companies are also addressed. Basel 2 and 3 regulations provide a specific treatment for shares issued by insurance companies. They are deducted in the computation of the regulatory capital. Moreover, in Europe, a specific regulation of financial conglomerates[1] exists [OJEU (2002)]. In top of complying to the banking and insurance regulations, the whole activities of financial conglomerates are supervised through capital adequacy requirements.

The objective of our paper is to understand and to assess the impact of interconnections between financial institutions. The many interpretations of interconnectedness have led to different measurement methods. We analyze their similarities and discrepancies in order to identify what each method really measures.

Our paper has three main contributions. First, we document interconnections between different financial institutions (banks, insurance companies and financial conglomerates) using a unique dataset on bilateral exposures across 21 French financial institutions. Second, we propose simple statistical methods to disentangle two features of interconnectedness that are the substituability (*i.e.* the similarity of lending relationship) and the integration (*i.e.* the degree of involvement in the network), respectively. Last but not least, we compare three main methods to measure interconnections that are statistical methods, topological structure identification and contagion risk assessments. We show that these measures are complementary and we explain their discrepancies. In particular, we suggest that the structural analysis is mainly driven by size.

The paper is organized as follows. Section 2 reviews the literature on interconnections between financial institutions and on the analysis of financial conglomerates. Section 3 describes the database with summary statistics and introduces substituability and integration measures. Section 4 measures the gap between the observed situation and stylized networks. In Section 5, contagion risk is assessed by a network stress-test. Section 6 concludes.

2 Literature Review

2.1 Theoretical insights on interconnections

Basic economics suggest different interconnection profiles for banks and insurance companies. On the one hand, the core activity of banking is maturity transformation and

[1] For clarity, we adopt the continental European vocabulary, contrasting with the Anglo-Saxon practice. From an Anglo-Saxon point of view, a conglomerate, sometimes called "universal bank", is a bank combining pure banking activity (collecting deposit and granting loans) and securities activities (investment). In this paper, we do not distinguish commercial banking activity from securities activities. We distinguish banking activity that encompasses commercial banking activity and securities activities from insurance activities. Therefore, a conglomerate is a group with banking and insurance activities. European Directive 2002/87/EC defines the supervisory features concerning financial conglomerates.

screening. The maturity transformation mechanism leads banks to borrow partly from other financial institutions and to invest in (typically) non-financial institutions. On the other hand, insurance companies –either life or non-life– are expected to lend to other financial institutions since their liabilities are composed of commitments to the policyholders. They invest the proceeds of the policyholder's premium, notably in financial institutions.

Several motives have been put forward by the literature to explain interconnections between financial institutions leading to different forms of exposures, either on- or off-balance sheet. Let us review few of them.

i) Liquidity. In a short-term perspective, interconnections mirror the resolution of the liquidity needs. One solution to this asynchronism of in-flows and out-flows is that every institution keeps its own cash buffer. This individual solution leads to a very large overall cash buffer: at any time each institution holds cash whereas only few cash buffers are used. Another solution is cooperation which holds in normal times (as opposed to "crisis time"): when liquidity shocks do not impact simultaneously all the institutions, a liquidity pool is a sound tool [Holmstrom and Tirole (1998), Rochet (2004), Tirole (2010)]. Liquidity pools enable institutions to form a mutual insurance system for liquidity risk. Each institution slightly contributes to a common cash reserve that is used to cover the needs for liquidity. When liquidity shocks are small and homogenously distributed, the contributions in cash are smaller than the individual cash buffers. This mechanism has been developed in corporate finance. It has been applied to financial networks by Allen and Gale (2000), who analyze optimal network structure according to the characteristics of liquidity shocks. More recently, Acemoglu et al. (2013) extend this approach to the renegotiation of loans.

ii) Horizontal integration. Industrial organization theory points horizontal integration since Banks and insurance companies share the same customer population (households and firms). This horizontal integration can be illustrated considering a household looking for a home. The household contracts a credit loan from a bank to buy its house. In order to be hedged against unemployment or death, the household seeks (or is legally forced to seek) an insurance policy. Of course, the insurance contract can be closed independently from the credit loan. However, the bank and the insurance company have incentive to collaborate with sharing information and resources to have a more efficient screening and pricing process. This horizontal integration leads to revenue enhancement and cost savings [Berger and Ofek (1995), Van Lelyveld and Schilder (2003)]. It is not unusual that the credit officer proposes jointly to the credit an insurance contract issued by a partner insurance company. The credit officer get a commission on all the insurance contracts he sells. Depending on the degree of (horizontal) integration, this motive can lead to mergers [Gollier and Ivaldi (2009)], to financial conglomerates or to interconnections between financial institutions from different market segments. When considering interconnections, this type of commercial relationships has no impact on the balance-sheet since commissions received by the bank on the insurance policies it sells are rather flows than stocks. However, the commission scheme results in moral hazard issues. Explicit balance sheet interconnections, such as cross share holding, is one way to avoid free-riding.

iii) Vertical integration. Industrial organization also points out vertical integration as regard risk transfers between financial institutions. Reinsurance is and securitization are another well-known risk transfer mechanism. Subramanian and Wang (2013) model the optimal strategy of an insurer to deal with its tail risks. The insurer combines self-insurance, re-insurance and securitization. The model underlines the trade-off between transferring tail risks and signaling a risky portfolio. More generally, off-balance sheet instruments (such as guarantee or credit commitment) and hedging derivatives (CDS for instance) are also a support of vertical integration. Generally speaking, risk transfer generates mostly off-balance sheet interconnections. In a particular way, the liquidity motive can be seen as a specific both-way vertical integration (whereas usual vertical integration is unidirectional).

iv) Diversification. Competition in markets where financial institutions is operating (mortgage, loans, life-insurance, car insurance...) do not necessarily take place in pure and perfect. Some institutions can be leader in niche markets. It may be easier to buy some shares or bonds on the secondary markets issued by one "niche" institution than overcome the entry barrier to the niche market. This diversification motive is a plausible explanation for on-balance sheet exposures between financial institutions [see Héam and Koch (2013)).

2.2 Empirical evidence of interconnections

Data confidentiality on bilateral exposures between financial institutions makes empirical analysis sparse. Consequently, academics propose other approaches to assess the interconnections within the financial sector. Three major strands of literature can be identified.

First, banking supervisors propose empirical analysis of interconnection between banks using structural models to assess contagion risk between banks: Furfine (2003) for USA, Wells (2002) for UK, Upper and Worms (2004) for Germany, Lublóy (2005) for Hungary, van Van Lelyveld and Liedorp (2006) for the Netherlands, Degryse and Nguyen (2007), Toivanen (2009) for Finland, Gauthier et al. (2012) for Canada, Mistrulli (2011), Fourel et al. (2013) for France. These empirical analysis draw various stylized facts for national banking sectors. A core-periphery structure is usually identified. Banks are gathered in two distinct groups that are the core and the periphery. The core banks are fully interconnected between themselves, while peripheral banks are linked only to core banks [Craig and Von Peter (2014)]. The core banks are interpreted as financial intermediaries while peripheral banks are either borrowers or lenders. Additionally, network stress-tests show little evidence of (solvency) contagion. Along these lines, Alves et al. (2013) carry out the analysis on 53 major European banks: the network tends to be more complete, contrasting somewhat with the core-periphery structure at a national level, while also contagion is limited.

Second, some authors study the impact of insurance sector on the re-insurance sector. Using aggregate data on balance-sheet of US insurers and re-insurers, Cummins and Weiss (2014) assess the potential contagious channel for different activities (core-activity, life-insurance, banking activity...). They conclude that "life insurers are vulnerable to intra-sector crises; and both life and property-casualty insurers are vulnerable to reinsurance crises". With bilateral exposures between insurers and re-insurers, Frey et al. (2013) examine the interconnectedness between French insurers and re-insurers. Contrary to the network analyses on banks that consider usually on-balance sheet items (in particular, loans), Frey et al. (2013) focus on provisions ceded between solo entities. They find preliminary results regarding the good resilience of the network but suggest additional investigations.

Third, due to the confidentiality on individual data, several research papers investigate the relationships between publicly traded equity returns. This approach gives interesting insights on the degree of interconnections between financial institutions as perceived by market participants. Of course, this network inferred from market data can differ from structural networks. A first way to go is to interpret simultaneous abnormal returns as contagious phenomenon underlying interconnections. Minderhoud (2003) finds "evidence of contagion for the US, Germany and the UK [and that] this result is stronger for the insurance sector than for the banking sector" by exploiting extreme stock return co-movements. Event studies for contagion between banks and insurers, such as Brewer and Jackson (2002) for US or Stringa and Monks (2007), present contrasted results. More recently, Billio et al. (2011) proposed to infer a network between financial institutions based on Granger causality test. Intuitively, there is a link from institution i to institution j when the returns of institution i have a direct impact on the returns of institution j. This approach leads the authors to analyze a time series of networks. Among other results, they show that the network structure is unstable.

Our paper clearly builds on the first field since we use similar data-set and structural models as well. However, we extend the methodology to a broader set of institutions by taking into account insurers. Our results can be put in contrast with the second and third strands.

3 Data

In this section, we present the perimeter (institutions, instrument, date) and report summary statistics on exposures. We derive the raw exposures into few risk indicators. Last, we define and measure two dimensions of interconnectedness which are integration and substituability.

3.1 Perimeter

We select 21 large French financial institutions, that are representative of the French financial sector. Among the 21 institutions, 6 of them (BNP, Crédit Agricole, Société Générale, BPCE, Crédit Mutuel and La Banque Postale) are financial conglomerates; 4

of them (HSBC, Crédit Logement, CRH and Oseo) are considered as pure banks and 11 of them (AG2R-La Mondiale, Aviva, Axa, Allianz, CNP, Generali, Groupama, Covea, Maif, Macif and Scor) are considered as pure insurance companies. The analysis is carried out at 12/31/2011. The selected banking/conglomerate institutions account for about 90% of the total assets of the French sector while the selected insurers represent about 85% of the total assets of the French sector. For confidentiality restriction, financial institutions are not identified hereafter.

All institutions are considered at a full consolidated level gathering all activities and geographical areas. Pure banks (hereafter "PB") are institutions with no significant insurance activity, whereas pure insurers (hereafter "PI") are institutions with no significant banking activity. Conglomerates (hereafter "CG") are institutions with significant insurance activity and significant banking activity. Conglomerates represent about half of the sector in terms of total equity while pure banks and pure insurers account for a quarter each (Figure 1). The conglomerate population presents more heterogeneity than the insurance population. Pure bank population is very heterogeneous with a key global bank and small domestic banks (. The banking sector (hereafter "BS") –encompassing pure banks and banking sub-groups of conglomerates– represents about two thirds of the whole financial sector while the remainder is accounted by the insurance sector (hereafter "IS") –gathering pure insurer and the insurance sub-groups of conglomerates–.

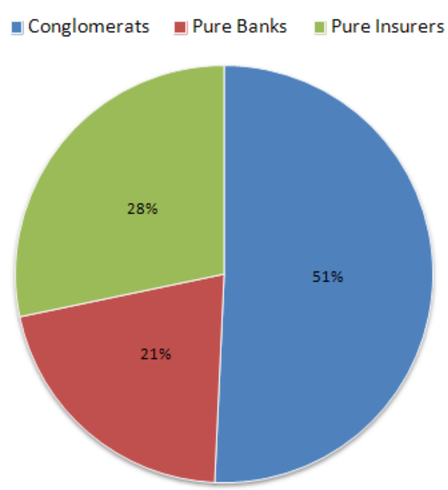


Figure 1: Repartition of Total Equity between Conglomerates, Pure Banks and Pure Insurers. 12/31/2011

The exposure matrices are built on regulatory reports on "Large Exposures" for banks (pure banks and banking subsidiaries of conglomerates) and "TCEP" reports for insurers. On the one hand, the Large Exposures reports gather all exposures at a consolidated level larger than 300MEuros (or 10% of capital). Since we consider only major players in the financial sector, we are confident that the censoring has little impact. On the other hand, TCEP is exhaustive (security-by-security basis) but only exposures of French subsidiaries are reported. This censoring is more pregnant for international groups (such as Axa, Allianz, Aviva or Generali) than for domestic-centered groups. Therefore, the data we analyze is underestimating exposures between financial institutions (for more details, see Appendix A).

In terms of instruments, we gather on-balance sheet exposures composed of shares securities, equity investments, participation, loans, debt securities... Excluding off-balance sheet exposures and derivatives exposures may imply that we fail to capture approximately one third of the total exposures [see Table 1 in Alves et al. (2013), 2013]. The exposures are on-balance sheet items gathered in two classes, according to the Value-of-the-Firm by Merton (1974). In Merton's model, two classes of stakeholders are distinguished: shareholders who are granted the net value of asset over nominal debt, and creditors who owns the debt. This partition corresponds to a risk decomposition: shareholders hold more risky assets than creditors. To mirror this decomposition, the first class is composed of all instruments corresponding to equity (shares, capital investments, participation...) while the second class is composed of all instruments corresponding to debt (debt securities, subordinated debt, borrowing...). For simplicity, the first class is called "shares" and the second class is called "debt securities". When the reporting institution is an insurer, the latter class is almost only composed of debt securities, which represent a small fraction of the total debt that is mostly composed of mathematical provisions (commitments to policyholders).

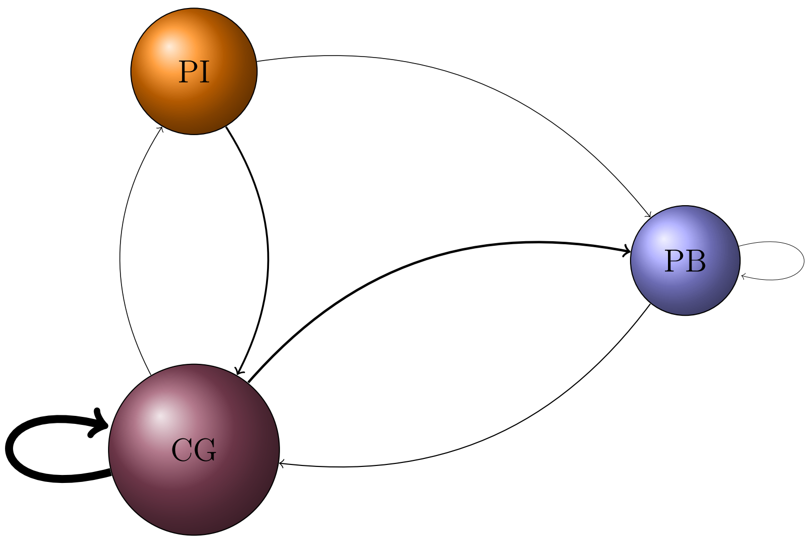
Thus we build two exposure matrices, one for shares and one for debt securities, between the 21 nodes representing the financial institutions. Summing these two matrices element by element, we get a total exposure matrix.

3.2 Summary statistics of extra-group exposures

In this part, we focus on extra-group exposures. We analyze firstly the distribution of total exposures between nodes according to their legal status (Conglomerate/Pure Bank/Pure Insurers). We complete the picture by examining activities (banking/insurance) and instruments (shares/debt securities). These steps lead to several stylized facts characterizing the financial network.

3.2.1 Conglomerates/pure banks/pure insurers breakdown

The 21 financial institutions report a total of 227 GEuros. Table 1 reports the exposures distinguishing between conglomerates, pure banks and pure insurance companies. Reading column "All institutions", the distribution of exposure between the 21 nodes has an average of 0.5 GEuros and a standard-deviation of 1.2 GEuros showing an important dispersion. This feature remains true when considering the partition CG/PB/PI. The last third columns "Conglomerates", "Pure Banks" and "Pure Insurers" show the breakdown by the status of the counterpart. The CG-CG exposures are the most important with an average of 3 GEuros. The exposures of CG to PB and the exposures of CG to PI have similar size (0.9 GEuros and 0.3 GEuros in average respectively) but these are much smaller than the exposures between CG. PB are almost only exposed to



Legend: Node size is proportional to the total equity, edge width is proportional to exposure.

Figure 2: Three-Sector Network (all instruments). 12/31/2011

CG: they are not lending to each other or to PI. PI are not exposed between themselves but are exposed mostly to CG, and to PB to a lesser extent. Figure 2 represents the network with three nodes "Conglomerates", "Pure Banks" and "Pure Insurers".

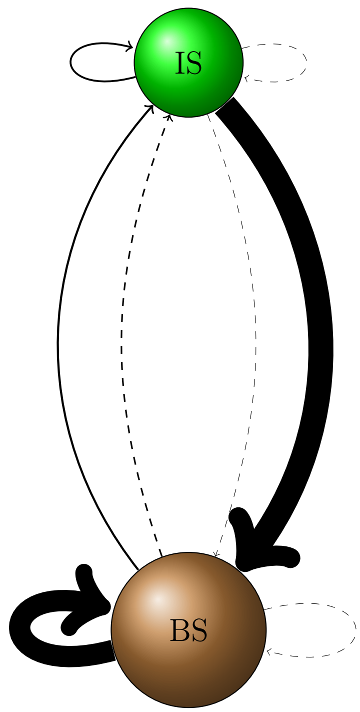
	Exposures (GEuros)		*to:* All Institutions	Conglomerates	Pure Banks	Pure Insurers
of:	All institutions	av	0.5	1.3	0.4	0.1
		sd	1.2	2.0	0.8	0.4
	Conglomerates	av	1.2	3.0	0.9	0.3
		sd	2.0	2.8	1.0	0.7
	Pure Banks	av	0.1	0.4	0.1	0.0
		sd	0.4	0.6	0.2	0.0
	Pure Insurers	av	0.3	0.7	0.3	0.0
		sd	0.6	1.0	0.6	0.1

Legend: "$f-m-t$" means that first quartile is x, the median is y and the third quartile is t.
Note: The average exposure of one conglomerate to another conglomerate is in average 3.01 GEuros with a standard deviation of 2.77 GEuros.

Table 1: Descriptive Statistics of Extra-group Exposures breakdown by CG/PB/PI (all instruments). 12/31/2011

3.2.2 Banking/insurance activity and instrument breakdown

Exposures breakdown by type of activity and instrument are reported in Table 2. Debt securities class, that includes also loans, is the main instrument representing about 91% of total exposures. 88% of exposures correspond to funding to the banking sector. In particular, the insurance sector is a (net) fund-provider of the banking sector with 87



Legend: Node size is proportional to the total equity, edge width is proportional to exposure. Dashed lines represent shares while solid lines represent debt securities.

Figure 3: Activity Network. 12/31/2011

Geuros composed for 98% of debt securities. Figure 3 represents the network with the two sectors and the two instruments.

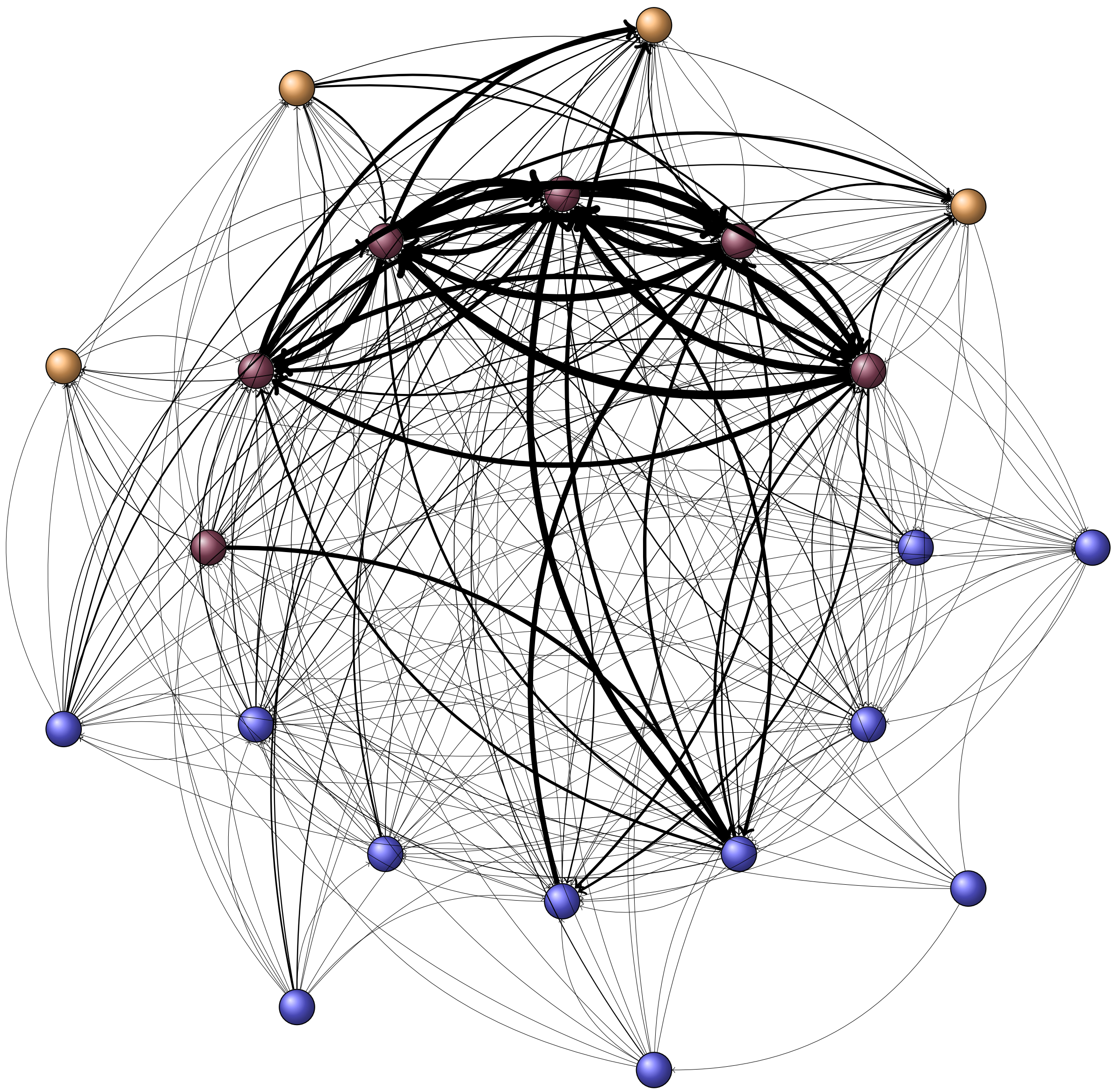
	Debt Securities		Shares		Total Exposures	
(GEURO)	BS	IS	BS	IS	BS	IS
Overall	174	15	10	8	184	24
BS	80	8	2	6	82	15
IS	94	7	8	2	102	9

Note: The total exposures of the banking sector to the insurance sector through debt securities 8GEuros.

Table 2: Descriptive Statistics of Total Extra-group Exposures breakdown by Activity and Instrument. 12/31/2011

3.2.3 Stylized facts

The previous analysis helps us draw four stylized facts. First, debt securities account for more than 90% of total exposures. Second, conglomerates are the most usual counterparts: almost all exposures involve at least one of them. Third, there are net funding flows from the insurance sector to the banking sector; net flows and flows internal to the banking sector have similar size. Fourth, pure banks are not exposed to pure insurance whereas pure insurers fund pure banks (besides conglomerates).
Figure 4 represents the network of total exposure on a fully-consolidated basis.



Legend: Node color indicates legal status (red for conglomerates, blue for pure insurers and yellow for pure banks), edge width is proportional to exposure.

Figure 4: Network of French financial institutions on a fully-consolidated basis for total exposures. 12/31/2011

3.3 Risk profile

Let us now introduce indicators to assess the riskiness of financial institutions with respect to their interconnections. First, a set of indicators at the institution level are presented in a microprudential perspective. Then, we aggregate them to build risk indicators at the network level, *i.e.* from a macroprudential perspective.

The risk profile is characterized along three dimensions. First, the exposure matrices describe how much and from whom and to whom a financial institution is lending or borrowing. This lending/borrowing role is a first feature to capture. Then, we focus on risks. An exposure is a relationship between two financial institutions: for the owner the exposure is an asset whereas for the issuer the exposure is a liability. For an asset, it is natural to consider it from a credit risk perspective. For a liability, the risk is related to funding issues. Therefore the same exposure falls into a credit risk and a funding risk that cannot be mixed. The credit and funding risks are the last two dimensions we used to characterized risk profile.

3.3.1 Microprudential risk indicators

To properly define the risk indicator we introduce the following notations. E^K is the share exposure matrix: $E^K_{i,j}$ is the exposure composed of shares from institution i to institution j. Similarly, E^L is the exposure matrix for debt. The total exposure matrix is $E^T = E^K + E^L$. Moreover, the equity (respectively nominal debt) of institution i is denoted K_i (respectively L_i). For the sake of simplicity, indicators are presented for the Total Exposures. Extensions to share and debt security exposures are straightforward.

i) Lender-Borrower Balance

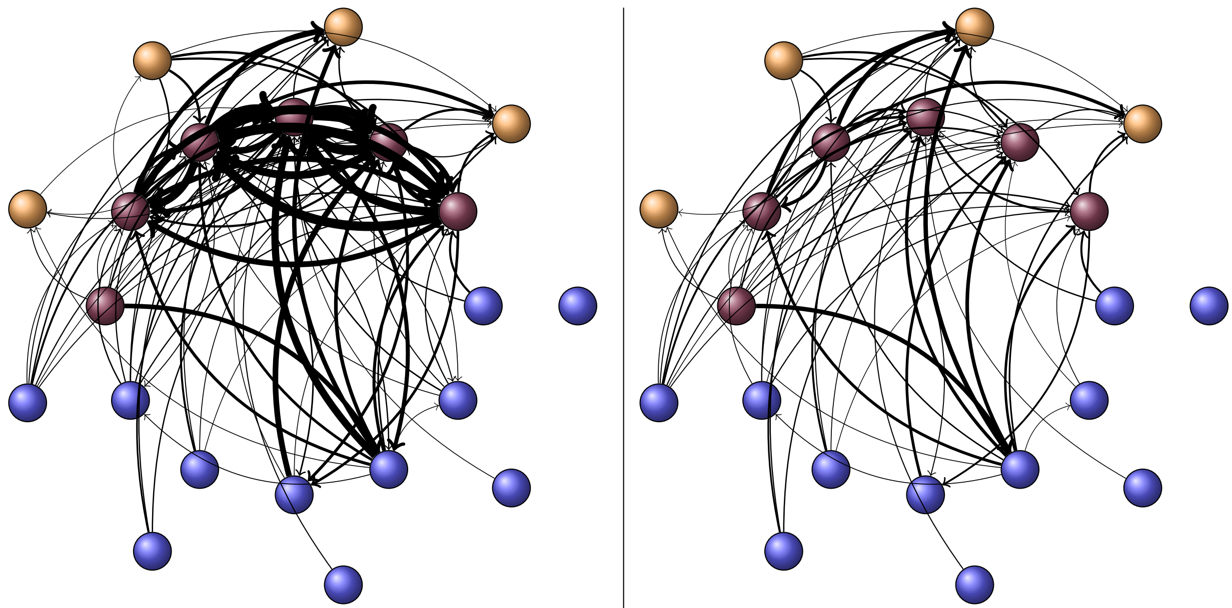
The first characterization is the "lender-borrower balance" (hereafter "LBB") defined as the net aggregating exposition of an institution:

$$LBB^T_i := \sum_{j=1}^{n} E^T_{i,j} - \sum_{j=1}^{n} E^T_{j,i}.$$

A positive LBB indicates that the financial institution is a net lender to the network whereas a negative LBB indicates that the financial institution is globally funded by other financial institutions. Among the 21 financial institutions, 12 are net lenders. 1 (out of 4) pure banks is a net lender while 9 (out of 11) pure insurers are net lenders. 2 (out of 6) conglomerates are net lenders confirming the importance of their banking activity. Looking from a sector perspective, only 2 banks (out of 10) are net lenders while 15 (out of 16) insurers are net lenders. As a matter of facts, we verify that, according to intuition, insurers are net lenders while banks are net borrowers. The LBB position analysis is completed by comparing the network of bilateral exposures and the network of net exposures (see Figure 5).

ii) Credit Risk and Funding Risk

To assess the credit risk, the exposure can be divided by the total equity of the investing



Bilateral Exposures over 500MEuros | Net Exposures over 500MEuros

Figure 5: Network of French financial institutions on a fully-consolidated basis for bilateral and net total exposures (over 500MEuros). 12/31/2011

institution, since the equity of the investor is the buffer absorbing a potential loss. Applying this operation to the exposure matrix E^T, we define a credit risk matrix denoted $CR^T = E^T_{i,j}/K_i$. To measure the credit risk at an institution level, we analyze the lines of matrix CR by considering basic statistics such as quartiles, average.... The median can be read as a Value-at-Risk at 50%. It helps us define what is a large exposure for the credit risk of the considered institution. Let us denote qCR_i and μCR_i the median and average of the credit risk of institution i:

$$qCR_i^T := \text{median}\left\{CR^T_{i,j}, \quad j = 1, ..., n \ \ / \ \ CR^T_{i,j} > 0\right\},$$
$$\mu CR_i^T := \text{average}\left\{CR^T_{i,j}, \quad j = 1, ..., n \ \ / \ \ CR^T_{i,j} > 0\right\}.$$

The considered set of exposures excludes exposures at 0 in order to enhance robustness. For funding risk, we propose to compare these exposures to equity.[2] We denote $FR^T_{i,j} = E^T_{j,i}/K_i$. As for the credit risk, we analyze the lines of matrix FR considering the median and the average and denote qFR_i and μFR_i the corresponding measures of the funding risk of institution i:

$$qCF_i^T := \text{median}\left\{CF^T_{i,j}, \quad j = 1, ..., n \ \ / \ \ CF^T_{i,j} > 0\right\},$$
$$\mu CF_i^T := \text{average}\left\{CF^T_{i,j}, \quad j = 1, ..., n \ \ / \ \ CF^T_{i,j} > 0\right\}.$$

Table 3 reports the median over the 21 groups of some micro-prudential indicators. For instance, an average exposure represents 3.5% of the total equity of the lender and

[2]In an ideal world, we would define the funding risk as the ratio of the exposure over the liquid assets. Liquid asset are expected to be used to pay the debt that is not rolled over. However, defining and identifying liquid assets is clearly out of scope of this paper.

1.46% of the total equity of the borrower. Comparing the quartiles, the distributions of credit risk and funding risk have fat (right) tails.

	Credit Risk	Funding Risk
1^{st} quartile	0.48%	0.29%
Median	1.30%	0.78%
4^{st} quartile	6.60%	1.99%
Average	3.50%	1.46%
Standard deviation	4.46%	1.60%

Table 3: Median over the population of micro-prudential indicators on total exposure (CR^T et FR^T). 12/31/2011

3.3.2 Macroprudential risk indicators

The indicators we derived in a microprudential perspective can be adapted to a macro-prudential framework. For credit and funding risks, the definitions extend easily by considering the whole set of exposures instead of the previous line by line analysis:

$$\begin{aligned}
qCR^T &:= \text{median}\left\{CR^T_{i,j}, \quad i,j = 1,...,n \ \ / \ \ CR^T_{i,j} > 0\right\}, \\
\mu CR^T &:= \text{average}\left\{CR^T_{i,j}, \quad i,j = 1,...,n \ \ / \ \ CR^T_{i,j} > 0\right\}, \\
qCF^T &:= \text{median}\left\{CF^T_{i,j}, \quad i,j = 1,...,n \ \ / \ \ CF^T_{i,j} > 0\right\}, \\
\mu CF^T &:= \text{average}\left\{CF^T_{i,j}, \quad i,j = 1,...,n \ \ / \ \ CF^T_{i,j} > 0\right\}.
\end{aligned}$$

Table 4 reports these indicators at 12/31/2011. The funding liquidity risk seems to be more salient than credit risk: the average funding risk is 26.7% while the average credit risk is 7.7%.

	Credit Risk	Funding Risk
1^{st} quartile	0.2%	0.3%
Median	1.5%	0.9%
4^{st} quartile	8.7%	3.2%
Average	7.7%	26.7%

Table 4: Macro-prudential risk indicators (CR^T and FR^T). 31/12/2011

3.4 Substituability and integration

Descriptive statistics and risk indicators are useful to understand the exposures between institutions. However, they would be overly basic indicators of interconnectedness. In this section, we discuss and propose a framework to model two features of interconnection that are *substituability*[3] and *integration*, respectively. First, we consider that each institution can be characterized by a specific profile of interconnectedness. Should

[3]Here substituability is the substituability within the network. This notion differs from the substituability item in the IAIS guideline to identify G-SIIs. For IAIS, substituability concerns the specificity of the services provided by insurer to the real economy.

this institution go to default, several partners will face difficulties to meet substitutes. In a supervisory perspective, attention must be paid to an institution with low substituability in terms of interconnections. A second dimension of interconnectedness is integration. Integration is linked but not reduced to the volume of exposures. Institution X is more integrated to the network than institution Y when institution X tends to lend more than institution Y. To illustrate the difference between these two dimensions, we consider the following toy examples of exposures:

$$\begin{aligned} X &= (2.1 \ ; \ 3.2 \ ; \ 5.0)\,, \\ Y_1 &= (2.2 \ ; \ 3.3 \ ; \ 5.0)\,, \\ Y_2 &= (5.1 \ ; \ 2.1 \ ; \ 3.3)\,. \end{aligned}$$

Institution X and institution Y_1 are considered close in terms of substitutability and in terms of integration: they lend similar volumes to the same counterparts. In contrast, institution X and institution Y_2 are close in terms of integration but distant in terms of substituability: they lend similar volumes but not to the same counterparts.

These two components of the interconnectedness can be derived in terms of total gross (or volume) exposures (E^T), credit risk exposures (CR^T) and total funding risk exposures (FR^T). As before, running these three parallel flows enable us to control our results for size.

3.4.1 Methodology

First, we analyze the substituability between institutions by measuring similarity between their their bilateral exposures to the rest of the network. Let us consider for instance institution i_0 and institution i_1 and the total gross exposures. We apply Wilcoxon's signed rank test to

$$X = \big(E^T(i_0,1), \ldots\ E^T(i_0,i_1-1), E^T(i_0,i_1+1), \ldots\ E^T(i_0,n)\big)$$

$$\text{and } Y = \big(E^T(i_1,1), \ldots\ E^T(i_1,i_0-1), E^T(i_1,i_0+1), \ldots\ E^T(i_1,n)\big)\,.$$

The null hypothesis is that the pairwise difference distribution has a median equal to zero. If institutions i_0 and i_1 have the same exposures to all the others institutions, *i.e.* they are perfectly substituable, the median is actually equal to zero. For each pair of institutions, we use the value of the test statistic as a distance in terms of substituability between the two institutions. Based on the distance matrix, we compute a hierarchical clustering based on the Ward criterion.[4]
Second, we compare the integration of each institution to the network. For any pair of institutions, we test whether one institution tends to be more interconnected to the rest of the network than the other institutions. We apply the Mann-Whitney test to the previously defined X and Y. The null hypothesis is that one institution is stochastically greater than the other.[5] If institutions i_0 and i_1 lend the same amount

[4]Results both for substituability and integration are robust using other criteria.

[5]A random variable X is stochastically greater at first order than a random variable Y if for all bounded, increasing function $f : \mathbb{R} \to \mathbb{R}$, $\mathbb{E}\,(f(X)) \geq \mathbb{E}\,(f(Y))$.

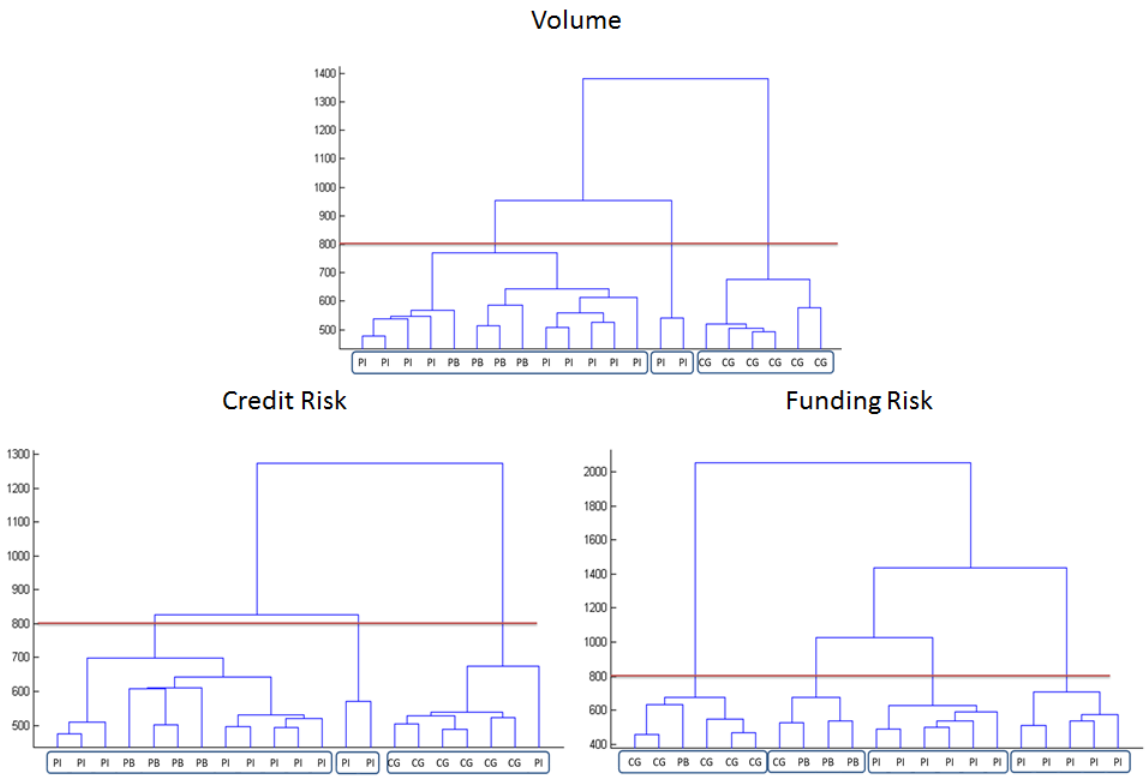


Figure 6: Results for Integration

and with (unsorted) similar breakdown between other institutions, then no distribution is stochastically greater. For each pair of institutions, the test statistic is used to define the distance between the two institutions with respect to integration. Based on the distance matrix, we compute a hierarchical clustering based on the Ward criterion.

3.4.2 Results

A cutting level ensuring three or four clusters has been arbitrary selected to help discussion.

i) Integration to the network

For volume (E^T), three clusters are identified: the 6 conglomerates shape a first group, two pure insurers a second group while the other institutions fall into the last group (see top panel in Figure 6). The credit risk (CR^T) perspective provides similar results except that one insurer joins the conglomerate cluster (bottom left panel in Figure 6). As funding risk is concerned (FR^T), 4 clusters are identified: two clusters regroup conglomerates and pure banks while the two last clusters gather all the pure insurers.

ii) Substituability in the network

When looking at volume (top panel in Figure 7), no institution appears as an outlier being very distant from other institutions. The distribution of conglomerates, pure banks and pure insurers in the cluster is not very clear: only one cluster can be identified

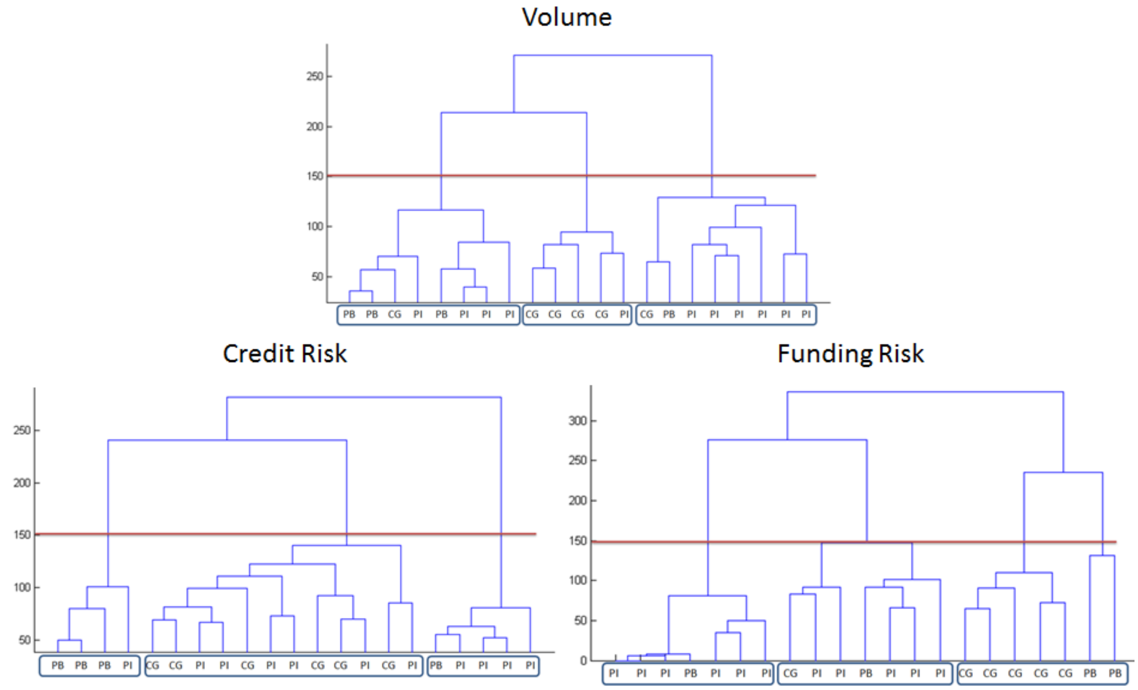


Figure 7: Results for Substituability

as a conglomerate cluster. In terms of credit risk and funding risk (bottom panels in Figure 7), institutions look very substituable. Whatever the perspective, no institution appear as having a singular position in the network.

3.4.3 Interpretation

From integration and substituability perspectives, conglomerates are specific players for volumes. They tend to form an homogeneous group distant from other institutions. One is substituable to another, but there is low substituability between one conglomerate and one pure insurance/bank. When considering size (either credit risk or funding risk), the picture is less clear. Concerning integration, conglomerates are still a specific group. This indicates that they share a common pattern in their lending and funding strategies. However, when looking at substituability results, conglomerates' specificity is much less clear. This means that even if they have similar strategies, their exposures are not allocated to the same counterparts.
There is no clear difference between pure banks and pure insurers. In terms of integration, they form a large homogeneous group (except for two pure insurers). The sole distinction may be made in terms of substituability in credit strategy where some institutions seem to have different portfolio strategies. However, the resulting clusters do not exactly match the distinction between pure banks and pure insurers.

In conclusion, the measure of interconnectedness along integration and substituability controlling for size gives us several stylized facts. Under several aspects, conglomerates form a more homogeneous group than pure banks and pure insurers. They share common patterns that they apply differently. Banks and insurances are not easily characterized apart from their differences to conglomerates.

4 Network Structure Identification

In this section, we compare the genuine network with various network structures studied in the literature. Stylized networks can result from theoretical models or from strong feature stemming from empirical analysis. The overall objective of this section is not to identify a specific structure but to derive a measure of interconnetedness from the structure identification. In contrast with previous methodology based on pair-wise comparisons, network structure identification techniques rely on the whole mapping of exposures between all institutions.
After presenting two "textbook" network structures, we calibrate them on our data sample to draw conclusions on interconnectedness. We compare these results obtain in Section 3.

4.1 Review of stylized networks

Economics theory provides stylized networks corresponding to various incentives to network formation.

4.1.1 Theoretical perspective: complete core-periphery structure

Game theorists has analyzed how various setup of pay-off between players leads to the formation of network. In game theory, networks are usually unweighted (i.e. there is no size attached to a link) and undirected (i.e. a link is both ways). For instance, Galeotti and Goyal (2010) analyze the resulting network for a set of player who benefits from their own efforts and from the efforts of their counterparts. Of course, getting connected is costly. Therefore for each player there is a trade-off between doing on its own knowing that this effort provide a positive externalities to its counterparts, and getting interconnected. The authors shows that the general structure is composed of a core of players, called hubs, who are completely interconnected and peripheral players who are connected only to all core-players. When the core is reduced to one player, the network is star-shaped (see Figure 8). Galeotti et al. (2006) propose a similar analysis with heterogeneous players and show that other network shape may emerge. In particular, some players can be intermediaries between local hubs (see Figure 9). Usually, game theorists have in mind network based on cooperation: friendship for social application, R&D partnership for firms...

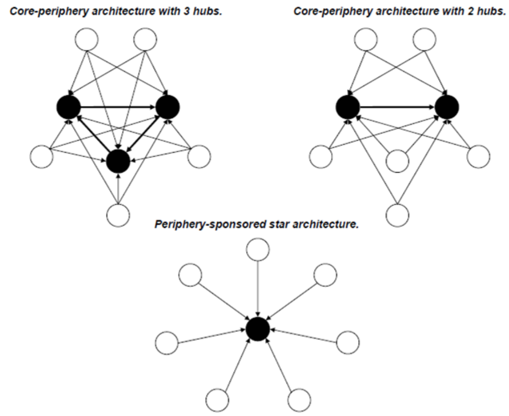


Figure 8: Core-Periphery structure *à la* Galeotti and Goyal (2010) [excerpt from Galeotti and Goyal (2010)]

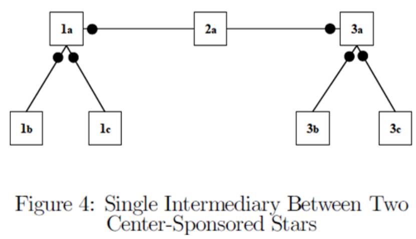


Figure 9: Intermediation between local hubs [excerpt from Galeotti et al. (2006)]

4.1.2 Empirical (banking) perspective: light core-periphery structure

Empirical analysis of banking system points to a core-periphery structure [see Craig and Von Peter (2014)]. This core-periphery structure is similar but different to the one introduced by Galeotti and Goyal (2010). In banking network, the core banks are fully interconnected as in game theory. But peripheral banks are connected to at least one core banks and not necessarily to all, contrasting with game theory definition. Moreover, links are directed: one distinguishes the lender from the borrower.
This core-periphery pattern has been observed in various countries for their domestic banking system. However, as our best knowledge, insurance companies have never been included.

Our methodology inherits significantly from the method developed in Craig and Von Peter (2014). The first step is to convert an exposure matrix into an adjacency matrix. An adjacency matrix is composed of 0 and 1: the coefficient (i, j) is 1 if and only if the coefficient (i, j) of the exposure matrix is strictly positive. The basic idea of the procedure is to count the number of discrepancies between two adjacency matrices. The first adjacency matrix is the observed one whereas the second one is the idealistic one corresponding to the tested stylized network. One drawback of using adjacency matrices is the lack of "size" effect: a significant exposure has the same weight as a tiny one. To deal with this aspect, we adopt two strategies. The first feature is to consider three exposures matrix : the total exposure matrix E^T, the total credit risk exposure matrix CR^T and the total funding risk exposure matrix FR^T (see Section 3). The second feature is to censored exposures that are considered. We consider censoring by 500 MEuros step for the total exposure matrix, 10% step for the credit risk exposure matrix and 1% for the funding risk matrix. For sake of place, we only report main results.

4.2 Identification of complete core-periphery network

4.2.1 Methodology

"Complete core-periphery network" refers to the structure proposed in Galeotti and Goyal (2010). If the core institutions are firstly indexed, the theoretical adjacency matrix A^{ccp} presents a block structure:

$$A^{ccp} = \left(\begin{array}{c|c} A^{ccp}_{1,1} & A^{ccp}_{1,2} \\ \hline A^{ccp}_{2,1} & A^{ccp}_{2,2} \end{array} \right),$$

where all the off-diagonal coefficients of $A^{ccp}_{1,1}$, $A^{ccp}_{1,2}$ and $A^{ccp}_{2,1}$ are equal to one, and all the coefficients of $A^{ccp}_{2,2}$ are zeros. A^{ccp} is a symmetric matrix since Galeotti and Goyal (2010) consider undirected links. For example, a network of 7 institutions with 3 core institutions is characterized by:

$$A^{ccp} = \left(\begin{array}{ccc|ccccc} 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ \hline 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \end{array} \right).$$

To compare this structure with our observation, the first step is to define a distance measure. For an observed adjacency matrix A with the first c indexes associated to the core, we define the aggregate error matrix:

$$E^{ccp}(A) = \left(\begin{array}{cc} c(c-1) - \sum_{i=1}^{c} \sum_{j=1}^{c} A_{i,j} & c(n-c) - \sum_{i=1}^{c} \sum_{j=c+1}^{n} A_{i,j} \\ c(n-c) - \sum_{i=c+1}^{n} \sum_{j=1}^{c} A_{i,j} & \sum_{i=c+1}^{n} \sum_{j=c+1}^{n} A_{i,j} \end{array} \right).$$

The distance is the sum of the coefficients of the error matrix over the number of links:

$$d^{ccp}(A) = \sum_{i=1}^{2} \sum_{j=1}^{2} E^{ccp}(A)_{i,j} \Big/ \sum_{i=1}^{n} \sum_{j=1}^{n} A_{i,j}.$$

Determining which institutions are in the core and which ones are in the periphery is seeking the partition which minimizes the distance $d^{ccp}(A)$.

	Volume	Credit Risk	Funding Risk
CG	C	C	C
CG	C	C	C
CG	C	C	C
CG	C	C	C
CG	C	C	C
CG	P	P	P
PB	P	C	C
PB	P	P	P
PB	P	C	P
PB	P	C	P
PI	P	C	C
PI	P	P	C
PI	P	C	C
PI	P	C	C
PI	C	P	C
PI	P	P	P
PI	P	P	C
PI	P	P	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
Distance (%)	3.6	16.2	14.6%
#Core	6	11	12
Thershold	1.5 GEuros	1%	0.1%

Table 5: Complete Core-Periphery Structure Identification

4.2.2 Application

Results of the structure identification are presented in Table 5. The best fitting is obtain by considering only exposure higher than 1.5 GEuros. The core is composed of 5 conglomerates and 1 pure insurer. The complete core-periphery structure is very plausible since there is only 3.6% of errors between the observed adjacency matrix and the theoretical one.
When looking at the structure with the credit risk lenses, the picture is different. If only exposures representing more than 1% of the equity of the lender are concerned, the complete core-periphery has a distance about 16%. Five conglomerates, three pure banks and two insurers are part of the core. However, when the threshold increases, the fitting is poor since error rate is between 30% and 71%. Similar results are got when looking at funding risk.
Comparing these results shows that the complete core-periphery structure is a suitable stylized network shape for the French financial network, only when considering raw exposures. In that case, the core is composed of conglomerates and one pure insurers. But when exposures are normalized by the size either of the lender or of the borrower, the complete core-periphery structure disappears. One interpretation is that five conglomerates and the pure insurers are in tight commercial relationships, with large volume of exposures. But these exposures does not represent an area prone to contagion either in terms of solvency (credit risk) or in terms liquidity (funding risk).

4.3 Identification of light core-periphery network

4.3.1 Methodology

"Light core-periphery network" refers to the structure proposed in Craig and Von Peter (2014). If the core institutions are firstly indexed, the theoretical adjacency matrix A^{lcp} presents a block structure:

$$A^{lcp} = \left(\begin{array}{c|c} A^{lcp}_{1,1} & A^{lcp}_{1,2} \\ \hline A^{lcp}_{2,1} & A^{lcp}_{2,2} \end{array} \right),$$

where all the off-diagonal coefficients of $A^{lcp}_{1,1}$, there is at least one non-zero coefficient in each line of $A^{lcp}_{1,2}$, there is at least one non-zero coefficient in each row of $A^{lcp}_{2,1}$ and all the coefficients of $A^{lcp}_{2,2}$ are zeros. Contrary to the complete core-periphery structure, A^{lcp} is not necessary symmetric. For example, a network of 7 institutions with 4 core institutions may be characterized by:

$$A^{lcp} = \left(\begin{array}{cccc|cccc} 0 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array} \right).$$

In the case of a light core-periphery structure, the aggregate error matrix for an observed adjacency matrix A with the first c indexes associated to the core is:

$$E^{lcp}(A) = \left(\begin{array}{cc} c(c-1) - \sum_{i=1}^{c} \sum_{j=1}^{c} A_{i,j} & (n-c) \sum_{i=1}^{c} max\left(0; 1 - \sum_{j=c+1}^{n} A_{i,j}\right) \\ (n-c) \sum_{j=1}^{c} max\left(0; 1 - \sum_{i=c+1}^{n} A_{i,j}\right) & \sum_{i=c+1}^{n} \sum_{j=c+1}^{n} A_{i,j} \end{array} \right).$$

The distance is the sum of the coefficients of the error matrix over the number of links:

$$d^{ccp}(A) = \sum_{i=1}^{2} \sum_{j=1}^{2} E^{ccp}(A)_{i,j} \Big/ \sum_{i=1}^{n} \sum_{j=1}^{n} A_{i,j}.$$

Determining which institutions are in the core and which ones are in the periphery is seeking the partition which minimizes the distance $d^{ccp}(A)$.

4.3.2 Application

Basically, the results with a light core-periphery structure does not differ significantly from results with a complete core-periphery structure (Table 6). The core-periphery structure is clear when considering gross exposures. The best distance of 3.6% got for exposures higher than 1.5 GEuros is very good ; for comparison, Craig and Von Peter (2014) have distance about 12% on the German interbank market. The core is

	Volume	Credit Risk	Funding Risk
CG	C	C	C
CG	C	C	P
CG	C	C	C
CG	C	C	P
CG	C	C	P
CG	P	P	P
PB	P	C	P
PB	P	P	P
PB	P	C	P
PB	P	C	P
PI	P	C	P
PI	P	P	P
PI	P	C	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
PI	P	P	P
Distance (%)	5.0	15.7	71.4%
#Core	5	10	2
Thershold	1.5 GEuros	1%	0.1%

Table 6: Light Core-Periphery Structure Identification

composed of five conglomerates only contrasting with the previous structure where one pure insurer was also spotted. The funding risk perspective show no core-periphery structure. Meanwhile, credit risk exposure (above 1%) includes several institutions in top of the same five conglomerates.
These results confirm the main finding of the complete core-periphery structure identification. Five conglomerates represent the heart of the volumes of financial exposures. However, in terms of risk, the partition is much blurry. The funding risk seems to be very diffuse with no compact set of highly interconnected institutions. The credit risk perspective do not provide good fitting when avoiding exposure lower than 1%. When taking into account these modest exposures, the core (in both model) represent about half of the sector. In terms of supervisions, there is no set of institutions with interconnections implying severe loss (higher than 10% of equity).

4.4 Results

The first finding is that the core-periphery structure, usually applied to banks, is also relevant when including insurance companies. We found similar quality of adjustment than those obtains by papers on banks only.
The second finding is that the "core" is mostly composed of conglomerates when considering the volume of exposures. However, controlling by size makes the core-periphery structure no longer a good candidate (even after an optimization step on the censoring threshold). Controlling by size is adopting a risk perspective rather than a flow perspective. This feature may be a valuable input for random graph model mimicking financial network; such an application is clearly out of scope of our paper.
Thirdly, there is no conclusive results as regard to chose between the complete core-periphery structure and the light core-periphery structure. Adjustment quality are

qualitatively similar.

Financial conglomerates are composing the "core" of volume network but are not as central when we control by size. In other words, conglomerates play a pivotal role to gather and distribute financial assets (*i.e.* inter financial institution assets) but not to gather and distribute risk. Since this pivotal role does not seem to come from their being the largest players, the explanation may come from their being active on the two sub-sectors (banking sector and insurance sector). Following the economic analysis of Galeotti and Goyal (2010), there is a benefit to get interconnected to a financial conglomerate but no special gain to get interconnected to one large institution. Diversification motive may accounts for this fact.

Deeper analysis would be necessary, in particular comparison with interconnections stemming from market participants' perceptions, as well as alternative theoretical stylized network (see Appendix B).

4.5 Comparison with findings on integration and substituability

Interconncedness measuring strategies based on hierarchical clustering (Section 2) and topological structure identification (Section 3) agree on a clear distinction between conglomerates and others institutions when considering volume exposures. However, core-periphery identification does not give insights on riskiness whereas hierarchical clustering provide a few elements for integration (based on credit risk) and for substituability (based on funding risk). One explanation of this discrepancy is the binary aspect of the core-periphery identification (even considering the optimization on the censoring threshold). Moreover hierarchical clustering provides insights on all the institutions while core-periphery distinguishes only two groups of institutions.
Keeping the core-periphery structure identification may be paramount because it draw a broad picture. Identifying the core can help identify systemic institutions that may be the source of wide-spread contagion phenomena. On a methodological point of view, we may advocate that hierarchical clustering tools, such as integration and subsituability measures, may help to make a diagnosis to neutralize the risk of contagion. On a factual level, the core-periphery structure did not enable us to identify risky institutions among our database. It only captured a size effect.

5 Contagion risk assessment

Spotting interconnectedness as a dimension of systemicity is considering contagion risk. Albeit informative, previous analyses are not specifically focused on contagion risk. In this section, we assess contagion-based interconnectedness of institutions by carrying out three classes of network stress-tests.
We use the contagion model proposed in Gourieroux et al. (2012). The structural model extends Eisenberg and Noe (2001)'s model by distinguishing contagion through shares and bonds. The contagion model is common to the three classes of network stress-tests,

but the shock hitting the network varies across the classes.

In the first class, we consider the impact of the individual default of each institution. The initial default of institution X is defined as the wiping out of all the external assets of institution X. Since we have 21 institutions, we have 21 scenarios of individual defaults. These scenarios leads to measure two dimensions of interconnectedness: *systemic importance* and *systemic fragility*. The systemic importance of institution X is the impact of institution X's default on the network whereas its systemic fragility is how much institution X is likely to be affected by the defaults of other institutions. Alves et al. (2013) propose to measure the systemic importance of institution X with the number of institutions in default due to institution X's default and to measure systemic fragility of institution X with the the number of scenarios where institution X is in default. Applying these definitions, we find too few distinctions between institutions. We consider a much more conservative approach by looking at contagion links where losses are larger than 10% of initial equity. Thus, the systemic importance of institution X with the number of institutions suffering from a loss higher than 10% of their initial equities following institution X's default. Similarly, the systemic fragility of institution X with the number of scenarios where institution X suffers from losses larger than 10% of its initial equity. Note that since Gourieroux et al. (2012)'s model considers contagion through equity, a loss propagation may exist even if no default occurs.
The second class consists in a focus on sector-specific risk: either all the banks default, or all the insurers default. The objective is to challenge the concern that the pivotal role of conglomerates highlighted in the previous section makes them a bridge between the two sectors. As we focus on the potential contagion between the two sectors, the two parts of financial conglomerates are considered as two different nodes. Indeed, the capitalistic relationship introduces a strong tie between the two nodes of a same financial conglomerate.
In the last class, we consider sovereign exposure as a common shock affecting all the institutions from both sectors.

A usual caveat for the two first classes is the arbitrary design of the shock. For the first class, the outcome is what happen when one specific institution defaults while all the others suffer from no loss on their own assets. In other words, the initial default is not due to a common factor, but only to individual factor. For the second class, the shock corresponds to wipe out one sector while the other sector do not suffer from assets' losses. The initial defaults are due to factors orthogonal to the remaining sector. And, of course, a shock wiping out a complete sector is very conceptual.

5.1 Systemic importance and systemic fragility

Figure 10 reports the number of institutions with specific level of systemic importance and systemic fragility. Three groups have been visually identified: one group is composed of institutions prone to be systemically important, another group is composed of institutions prone to be systemically fragile and the last group gathers institutions that are neither systematically important nor fragile. Note that we find no institution with significant systemic importance and significant systemic fragility. To limit the

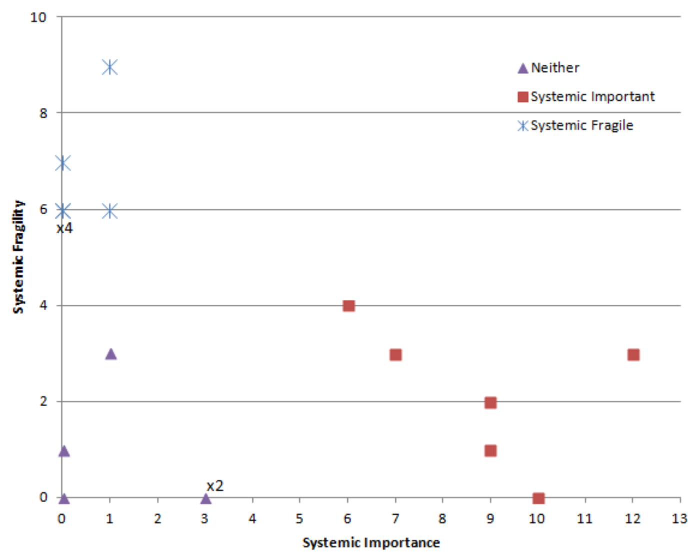


Figure 10: Importance and Fragility. 12/31/2011.

impact of using a threshold (10% of equity), we simply consider groups and not exact figures. Considering higher thresholds would globally decrease the figures of systemic importance and systemic fragility.

5.2 Comparison with previous findings

Network substituability and network integration analyses (see Section 2), topological structure identification (Section 3) as well as systemic importance and systemic fragility analyses (see above) provide us several partitions of the sample. The objective is to assess how contagion-based measures of interconnectedness are related to the previous measures. To do so, we run exact Fisher test[6] on the contingency table build on one group identified by contagion-based measures and one group identified by any other method. Table 7 reports the quality of adjustment between the interconnectedness measures.

The main result is that no measure is able to identify systematically fragile institutions whereas most methods are able to identify systematically important institutions. This mismatch may be structural for the core-periphery since one partition is composed of two groups while the other is composed of three. But even when the two partitions are composed of three groups, there is no detecting the fragile institutions. Therefore, there is only a partial overlapping of the information brought by substituability/integration analysis and the contagion analysis. Substituability and integration analyses are run on a pair-wise basis. Therefore, results indicate that two institutions have similar interconnectdeness but do not provide the scale of this common level. On the contrary, contagion based analysis provides directly the levels of interconnectedness for each institution.

[6]Since our sample is small (with only 21 observations), considering exact Fisher test is more robust than usual chi-2 test.

		Importance	Fragility	Neither
Volume	Substituability	++	.	++
	Integration	+++	.	+++
	Core	+++	.	.
	Periphery	.	.	+++
Credit Risk	Substituability	.	.	.
	Integration	+++	.	++
	Core	+	.	.
	Periphery	.	.	.
Funding Risk	Substituability	+++	.	++
	Integration	.	.	.
	Core	.	.	.
	Periphery	.	.	.

Legend: "+++" indicates a p-value lower than 1% for the exact Fisher test between at least one group of the method in line and the group identified in column. Similarly, "++" for a p-value lower than 5%, "+" lower than 10%.

Table 7: Group comparison. 12/31/2011.

5.3 Sector-specific stress-test

In case of the default of the banking sector, nine (out of 17) insurers are in default, with all the insurances subsidiaries of the conglomerates. However, owners of the debt of defaulted pure insurers recover (in average) 97% of their investment. In case of the default of the insurance sector, no bank is in default.
The risk of contagion from one sector to another is very low although financial conglomerates are core institutions.

5.4 Common exposures

We propose a network stress-test of sovereign exposures. We complete our data set by the sovereign exposures of the 27 institutions [7] on Germany, Spain, France, United-Kingdom, Ireland, Italy, Portugal and United-States of America. The exposures are based on Large Exposures reports for banks and TCEP reports for insurance companies. We define one scenario by country by assuming that all institutions suffer a loss of half their respective exposures to the considered country.
Table 8 reports the results of these nine stress-tests. Except for France and Italy, the impaired losses do not lead any institutions to default. The losses represent in average about 10% of the equity. The domestic bias is pregnant since in case of a French sovereign crisis, eleven institutions would be in default. However, surviving institutions loss only about 30% of their equity and the recovery rate on the defaulted institutions is at 94%. Last, Italy appears to be the second largest sovereign risk for the French financial sector since two defaults may occur. As for France, the recovery rate of the defaulted institutions is very high (93%) and the surviving institutions keep most part of their capital buffer (about 80%).

[7] As for sector-specific stress-test, conglomerates' activities are distinguished.

Country	DE	ES	FR	UK	GR	IE	IT	PT	US
# of default	0	0	11	0	0	0	2	0	0
Equity Recovery	91%	89%	70%	99%	97%	96%	81%	93%	94%
Debt Recovery	.	.	94%	.	.	.	98%	.	.

Legend: Equity Recovery is the average over the non-defaulted institutions of the ratio of equity after shock and equity before shock. Debt Recovery is the average over the defaulted institutions of the ratio of debt value after shock and before shock.

Table 8: Sovereign Exposure Stress-Test Results. 12/31/2011.

6 Concluding remarks and further research

This paper documents actual bilateral exposures between banks and insurers in France at 31/12/2011. Descriptive statistics indicate the key role of financial conglomerates that are both significant lenders and massive borrowers in the network. Using this unique database, we investigate three strategies to measure interconnectedness (see Table 9).

Interconnectedness Measure	Pair-Wise	System-wise	Binary	Continuous
Integration	✓			✓
Substituability	✓			✓
Core-Periphery		✓	✓	
Contagion-based		✓		✓

Table 9: Characteristics of Interconnectedness Measurement Strategies

First, we measure the degree of interconnection along the *substituability* and *integration* concepts. This strategy provides continuous results based on a pairwise approach. Conglomerates appear as an homogeneous population sharing common features. Banks and insurers are distinct from conglomerates but are not easily distinguishable among themselves.
Second, we calibrate a *core-periphery* structure, usually applied to banking networks. This approach enable us to consider the whole system but only on a qualitative base. We show that this structure is still relevant for a network composed of insurance companies in addition to banks. However, it appears that this structure is more likely to be driven by institutions' sizes than by their levels of interconnectedness. The resulting "core" is composed of conglomerates. This tends to indicate that there is a benefit to get interconnected to a institution active on both sectors (regardless of its size).
Third, we study *systemic fragility* and *systemic importance* of institutions based on a contagion risk assessment. The informative content of this last method is complementary to the previous analyses.

As interconnectedness becomes a major concern for systemic risk supervision, being able to measure interconnectedness is paramount. Interconnectedness is a multi-faceted

concept that no unique measure may summarize. In this paper, we review and propose a few methods that measure different aspects of interconnectedness. We stress their conceptual differences as well as their contrasting operational results.
In terms of supervision of systemic risk, our results call for a clear distinction between size dimension and interconnectedness dimension. Moreover, addressing contagion risk without contagion stress-test exercises seems difficult: aggregate balance-sheet information or static exposure information are relatively poor indicators of riskiness. Nonetheless, these last information sets are very important to understand (and monitor) the behavior of financial institutions. On a very practical level, all the pros and cons of each method have to be balanced with data frequency as well as computational complexity (particularly when the sample size becomes large).
Regarding to stylized facts on financial networks, our results provide inputs for network generating methods. The structure of the network, as well as the degree (or edges) distributions, are not independent of the size of the nodes.
Two main paths for further research are identified. First, a deeper understanding of the conglomerate structure would be required. To do so, we plan to adapt our measures to compare the banking part of conglomerate with pure banks and the insurance part of conglomerate with pure insurers. Second, introducing a time dimension applying the same methodology to the same sample would enrich the analysis.

References

Acemoglu, D., Ozdaglar, A., and Tahbaz-Salehi, A. (2013). Systemic risk and stability in financial networks. *National Bureau of Economic Research Discussion Paper*, 18727.

Allen, F. and Gale, D. (2000). Financial contagion. *Journal of political economy*, 108(1):1–33.

Alves, I., Ferrari, S., Franchini, P., Héam, J.-C., Jurca, P., Langfield, S., Laviola, S., Liedorp, F., Sanchez, A., Tavolaro, S., and Vuillemey, G. (2013). The structure and resilience of the european interbank market. *European Systemic Risk Baord (ESRB) Occasional Paper*, 3.

BCBS (2013a). Global systemically important banks: updated assessment methodology and the higher loss absorbency requirement. *Basel Committee on Banking Supervision Consultative Document*.

BCBS (2013b). Supervisory framework for measuring and controlling large exposures. *Basel Committee on Banking Supervision Consultative Document*.

Berger, P. G. and Ofek, E. (1995). Diversification's effect on firm value. *Journal of financial economics*, 37(1):39–65.

Billio, M., Getmansky, M., Lo, A. W., and Pelizzon, L. (2011). Econometric measures of systemic risk in the finance and insurance sectors. *Journal of Financial Economics*, 104(3):535–559.

Brewer, E. and Jackson, W. E. (2002). Inter-industry contagion and the competitive effects of financial distress announcements: Evidence from commercial banks and life insurance companies. *FRB of Chicago Working Paper*, 02-03.

CEBS (2009a). Guidelines on the revised large exposures regime. *Committee of European Banking Supervisors*.

CEBS (2009b). Revised guidelines on financial reporting. *Committee of European Banking Supervisors*.

Craig, B. and Von Peter, G. (2014). Interbank tiering and money center banks. *Journal of Financial Intermediation*.

Cummins, J. D. and Weiss, M. A. (2014). Systemic risk and the us insurance sector. *Journal of Risk and Insurance*.

Degryse, H. and Nguyen, G. (2007). Interbank exposures: An empirical examination of contagion risk in the belgian banking system. *International Journal of Central Banking*, 3(2):123–171.

Eisenberg, L. and Noe, T. H. (2001). Systemic risk in financial systems. *Management Science*, 47(2):236–249.

Fanto, J. (2011). Breaking up is hard to do: should financial conglomerates be dismantled? *University of Cincinnati Law Review*, 79(2):5.

Fourel, V., Héam, J.-C., Salakhova, D., and Tavolaro, S. (2013). Domino effects when banks hoard liquidity: The French network. *Banque de France Working Paper*, 432.

Frey, L., Tavolaro, S., and Viol, S. (2013). Counterparty risk from re-insurance for the french insurance companies. *ACPR Economic and Financial Discussion Notes*, 1.

FSB (2009). Guidance to assess the systemic importance of financial institutions, markets and instruments: Initial consideration. *Financial Stability Board*.

FSB (2012). A global legal entity identifier for financial markets. *Financial Stability Board*.

Furfine, C. H. (2003). Interbank exposures: Quantifying the risk of contagion. *Journal of Money, Credit & Banking*, 35(1).

Galeotti, A. and Goyal, S. (2010). The law of the few. *The American Economic Review*, pages 1468–1492.

Galeotti, A., Goyal, S., and Kamphorst, J. (2006). Network formation with heterogeneous players. *Games and Economic Behavior*, 54(2):353–372.

Gauthier, C., Lehar, A., and Souissi, M. (2012). Macroprudential capital requirements and systemic risk. *journal of Financial Intermediation*, 21(4):594–618.

Gollier, C. and Ivaldi, M. (2009). A merger in the insurance industry: Much easier to measure unilateral effects than expected. *Université Toulouse Discussion Paper*.

Gourieroux, C., Héam, J.-C., and Monfort, A. (2012). Bilateral exposures and systemic solvency risk. *Canadian Journal of Economics/Revue canadienne d'économique*, 45(4):1273–1309.

Héam, J.-C. and Koch, E. (2013). Diversification and endogenous financial network. Technical report, Mimeo.

Holmstrom, B. R. and Tirole, J. (1998). Private and public supply of liquidity. *Journal of Political Economy*, 106(1):1–40.

IAIS (2013). Global systemically important insurers: Initial assessment methodology. *International Association of Insurance Supervisors*.

Lublóy, Á. (2005). Domino effect in the hungarian interbank market. *Hungarian Economic Review*, 52(4):377–401.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates. *The Journal of Finance*, 29(2):449–470.

Minderhoud, K. (2003). Extreme stock return co-movements of financial institutions: Contagion or interdependence? *De Bederlandsche Bank Working Paper*, 2003-16.

Mistrulli, P. E. (2011). Assessing financial contagion in the interbank market: Maximum entropy versus observed interbank lending patterns. *Journal of Banking & Finance*, 35(5):1114–1127.

OJEU (2002). Directive on the supplementary supervision of credit institutions, insurance undertakings and investment firms in a financial conglomerate. *Official Journal of the European Union*, Directive 2002/87/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002.

Rochet, J.-C. (2004). Macroeconomic shocks and banking supervision. *Journal of Financial Stability*, 1(1):93–110.

Stringa, M. and Monks, A. (2007). *Inter-industry contagion between UK life insurers and UK banks: an event study*, volume 325.

Subramanian, A. and Wang, J. (2013). Catastrophe risk transfer. *Available at SSRN*.

Tirole, J. (2010). *The theory of corporate finance*. Princeton University Press.

Toivanen, M. (2009). Financial interlinkages and risk of contagion in the finnish interbank market. *Bank of Finland Discussion Paper*, 2009-06.

Upper, C. and Worms, A. (2004). Estimating bilateral exposures in the german interbank market: Is there a danger of contagion? *European Economic Review*, 48(4):827–849.

van Lelyveld, I. and Knot, K. (2009). Do financial conglomerates create or destroy value? evidence for the eu. *Journal of Banking & Finance*, 33(12):2312–2321.

Van Lelyveld, I. and Liedorp, F. (2006). Interbank contagion in the dutch banking sector: A sensitivity analysis. *International Journal of Central Banking*, 2(2):99–133.

Van Lelyveld, I. and Schilder, A. (2003). Risk in financial conglomerates: Management and supervision. *Brookings-Wharton Papers on Financial Services*, 2003(1):195–224.

Wells, S. (2002). Financial interlinkages in the united kingdom's interbank market and the risk of contagion. *Bank of England Working Paper*, 230.

A Building data set

A.1 Defining nodes

The very first step is to define the 27 nodes of the network.

For conglomerates, we use the detailed list of the entities of the group (consolidation perimeter in the annual reports or regulatory Reports Implantat, ACPR). This list of all subsidiaries includes information such as the name, the activity code, the country, the size, the interest control, the voting control... We define the sub-group "insurance activity" as the combination of all subsidiaries whose activity code is insurance. In contrast, we define the sub-group "banking activity" as all the remaining entities in the list (that are not in the sub-group "insurance activity"). We keep track of the interest control in case of entities that are not fully controlled by the head (see below).
For pure banks, we use the same information as for conglomerates. However, all entities in the list of consolidation perimeter are considered part of the node (regardless of the activity code). For pure insurance, we consider all insurers that are part of the group we consider.

A.2 Collecting balance sheets

French banks are required to report to the Autorité de Contrôle Prudentiel et de Résolution a detailed balance sheet [see FINREP detailed inCEBS (2009b)] at a consolidated level. This consolidation level is suitable for pure banks. But for conglomerates, this report encompasses the banking and the insurance activities. We split the assets and the liability using the ratio of the required capital for banking activity on the total required capital (for banking activity and insurance activity) provided by an auxiliary report.
Insurance supervision is on a solo basis. Therefore, supervisory reports for insurance companies are not directly providing consolidated balance sheet. We use the public annual reports of the 11 insurers we consider.

A.3 Collecting data from banks on extra-group exposures

French banks are also required to report all the large extra-group exposures [see Large Exposures Reports detailed in CEBS (2009a)]. In the Large Exposure Report, the financial institution consider the exposures of all its banking subsidiaries (i.e. excluding any potential insurance subsidiary) that exceed 10% of its capital or more than 300 millions of Euros. The counterpart are consolidated. From Large Exposure Reports, we can reconstruct the exposure of all the pure banks and all the banking nodes of the conglomerates towards all others nodes.
Large Exposure Rreport declaration perimeter has few exceptions : in particular, exposures that are deduced in the computation of the regulatory capital are not reported [see CEBS (2009a)]. We check with off-site supervision teams the deduced elements and incorporate them.

A.4 Collecting data from insurers on extra-group and intra-group exposures

French insurance companies reports a highly detailed balance sheet (TCEP report, ACPR 2013) at a solo basis (i.e. without including any subsidiary). Going security by security on the asset side, one can reconstruct exposures to nodes using the very first step about defining nodes. In contrast of Large Exposure reports, TCEP has no exceptions but is on a solo basis. Therefore, we are underestimating the exposures of insurers by neglecting the exposures of the non-domestic entities. This bias is expected to be insignificant for insurers whose activity are only in France and more pronounced for globally active insurers.
The TCEP is very useful to assess the structure of exposures to a conglomerate. For each insurance company, the TCEP distinguishes the exposures to the sub-group "insurance activity" from the exposures to the sub-group "banking activity". We observe that almost all exposures are reported to the the sub-group "banking activity". For simplicity, whatever the nature of the reporting institutions (conglomerate, pure bank or pure insurer) we consider that any exposures to a conglomerate is actually an exposure to the sub-group "banking activity".

B Identification of Intermediary-Lender-Borrower structure

To take into account the existence of insurers in the network, we adapt the light core-periphery structure. We identify three categories of institutions: pure lenders, pure borrowers and intermediaries. Intermediaries are similar to core institutions while pure borrowers and pure lenders are a partition of peripheral institutions. Insurers are expected to be pure lenders. If institutions are sorted as intermediaries, pure borrowers and pure lenders, the corresponding adjacency matrix A^{ibl} presents a block structure:

$$A^{ibl} = \left(\begin{array}{c|c|c} A^{ibl}_{1,1} & A^{ibl}_{1,2} & A^{ibl}_{1,3} \\ \hline A^{ibl}_{2,1} & A^{ibl}_{2,2} & A^{ibl}_{2,3} \\ \hline A^{ibl}_{3,1} & A^{ibl}_{3,2} & A^{ibl}_{3,3} \end{array}\right),$$

where all coefficients of $A^{ibl}_{1,3}$, $A^{ibl}_{2,3}$, $A^{ibl}_{3,3}$, $A^{ibl}_{2,1}$, $A^{ibl}_{2,2}$ and $A^{ibl}_{3,2}$ are zeros, all the off-diagonal coefficients of $A^{ibl}_{1,1}$ are 1, there is at least one non-zero coefficient in each line of $A^{ibl}_{1,2}$ and there is at least one non-zero coefficient in each row of $A^{ibl}_{3,1}$.
For example, a network of 7 institutions with 3 core institutions, 2 borrowers and 3 lenders may be characterized by:

$$A^{ibl} = \left(\begin{array}{ccc|cc|ccc} 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right).$$

The aggregate error matrix for an observed adjacency matrix A with the c first indexes associated to the intermediary, and the next b indexed associated to the borrowers is:

$$E^{ibl}(A) = \begin{pmatrix} c(c-1) - \sum_{i=1}^{c}\sum_{j=1}^{c} A_{i,j} & (n-c)\sum_{i=1}^{c} max\left(0; 1 - \sum_{j=c+1}^{c+b} A_{i,j}\right) & \sum_{i=c+b+1}^{n}\sum_{j=c+b+1}^{n} A_{i,j} \\ \sum_{i=c+1}^{c+b}\sum_{j=1}^{c} A_{i,j} & \sum_{i=c+1}^{c+b}\sum_{j=c+1}^{c+b} A_{i,j} & \sum_{i=c+1}^{c+b}\sum_{j=c+b+1}^{n} A_{i,j} \\ (n-c)\sum_{j=1}^{c} max\left(0; 1 - \sum_{i=c+1}^{c} A_{i,j}\right) & \sum_{i=c+1}^{c+b}\sum_{j=c+1}^{c+b} A_{i,j} & \sum_{i=c+1}^{c+b}\sum_{j=c+1+b}^{n} A_{i,j} \end{pmatrix}.$$

The distance is the sum of the coefficients of the error matrix over the number of links:

$$d^{ibl}(A) = \sum_{i=1}^{3}\sum_{j=1}^{3} E^{ccp}(A)_{i,j} \Big/ \sum_{i=1}^{n}\sum_{j=1}^{n} A_{i,j}. \tag{6.1}$$

Determining which institutions are in the core and which ones are in the periphery is seeking the partition which minimizes the distance $d^{ibl}(A)$.