Calibrating limits for large interbank exposures from a system-wide perspective

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Abstract

We examine the role of imposing tighter limits on interbank exposures in reducing contagion and aggregate losses. In our model contagion risk arises as a result of the individual idiosyncratic failure of each bank in the banking system. Following Graf et al. (2005), we use a sequential default algorithm that is useful to trace the path of contagion from a trigger bank to other banks during several contagion rounds. In presenting results, we test different types of limits on both inter-SIB exposures and non-SIBs-to-all-other banks exposures, and we study three different assumptions of banks' behavioural responses under a stricter regulatory lending regime. We also 'stress test' all banks within the banking system and extend the analysis on the benefits of using tighter limits in a fragile banking system. Calibrating the model to Mexican banking sector data, this network model shows that tighter limits for inter-SIB exposures are a useful tool for reducing contagion risk.

JEL Classification: G17, G21, G28

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1. Introduction

The global financial crisis of 2007–08 exposed many shortcomings in the financial system as a whole as well as in its regulation. The key post-crisis aim for regulators is to find policy tools to mitigate systemic risks.[1] In March 2013, the Basel Committee on Banking Supervision (BCBS) published proposals for an internationally-harmonized supervisory framework for measuring and controlling large exposures. The aim is to promote consistency in the regulation for large exposures at the global level. The proposed regulation for large exposure publicly available in BCBS (2013a) serves as a backstop and supplements the Committee's risk-based capital standard. In particular, proposed standards focus on limiting banks' concentration risk to the unexpected default of an external single private sector counterparty, and extends the framework for the case of banks' exposures to a group of connected counterparties that can be regarded as a source of single name concentration risk.

A key proposal within the Committee's large exposures framework is to limit contagion between global systemically important banks (G-SIBs) by applying a tighter limit on exposures between G-SIBs. This is consistent with the framework for systemically important financial institutions (SIFIs) developed under the aegis of the Financial Stability board (FSB) and the BCBS, and endorsed by the G20 in November 2011. Previously, FSB introduced capital surcharges according to the systemic importance of the given institution (see BCBS (2011a)), and measures for enhancing the restructuring and resolution of SIFIs. A remarkable feature of the SIFI framework is that it has varying degrees of flexibility in practice as it can be applied at a global, domestic or entity level. Limits on interbank

[1] Bisias et al. (2012) provide a comprehensive survey paper on systemic risk.

exposures are a useful tool to reduce the degree of interconnectedness among banking institutions. In so doing, limits on interbank exposures promote the individual solvency of the banking entity, and help in reducing contagion risk in the financial system. However, tighter limits on interbank exposures may also entail large efficiency costs as small banks' funding may be unnecessarily constrained.

The regulation of large exposures (LE) is not consistent at the global level. Any form of risk concentration can expose global economies to systemic risk through the highly complex interconnected network of financial markets across borders. In March 2013 the Basel Committee on Banking Supervision published proposals for an internationally-harmonized supervisory framework for measuring and controlling large exposures. A noteworthy contribution is a proposal to impose a relatively tighter limit on exposures between Global Systemically Important Banks (G-SIBs) to reduce the risk of contagion between these entities.

For this purpose, this work sets out a calibration framework to assess the benefits of using tighter limits to reduce contagion risk in the presence of systemically important banks (SIBs), and outlines the perils of applying tighter limits on small banks' funding. We use a network model of a banking system originally developed by Graf et al. (2005) involving a diverse set of banks, namely domestic banks, which are linked together by their claims. We calibrate the model to emerging country banking sector data (i.e., Mexico) to illustrate how contagion and aggregate loss arising from the idiosyncratic failure of a particular institution reduce in the presence of tighter limits. In so doing, we study three different assumptions of banks' behavioural responses that change their balance sheet composition.[2] We test

[2] In particular, we focus solely in changes on the asset side of the commercial banks' balance sheet.

different type of limits on both inter-SIB[3] exposures and non-SIBs-to-all-other banks exposures and provide empirical evidence on their performance. The analysis enables us to explore the impact on contagion risk of alternative limits on interbank exposures and, in particular, exposures involving SIBs.

We also ‘stress test’ all banks within the banking system and demonstrate how the model can be used to calibrate exposure limits. In particular, we assume that a large capital-shock takes place such that the capital ratios of all banks are reduced to the Basel III minimum requirements (i.e., capital ratio of 10.5%). This type of capital shock exercise is more severe in terms of capital reduction than the shock that arises from macroeconomic shocks where the source of the macro shock is solely related to market variables (see Elsinger et al. (2006a, b), Martinez-Jaramillo et al. (2010) and López-Castañón et al. (2012)). The evidence of the most recent global crisis shows that generalized shocks may weaken the resiliency of the remaining banks and thus increase the risk of contagion.

The main contribution to the existing literature is twofold. First, it enriches the available evidence on financial contagion by providing the first comprehensive calibration on interbank exposures from a system-wide perspective. This aspect has been absent in previous works. Second, the paper introduces three different banks’ behavioural responses that lead to differences in: (i) the size of bilateral exposures; (ii) the composition of interconnectedness; (iii) aggregate losses; (iv) number of institutions defaulting (i.e., contagion); and (v) network structure. We show that contagion risk reduces in a network where the excess exposure is allocated at the bank’s account with the central bank (i.e. outside of the commercial bank network). However, we also show that contagion risk may

[3] The D-SIB framework is work in progress for Mexican authorities. We use the SIB term as a short way to designate the largest banks in the Mexican system as measured by the size of their assets.

increase in a network where the excess exposure is allocated among each bank's counterparties. This allows us to show that limits on interbank exposures may be a useful tool to reduce contagion risk only under certain banks' behavioural responses.

The paper proceeds as follows. Section two provides a literature review and describes the design of the large exposure regime under study. Section three presents the methodology highlighting its key components and the way we model banks' behavioural responses. In Section four, we present the results for the baseline exercise, the stress testing exercises and we assess the impact of tighter limits on small bank funding. Finally, Section five provides concluding remarks.

2. Type of large exposure limits

In this section we proceed as follows. First, we summarize the main findings of the literature and we explain how this work fits in the literature. Then, we review key characteristics about the large exposures regime used in practice by different world-wide regulators. In so doing, we describe the design of the different options under study for limiting interbank exposures.

2.1 Literature Review

This paper is related to four strands of the literature. The first strand is about empirical evidence on counterfactual simulation methods to assess the danger of contagion in the interbank markets. It is well known that the interbank lending market represents one of the most important channels for financial contagion. The credit loss due to contagion in this literature arises mainly from direct interconnections.[4] This type of contagion occurs when a creditor bank does not has enough capital to absorb the credit loss that occurs as a

[4] Chen (1999) illustrates how contagion may arise as a result of indirect interconnection.

consequence of the default of any of its debtor bank counterparts. Upper (2011) provides a comprehensive review on the main findings, recent advances, and key modelling limitations. The empirical results in this literature suggest that the loss in the banking system is in general economically small,[5] and depends to a large extent on the value of the loss given default. A limitation in most studies is the lack of reliable data on bilateral interbank exposures in the market (see Upper (2011, pp.116)). In this paper, we overcome this shortcoming by using proprietary data of Banco de México that includes detailed actual aggregated bilateral interbank exposures (i.e., both on-balance and off-balance sheet exposures) for all banks that form part of the system. Moreover, our sample period covers an international period of global crisis.

The second strand of literature we contribute relates to banks' behavioural response. A second source of limitation in the empirical literature on counterfactual network simulation relates to the 'mechanic' domino effects characterized by banks that do not optimise reactions to a failure. The so-called new "second generation" counterfactual models (see Cifuentes et al. (2005) and Peydró-Alcalde (2005)) try to incorporate banks' strategic behaviour. In a recent study, Karas and Schoors (2012) enrich the standard transmission channel based solely on credit losses by incorporating funding liquidity losses, fire asset sales, and active liquidity runs on infected banks. Karas and Schoors (2012) study the Russian interbank market during the period of 1998-2004, and find that allowing for active liquidity runs on infected banks leads to large losses that properly match actual interbank losses during the Russian 1998 crisis. In the same vein, Glasserman and Young (2013) use data on European banking system and show that expected credit losses in the interbank market are small when interbank funding, fire asset sales and mark-to-market

[5] See Furfine (2003) and Karas and Schoors (2012).

revaluations are not taken into account. In contrast, in this paper we use the lending preference index as proposed by Cocco et al. (2009) and show that large credit losses may happen as a result of specific banks' behavioural responses in the presence of tighter limits. In particular, we find that tighter large exposure limits under specific banks' behavioural responses may increase contagion risk.

The third strand of literature deals with the structure of the interbank market. The propagation of contagion risk depends on the network topology. Large exposure limits are a useful tool to reduce excessive interconnectedness among banks. The structure or shape of the banking network may be useful to identify banks that are highly interconnected. In a novel study, Craig and von Peter (2010) show that a 'core-periphery' structure outperforms three popular random processes (i.e., 'random graphs', 'small world', and 'scale-free networks) in fitting the German interbank market structure. In a 'core-periphery' structure, core banks have exposures to each other as well as links with banks in the periphery, while banks in the periphery only have direct links to banks in the core. In other words, there is a subset of banks that play an essential role (i.e., banks in the core) and banks that play a less important role in holding together the interbank market. The size of the bank is not the same as the core. However, the probability that a big bank forms part of the core is high. The result found by Craig and von Peter (2010) is supported by Solis-Montes (2013) for Mexico, Fricke and Lux (2012) for Italy, and van Lelyveld and in't Veld (2012) for the Netherlands.

The structure proposed by Craig and von Peter (2010) remains stable over time even though the financial system is often characterized as a complex adaptive system that varies in time (Haldane (2009)). Although the core-periphery structure is promising, we can conclude that more research is needed before we support the view that a single structure has the flexibility to characterize all banking systems perfectly. Moreover, Cerutti et al. (2011) adds another layer of complexity as the type of data is a crucial element for studying interconnectedness. To solve this issue, regulators may assume that the structure in the payments system network is similar to that of the interbank market. However, Martinez et al. (2012) show that: (i) the network based on the flow of payments system in Mexico is more densely connected than the interbank network; (ii) some banks which play an important role in the interbank network, play less important roles in the payments system network; and (iii) some banks which would not be considered important by their size or their roles in the interbank exposures network become important players in the payments system network. This evidence is important because regulators must be careful in using adequate data not only for the understanding of the network structure, but also for limit calibration purposes.

Solis-Montes (2013) shows that in Mexico all big banks and a few small banks as measured by their asset size form part of the core. A deeper study of the core-periphery methodology may be particularly useful for determining granular risk weights for interbank exposures. In our paper, we believe that setting tighter limits for banks that form part of the core entails large efficiency costs due to liquidity needs of small banks that could be constrained. Instead, we propose setting tighter limits based solely on bank's size. An accurate measurement of the complexity, concentration and interconnectedness is beyond our goal. However, using a small number of topological measures comparison between the structure of the network after applying both tighter limits and different banks' behavioural responses. We find that in a few particular cases a more complete network is more sensitive to contagion than a less complete structure. This result contrasts to the previous findings of Allen and Gale (2000) that show from a theoretical perspective that incomplete networks are more prone to contagion than complete structures.[6] Thus, we contribute to the literature in that we show empirically that a complete structure does not necessarily leads to a more robust structure in terms of contagion risk.

The fourth strand of literature is related to the calibration of regulatory models. This is an issue of paramount importance to achieve international credibility and support. In our view, calibration may be regarded as the next great financial challenge for international standard setting bodies. The issue on calibration is complex. BCBS (2010, pp.1) explicitly recognizes this as: “there is no single correct approach to determine the adequate calibration, a single model may not provide the ‘right’ answer, and results should be interpreted with care as the use of historical data is generated under a different regulatory regime from that which will prevail in the future.” Sometimes calibration is not enough. In this case, a cost benefit analysis and a quantitative impact study of the effects of the proposed regulatory measures serve as a complement.

The literature on calibration is large. BCBS (2005) illustrates the calibration of the Basel II Internal Ratings Based risk weight functions. BCBS (2010) shows a top-down calibration for regulatory minimum capital requirements and capital buffers. BCBS (2011a) contains the methodological approach used to calibrate the additional loss absorbency requirement for G-SIBs, while BCBS (2012) extends principles that for D-SIBs. BCBS (2013c) shows the calibration of the Revised Ratings Based Approach for the Securitisation Framework. The large exposures regulation in BCBS (2013a) supports using a limit of twenty-five per cent of a bank’s capital base. Unfortunately, there is no publicly available paper that informs about the adequacy of this limit (i.e., 25%) for solvency purposes. We

[6] A market structure is complete if each Bank lends to all the others. In a complete market structure banks are financially linked to all the others only by direct exposures.

contribute in providing a calibration from a system-wide perspective using a network model of counterfactual financial contagion. Our study is limited with respect to those of BCBS in that we don't have data for large internationally active banks. Moreover, all studies are limited in that we don't have the overall effects of successively adding different layers of regulation.[7]

2.2 Regulatory approach taken by world-wide regulators

A limit on banks' exposures to a third party is expressed as a percentage of eligible capital. The key factors that should be taken into account in setting a regulatory limit are (see BCBS (2013a, pp. 1)): (i) scope of application (i.e., on a solo entity level or at a consolidated level); (ii) the value of large exposure limits, (iii) the definition of the capital base on which limits are based; (iv) methods for calculating exposure values; (v) treatment of credit risk mitigation techniques; and (vi) exemptions.

In practice, regulators adopt two different large exposure regimes. The first consists in applying the same limit for all banks (i.e., general limit). Alternatively, regulators may promote a dual regime where a tighter limit applies for large or systemically important banks. The current large exposure regime proposal of the Basel Committee is based on a dual regime (see BCBS (2013a)), where a 25% large exposure limit applies to interbank exposures[8] (see BCBS (2013a, pp.18), and a tighter 10% to 15% large exposure limit applies to a G-SIB's exposure to another G-SIB[9] (see BCBS (2013a, pp.28)). In a similar vein, some jurisdictions such as the United States of America recently introduced a proposal (see BGFRS (2012)) for applying tighter single counterparty credit limits of 10

[7] We thank Philip Hartmann for this remark.
[8] In the same way that it is applied to any other exposures to third parties.
[9] The Committee has not decided whether the limit should be based on Common Equity Tier 1 or Tier 1.

percent of the capital stock and surplus for so-called covered companies.[10] In the United Kingdom a firm must ensure that the total amount of its exposures to a single counterparty does not exceed 25% of its capital resources. However, for smaller firms there is an exemption that relaxes the limit up to 100% of a firm's capital base when the total exposure remains below EUR150m (see FSA (2012, pp.8)). Similarly, Germany extends the 25% limit up to 100% of an institution's own funds for interbank exposures of small institutions, but the size of the exposure should not exceed 150 Million Euro. The regulation in UK and Germany adds flexibility for interbank exposures of small institutions. In contrast, in Mexico the limit on inter-bank exposures is 100% of Tier 1 Capital, and this limit applies in the same way for all banks.

The aim of this paper is to assess the effectiveness of both regimes (i.e., general and dual) versus each other and versus the default option. The default option corresponds to the current Mexican regulatory limit which is 100% of Tier 1 capital. This means that any Bank in Mexico can lend up to 39 times its Tier 1 capital base. In this paper, the Systemically Important Banks (SIBs) are defined as the seven largest banks in terms of their asset size within the Mexican banking system.

The five options under study are: (i) a tighter limit of twenty-five per cent of Tier 1 capital for all bank's exposures; (ii) a relatively tighter limit (i.e., smaller than twenty-five per cent) for non SIB-to-SIB exposures and a twenty-five per cent limit for the remaining banks; (iii) a relatively tighter limit for SIB-to-SIB exposures and a twenty-five per cent limit for the remaining banks; (iv) a relatively tighter limit for both SIB-to-SIB and non SIB-to-SIB exposures; and (v) a conservative limit of ten per cent of Tier 1 capital for all

[10] The proposal defines a ''major covered company'' as any nonbank covered company or any bank holding company with total consolidated assets of $500 billion or more.

bank's exposures. In this context, a relatively tighter limit means a limit that is less than the twenty-five per cent. In particular, we use three different types of tighter limits: 20%, 15% and 10%. We use twenty-five per cent as reference because this is the limit that is used in a majority of countries according to a Committee's stock-take which is reported in BCBS (2013a, pp.18). Figure 1[11] illustrates schematically the benchmark case and the five options under analysis.

[**Insert Figure 1 here**]

Figure 2 shows each bank's exposure as a per cent of Tier 1 capital for SIB-to-SIB exposures, SIB-to-non SIB exposures, non SIB-to-SIB exposures and non SIB-to-non SIB exposures. In the figures we can see that exposures between SIBs-to-any bank are significantly lower than those of non SIBs-to-any bank. In particular, SIB-to-non SIB exposures are lower than the ten per cent of Tier 1. We can conclude that the large capital base of SIBs provides them with good capacity as compared to that of small banks.

[**Insert Figure 2 here**]

A complete network is one where every bank has a symmetric exposure to all other banks (see Upper (2011)). The completeness index measures how close is a specific network to a complete network and takes a value of one when the network is complete and a value of zero when there is no single bilateral exposure among banks (i.e., a fully disconnected structure). Panel A in Figure 3 shows how complete is the structure of inter-bank exposures for the Mexican banking system and its corresponding sub-groups.

[Insert Figure 3 here]

[11] We are grateful to Matthew Willison and Rodney Ramcharan for their help in designing Figure 1.

The completeness index for SIB-to-SIB exposures stands out as its value is close to one. This means that SIBs are highly interconnected as compared to other bank types. The noteworthy feature about the index for non SIB-to-SIB exposures is that it increases from thirty to forty-five per cent. The completeness index for the banking system remains relatively low on average and around twenty per cent. Panel B in Figure 3 shows the strength of the relationship measured as the sum of Bank-to-Bank exposures as per cent of the total interbank exposure. Clearly, SIB-to-SIB exposures have a time-varying, but persistently strong link.

Figure 4 shows six Panels that serve to compare the difference in the structure of the interbank network for a specific point in time under analysis. In each Panel, each node represents a single bank, while the width of each 'arc' or 'link' reflects the size of the gross bilateral interbank exposure. Panel B stands out as it shows that the SIB-to-SIB interbank structure is relatively dense as almost all nodes are connected, while the wideness of most links suggests that the connection is relatively strong.

[Insert Figure 4 here]

We can conclude that there are two types of exposures that could have an impact on interconnectivity under stricter limits: SIB-to-SIB and non SIB-to-SIB exposures. Since the interconnectivity among SIBs is higher, we expect that limits on SIB-to-SIB should be more effective in reducing contagion risk.

3. Methodology

In this paper, we assess empirically the potential benefits of options (i)-(v) in reducing contagion risk. We perform two exercises: first, we assess the impact of an individual bank failure on the rest of the banks in an inter-bank ‘network’. Then, we do a stress test where we arbitrarily reduce the capital ratio of all banks to 10.5% (the Basel III minimum) to represent the impact of a simultaneous shock to all banks’ capital.[12] Although banks would not lend to each other in this type of extreme scenario,[13] setting all banks’ capital ratios at the minimum regulatory capital threshold provides an effective way to assess the effectiveness of LE limits for containing the risk of contagion. We use daily interbank data from 2008 to 2012. We identify the worst contagion chain for the period as the point in time where we find the highest share in total assets that is destroyed by contagious defaults (i.e., excluding the trigger bank). Default takes place when a bank incurs in losses that reduce its capital ratio below eight per cent.

It is important to point out that we solely focus on assessing potential benefits as measured by the effectiveness of tighter exposure limits to reduce the risk of contagion. The potential costs of tighter exposure limits may lead to disruptions in the functioning of inter-bank markets (i.e., efficiency costs). According to Upper (2011), a drawback of network models is that these are not ready to be used in cost-benefit analysis. However, we believe that this may not be an unsolvable issue in that a regulator may always request the banking industry to provide evidence of the cost of using a tighter limit.

In this section we explain how the sequential default algorithm works in practice and we present a framework for modelling the banks behavioural when the limit is tightened.

[12] Lopez-Castañon et al. (2012) show that the Mexican banking system is so highly capitalized that only extreme macro-economic scenarios serve for introducing generalized contagion.

[13] We thank Phillip Hartmann for highlighting this issue.

3.1 Sequential default algorithm

We follow the algorithm as suggested by Graf et al. (2005). The structure of the interbank relationships can be represented in matrix form as:

$$X = \begin{bmatrix} 0 & \cdots & x_{1j} & \cdots & x_{1N} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i1} & \cdots & 0 & \cdots & x_{1N} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & 0 \end{bmatrix} \quad \textit{with} \quad \sum_{j=1}^{N} x_{ij} = a_i, \quad \sum_{i=1}^{N} x_{ij} = l_j$$

Where X is an $N \times N$ matrix of bilateral interbank exposures, $x_{i,j}$ is the exposure of bank i vis-à-vis bank j such that a_i is bank's i interbank assets and l_j is bank's j interbank liability. The zeros on the diagonal are due to the fact that banks do not lend to themselves. Each element $x_{i,j}$ represents a bilateral aggregated interbank exposure. It is important to point out that each aggregate exposure represents the sum of gross bilateral current exposures. For each point in time under consideration, we compute each interbank exposure as the sum of the amount of concerted exposures during the day plus any remaining current exposure from previous periods. Our measurement process takes into account the fact that outstanding interbank exposures may have a term of more than one day.

In the literature, there are two approaches for populating the matrix of interbank exposures: maximum entropy (ME) or observed (i.e., actual) interbank exposures. We populate the interbank matrix with reliable direct information on bilateral exposures. Commercial banks fill in a regulatory report that is collected by Banco de Mexico. The report is comprehensive and complete in that it includes information for off-balance sheet exposures. The ME approach is based on banks' balance sheet data. The underpinning assumption is that banks maximise the dispersion of their interbank exposures, that is, banks spread their lending as evenly as possible given the assets and liabilities reported in the balance sheets of all other banks. Mistrulli (2011) shows that an interbank matrix based on actual bilateral exposures has several advantages over an interbank matrix based on ME. Figure 5 compares the difference in terms of structure between a network generated by ME vis-à-vis a network based on actual bilateral exposures. Each 'node' represents a bank, while each 'arc' represents a bilateral exposure between each pair of banks. The nodes do not reflect the size of the banks due to confidentiality reasons. The difference in the size of the arcs shows that a network based on ME does not reflect the complex structure of a network based on actual data.

[Insert Figure 5 here]

Moreover, Upper (2011) concludes that any estimates obtained from ME are biased as this method is not able to reproduce a number of stylised facts of interbank markets such as the sparseness of X or tiering. It is convenient to point out that tiering arises because lower tier banks do not lend to each other but transact only with top tier banks, which tend to be tightly linked (see Upper and Worms (2004) and Craig and von Peter (2009) for evidence on tiering). Ideally, from an informational perspective, an exercise on the calibration of interbank limits requires as a minimum: observed data on bilateral exposures and a period of time that covers a bad economy state. This paper broadly satisfies these two conditions. Unfortunately, the paper may be regarded as limited in that the Mexican banking system has no consolidated data for large internationally active banks.

Exposures in the Mexican Interbank market include: uncollateralized interbank lending, holdings of securities issued by bank counterparties[14] and credit components that

[14] Data does not include non-negotiable securities

arise in derivative transactions.[15] All exposures are measured after credit risk mitigation. It is important to point out that FX transactions are not included as most of these are cleared through the Continuous Linked Settlement (CLS) Bank which serves as a central counterparty (see Banco de México (2011, pp. 105-106)). We do not consider any netting agreements among banks.[16] The current limit for interbank exposures is 100% of Tier 1 capital. This limit applies solely for the aggregate bilateral credit exposures such as loans, securities and derivative positions.

Contagion mechanism follows a sequential default algorithm that can be described as a four-step process: (1) A bank *k* fails by assumption due to an unknown exogenous reason (i.e., due to an idiosyncratic shock); (2) As a result, any bank *j* fails if it has a large bilateral exposure to bank *i* such that its capital ratio falls below the 8% threshold; (3) An additional round of contagion occurs when the aggregate exposure of any creditor bank to other banks that have failed in any previous round exceed its minimum 8% capital requirement; (4) The contagion process stops when no new failure occurs in a specific round. This sequential default algorithm is in line with current minimum capital requirement standard in the new Basel Accord.[17]

We compute the capital ratio for any bank *j* that is exposed to contagion risk as:

$$CR_j = \frac{RC_j - \sum_k \left(\theta_{jk} \times x_{jk} \times 1_{k\in D}\right)}{RWA_j - \sum_k \left(w_{jk} \times \theta_{jk} \times x_{jk} \times 1_{k\in D}\right)} \tag{3.1}$$

Where CR_j is bank's *j* capital ratio, RC_j is bank's *j* regulatory capital (Tier 1 Capital plus Tier 2 Capital), θ_{jk} is the loss given default (*LGD*) of bank's *j* exposure to bank *k*, w_{jk} is the

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[15] The credit component arising in derivative transactions considers OTC Forward, Swaps and Options transactions. More information on how these exposures are aggregated may be provided upon request.

[16] However, when we analyse forward derivatives, we consider that contracts terminate at the time of failure. Therefore, the maximum loss considered for the failing bank's counterpart due to derivatives is the favourable net amount due at the time of failure.

[17] See BCBS (2011b, paragraph 50).

regulatory risk-weight for interbank exposures and x_{jk} is the exposure of bank j to bank k, $1_{k \in D}$ is an indicator variable that takes a value 1 when bank k fails (and 0 otherwise).[18] Note that the actual interbank loss of the creditor bank in the event that the debtor bank fails is the sum of the *LGD* multiplied by the total bilateral aggregate exposure of a creditor bank to any potential failing debtor bank.

As in similar studies, we assume that banks in the second stage don't take any corrective action in response to the initial bank failure. We assume that θ_{jk} is constant across banks and rounds (i.e., θ_{jk}=100%). We follow the standardized approach for credit risk such that w_{jk}=20% (i.e., $w_{ji}=w$).[19] As shown in the denominator of eq. (3.1), we discount from the creditor bank's risk-weighted assets every claim to a failed bank. It is important to point out that we could follow an alternative default criterion based on Basel Accord standards such as a minimum Common Equity Tier 1 that is at least 4.5% of RWAs at all times or a Tier 1 capital of at least 6% of RWAs at all times. However, our approach is the most conservative as a large share of the regulatory capital of all banks in Mexico is composed by Tier 1 Capital.

Our algorithm is similar in nature to that of Furfine (2003).[20] Upper and Worms (2004), Furfine (2003) and Van Lelyveld and Liedrop (2006) find that losses in the total banking system depend to a large extent on the *LGD* value. The standard in the literature on interbank contagion is to assume a fixed value for the *LGD* such that the analysis is repeated across a large number of *LGD* values between 0 and 1.[21] Our analysis differs from

[18] The subscript *D* is a set that comprises all banks that fail in any round.
[19] A risk-weight of 20% corresponds to the standard available in the Basel I and Basel II framework.
[20] Both Márquez and Martinez (2009) and Solórzano et al (2013) provide an alternative way for solving this algorithm that is significantly more efficient in that it is less time consuming.
[21] Memmel et al. (2012) extend this framework for the case where the *LGD* follows a stochastic process and find that this leads on average to a more fragile banking system than under the assumption of a constant *LGD*.

others in that we don't measure the risk of contagion for different *LGD* rates. Instead, we simply take the most conservative approach in that we fix the *LGD* at 1 which in our view allows a more realistic assessment of contagion risk. This approach is consistent with the long held view that real world recovery processes are characterized by a large degree of uncertainty.

As pointed out by Memmel et al. (2012, pp.178) the sequential default algorithm under study investigates solely the direct mechanic contagion effect in the interbank market. In so doing, this analysis is limited in that it incorporates only a part of the possible contagion effects. Moreover, this methodology does not consider potential reactions of the creditor bank such as the use of alternative reserves which may be released to raise their regulatory capital. However, in our paper this analysis is reliable (i.e., relatively accurate and precise) in that it has the benefit of being based on actual interbank data and comprehensive in that we cover 100 percent of the total assets of the Mexican banking system.

3.2 Banks' behavioral response in the presence of a tighter limit

A key issue that remains unsolved is how to model the effect of tightening a large exposure limit. In other words, we want to know how would banks respond if the limit is reduced from x% to y%. In principle, we identify two polar responses: (i) a bank with inter-bank exposures of z% exceeding the y% limit could reduce its exposure to y% and leave the (z-y)% excess amount in its account with the central bank (i.e., out of the interbank network of bilateral exposures); or (ii) a bank with inter-bank exposures of z% exceeding the y% limit could reduce its exposures to y%, but increase exposures to other banks so that the size of its balance sheet does not change. Polar case (ii) assumes that all the counterparties of a bank have the capacity to take the excess exposure. However, full allocation of any bank's excess exposure may not be feasible in an extreme scenario along with a tight limit. In addition, polar case (ii) requires a rule for determining how allocation will take place (i.e., how much of the exceeding exposures will be allocated to each potential counterpart). The two behavioural responses could have different implications for the effect the reduction in the limit has on contagion risk. For instance, the latter response might lead to greater contagion because losses from the failure of a bank might spread across more counterparties, and hence there may be more counterparties affected.

In a real-world network, the answer would lie somewhere in between polar case (i) and (ii). A good starting point would be to allocate the excess exposure amount evenly among all the counterparts of any bank. However, this modelling option lacks any economic rationale and may introduce a number of inconveniences such as the creation of new bilateral links that might never occur in practice. Therefore, we suggest using the lending preference index (*LPI*) as proposed by Cocco et al. (2009) for modelling the process by which a bank allocates inter-bank lending that exceeds the regulatory limit. *LPI* measures the intensity of lending activity between banks. In particular, for every lender (*L*) and every borrower (*B*), the *LPI* is computed as the ratio of total funds that *L* has lent to *B* during a given period, over the total amount of funds that *L* has lent in the interbank market during the same period. Let $F_i^{j \to k}$ denote the amount lent by bank *j* to bank *k* on loan *i*, then:

$$LPI_{L,B,t} = \sum_{i \in t} F_i^{L \to B} \Big/ \sum_{i \in t} F_i^{L \to all} \tag{3.2}$$

Where *t* denotes the time period. A feature about this index is that if *L* is an important lender for B, then the *LPI* should be close to one. An index with a low value highlights a weak relationship between any pair of banks. In practice, banks lend to each other for different reasons and show a preference to lend to specific banks. Table 2 shows the *LPI* for each bank's top five counterparties. We compute the *LPI* for the past 120 days. In Cocco et al. (2009), the choice for the number of past days is somehow arbitrary. However, Cocco et al. (2009) compute the *LPI* on a quarterly basis and they show that this time-window provides a robust measure.

There are significant asymmetries in financing in the Mexican interbank market. In particular, SIBs lending preference is largely concentrated among SIBs. We can conclude that both SIBs and non SIBs find it hard to establish new lending relationships with other borrowers and show a preference to lend to specific banks. Moreover, a large number of banks show preference indexes near to zero or even zero, which means that banks do not establish relationships with all banks.

In this paper, we set out the following proposal for how the *LPI* can be used to adjust an inter-bank exposures matrix for different values of a large exposure limit. In short, we propose to allocate any bank's *i* excess exposure among its counterparts according to its lending preference index. In so doing, we identify two possible cases. In the 'partial-allocation' case, we assign (i.e., based on the preference index) solely once the amount that is possible to reassign without breeching the individual limit, while the remainder is kept at the bank's *i* current account with the central bank (i.e. out of the network). The economic rationale is that when banks are constrained by tighter limits on their bilateral exposures, then they will try to reallocate a share of their excess exposure among their traditional or well-known counterparties, and any remainder will be kept on the bank´s account at the central bank. This scenario implicitly assumes that each bank's informational asymmetry about other banks is huge.

In the 'full-allocation' case, we assign the excess exposure as much as possible, based on the preference index, while the remainder is re-allocated evenly on the remaining banks that have capacity to take the excess exposure. The excess exposure for any bank *i* is allocated as follows: (a) first, we identify which banks have spare capacity. We say that any bank *j* has spare capacity when the size of its bilateral exposure with bank *i* has not breached the limit. (b) then, we assign the excess exposure according to the *LPI* such that we fill the bilateral exposure of those banks that do not have enough capacity to take their corresponding excess exposure (c) finally, we allocate the remainder evenly among banks with spare capacity. Note that in an extreme case we may not be able to fully allocate the remainder in full. In this case, we assume that the excess amount is deposited at the current bank's account with the central bank. The economic rationale is that the cost of not lending the excess funds outweighs the cost associated with the risk of doing business with non-regular counterparties. A minor drawback in implementing our allocation scheme is that we don't take into account the composition of banks' assets when allocating each creditor bank excess exposure.[22] However, we believe that refining the allocation scheme will not change the paper key findings.

For the point in time under consideration, we create a number of new bilateral links under both 'partial' and 'full' allocation. The main difference between these two allocation schemes is that we don't create artificial lending relationships (i.e., links) in the 'partial' allocation case. We say that a lending relationship is artificial when a new exposure is created between any bank pair even though their corresponding *LPI* is zero. In the 'full' allocation we diversify the excess exposure as much as possible among the bank's counterparts. For any bank we assume under both 'partial' and 'full' allocation that lending

[22] We thank Philipp Hartmann for raising this issue.

in the interbank market is more attractive than putting their resources at their current account with the central bank. In contrast, Polar case (i) assumes that the cost of lending to other banks is larger than its corresponding benefit.

An example is useful to illustrate how to implement this proposal in practice. Assume that the interbank market comprises five banks: A, B, C, D and E. Moreover, assume that the lending preference indexes for bank A to its four counterparts (i.e., B, C, D, E) are 50%, 30%, 15% and 5%, respectively. Assume that the single exposure that breaches the limit by an amount '*x*' is the exposure of bank A to bank B. Then, excess exposure *x* can be assigned in the following way: 60% will be allocated to bank C (i.e. $2*LPI_{A,C}$), 30% to bank D (i.e., $2*LPI_{A,D}$) and 10% to bank E (i.e., $2*LPI_{A,E}$). The idea is to ensure that the full amount *x* is allocated among bank A counterparts. Some counterparts may not be able to absorb their full excess amount. In the partial allocation case, we leave the remainder at the central bank (i.e., out of the network). In the full allocation case, we redistribute the remainder among the counterparts that have spare capacity.

4. Results

In this section, we report and analyse the results of the network simulation. First, we assess the impact of an individual bank failure on the rest of the banks in an interbank network. We compare descriptive and contagion statistics for the five options (i)-(v) that we identified in Section 2. We show that the modelling of the banks' behavioural responses does not alter the main findings. This result is a consequence of the highly capitalized Mexican banking system. Then, we analyse stress test results where we arbitrarily reduce the capital ratio of all banks to 10.5% (the Basel III minimum) to represent the impact of a simultaneous shock to all banks' capital. For each of the five options (i)-(v), we compare how contagion risk evolves as a result of the banks' behavioural response. In this case, we show that results are significantly sensitive to the modelling of the banks' behavioural responses. Finally, we assess whether tighter limits may be binding for non SIB banks in Mexico. In particular, we focus on the share of non SIB interbank funding and we analyse how much funding would be precluded in the presence of a tighter limit.

4.1 Impact of an initial idiosyncratic bank failure

Table 3 shows a set of useful descriptive statistics about the Mexican interbank market. The sum of banks' assets to GDP is approximately 42%. The banking system is largely concentrated among SIBs as the share of assets to GDP is approximately 36%. The sum of SIBs interbank exposures to SIBs total assets remains small at 2.46%, while the sum of SIBs interbank liabilities to SIBs total liabilities is low at 3.07%. The average SIBs regulatory capital ratio remains high at 15.85%, while non-SIBs corresponding capital ratio more than doubles that of SIBs. However, standard deviation of the regulatory capital ratio remains low solely for SIBs. The average leverage ratio is around 5% for both SIBs and non-SIBs. The average bank in the Mexican interbank market is a net borrower. In turns, an average SIB is a net borrower in the interbank market, while on average a non-SIB is a net lender.

Descriptive statistics for the case where a bank puts its excess interbank exposure amount in its current account at the central bank are shown in Table 4.[23] Panel A reports the number of exposures exceeding the limit as a per cent of the number of exposures in both the banking system and per type of interbank exposure[24] for the five options under

[23] We are grateful to Matthew Willison and Rodney Ramcharan for their suggestions on meaningful limits.
[24] We identify and aggregate interbank exposures in four types: SIB-to-SIB, SIB-to-NonSIB, Non-SIB-to-SIB, and Non SIB-to-Non SIB.

consideration. From Panel A we can see that: (i) there is no exposure breaching the regulatory limit; (ii) the percentage of the number of exposures that breach the limit increases as we move from Option 1 (i.e., 8%) to Option 5 (i.e., 16%); (iii) the percentage increase is largely driven by the significant increase in SIB-to-SIB exposures (e.g., the percentage increases from 5% in Option 1 to 14% in Option 5); (iv) the percentage increase in Non SIB-to-SIB exposures is material (e.g., percentage increase from 20% in Option 1 to 31% in Option 5); (v) the percentage of SIB-to-Non SIB is zero for all options due to the fact that exposures of SIB-to-Non SIB are relatively small in terms of the capital base of large banks; (vi) The percentage of Non SIB-to-Non SIB remains relatively small at 6%, but increases significantly in Option 5 to 15%. This suggests that the flow of funds provided by non SIBs-to-Non SIBs will be hampered in the presence of a tight limit (i.e., 10% limit). Information about the number of exposures that breech a limit is partially useful as this number does not identify the amount of interbank exposure that breaches the limit. Panel B in Table 4 shows that the size of the interbank exposures exceeding the limit as per cent of the sum of all exposures in the banking system is 45% for the case of Option 5 (i.e., the most conservative option). This means that nearly half of the interbank resources are deposited at the end of the day in the banks' current accounts at the Central Bank. The results could be sensitive to the assumptions made about how banks respond to a tightening of the large exposure limit.

Panel A in Table 5 reports statistics for the number of bank failures. This is useful to identify the number of contagion cases in the worst day and in how many of these cases we observe a SIB failure due to contagion. Since the banking system comprises forty banks, we assess up to forty idiosyncratic bank failures. We observe a contagion case in five out of forty idiosyncratic bank failures. The maximum number of bank failures in a single contagion case is four. The noteworthy feature is that we observe a single SIB failure in only one case out of the five contagion cases. The impact of the SIB failure is significant. Panel B in Table 5 reports statistics for the loss solely due to contagion. The average interbank loss as per cent of regulatory capital is 7%, while the maximum loss as per cent of the system's regulatory capital is 17%.

It is common practice in the literature when analysing the results concerning single bank failures to focus in the share of total assets that is destroyed by contagious defaults (i.e. excluding the trigger bank). The last row in Panel B in Table 5 shows that the share of total assets destroyed by contagion due to idiosyncratic failure for the Benchmark case is 18%. This result is significant and similar to those reported in the literature. Van Lelyveld and Liedorp (2006) find that contagion due to the failure of a domestic institution in the Netherlands affected at most 7% of total assets. Upper and Worms (2004) find that contagion in the worst case scenario represents 15% of total assets in the German banking system. In a recent study, Memmel et al. (2012) find that on average 14 percent of assets in the remaining banking system are affected by bank failure, while Karas and Schoors (2012) find a 13% of total assets for Russia in a worst case scenario. These numbers are similar in magnitude to: (i) the 20% of total assets obtained by Degryse and Nguyen (2007) for Belgium; (ii) the 16% found by Mistrulli (2005) for Italy; and (iii) 16% found by Wells (2004) for the UK. Upper (2011) summarises the various sources of differences in methodologies and the corresponding biases that may arise from the assumptions that underlie the simulations.

Table 5 shows that there is risk of contagion under the current regulatory large exposure limit in Mexico.[25] However, the risk of contagion disappears when the limit is reduced to 25% of Tier 1 or lower under any of the alternative options. It is important to point out that this result holds even when we consider different banks' behavioural responses.[26] This exercise suggests that it is enough to impose a 25% limit to completely eliminate the risk of contagion. However, these results may be driven in part by the high capital ratios of the Mexican banks. The average capital to risk-weighted assets ratio of a Mexican Bank for this period was close to 15.71%. This average capital ratio is significantly higher than mandated by the Basel Accord. Moreover, deductions from Tier 1 capital under Mexican regulation were already in line with Basel III recommendations.

It is worth exploring stress test results as: (i) banks in other jurisdictions might not have high capital ratios; (ii) the analysis so far focuses on contagion only among banks operating in Mexico; (iii) we don't consider alternative channels of contagion such as those arising from exposures from the payments and settlement systems (see Mistrulli (2011, pp.1116)); (iv) banks are not allowed to issue shares in order to compensate for the losses they suffer from the failure of some interbank market counterparties (see Mistrulli (2011, pp.1116)); (v) we don't assess the role of multiple initial bank failures that may arise as a consequence of a large macroeconomic shock (see López-Castañon et al. (2012)); (vi) we don't consider the potential adverse impact of banks' exposures to non-bank intermediaries (see Solórzano-Margain et al. (2013)); (vii) we don't model funding liquidity risk (see Bhattacharya and Gale (1987), Cifuentes et al. (2005), Aikman et al (2009), Gauthier et al. (2010)); (viii) we don't allow for specific factors such as fire asset sale externalities (see

[25] This result arises for the worst possible day -in terms of contagion- during the period of study.
[26] Since results don't differ, we don't duplicate Tables. However, these are available upon request.

Alessandri et al. (2009), Gauthier et al. (2010)); (ix) we don't consider the role of central bank intervention when confronted with a systemic shock (Freixas et al. (2000, pp.612)); (x) we don't take into account that a well-capitalized foreign parent may support or bail out its Mexican subsidiary (see FSB (2012, pp.18)); and, (xi) there is a need to assess the role of limits on interbank exposures in a fragile banking system. Even though there are a number of shortcomings, we believe that our system-wide calibration approach is adequate. The reason is that the limits on interbank exposures for single name concentration risk should focus on mitigating the traumatic loss that a bank may incur when a single counterparty defaults.

4.2 Stress testing

In this Section we analyse what happens if the capital ratios of all banks are reduced to Basel III minimum requirements. In so doing, we implicitly assume that there is a large shock to the banking system that reduces the capital of all banks. We still keep the contagion framework simple as we measure the impact of an individual bank failure on the rest of the weakened banks in the interbank network.

Table 6 compares the size of the inter-bank exposure that exceeds the limit for the three different types of banks' behavioural responses. The Table shows that when there is no allocation, the size of the exposure exceeding the limit as per cent of the sum of all banks' exposures for Option 5 (i.e., the most conservative) increases from 45% in a no stress scenario to 63% under stress. The percentage increases by almost one third. Therefore, the capital shock may be regarded as large. When partial allocation and full allocation take place, we observe in Table 6 that the percentage in Option 5 reduces to 34% and 1%, respectively. Thus, our partial allocation mechanism is good in that we redistribute almost half of the excess exposure percentage that would stay out of the network in the no allocation case, while our full allocation mechanism is efficient in that we are able to reallocate almost the full excess exposure within the network.

The simplest way to assess the impact of the banks' behavioural responses under stress is to compare the three banks' responses per limiting option. Table 7 shows banks' behavioural responses for limit Option 1. The Table reveals that the 25% limit is no longer enough to contain the risk of contagion. The assumed capital shock is severe in nature and we have to introduce tighter limits, especially to prevent the failures of SIBs. Moreover, the first row in Panel A shows that the number of cases where contagion occurs increases significantly from the no allocation (i.e., 7) to the partial allocation (i.e.,11) to the full allocation (i.e., 14). The last row in Panel B shows that the share of assets destroyed by contagion increases from 27% to 44% as we move from the no allocation to the full allocation. Moreover, Panel C shows three topological measures. The total number of exposures (i.e., total number of arcs) increases from 263 under no allocation to 467 in the partial allocation to 902 in the full allocation. In the same way, the average number of banks that a bank is linked to (i.e., the average degree) increases from 9 under no allocation to 15.3 in the partial case to eventually 31, while the completeness index[27] increases from 23.1% (i.e., no allocation) to 39.2% (i.e. partial allocation) to 79.5% (i.e. full allocation). Thus, the modelling of the banks' behavioural responses alters the structure of the network considerably.

The rationale for having more contagion in the partial and the full allocation case can be understood in terms of the cost and benefits of allocating the excess exposure. The benefit of introducing a general tighter limit is that we reduce large bilateral interbank

[27] A market is complete when each Bank lends to all the others, and so, the completeness index is 100%.

exposures. A second benefit may arise if we allocate the excess exposure evenly among all banks counterparties. An even allocation where we distribute a small excess exposure amount may have an inconsequential impact in terms of contagion as the bilateral links may not be largely modified. The downside is that the structure of the network is altered as we create artificial links that may never occur. However, allocating the excess exposure according to the *LPI* comes at a cost of widening key lending links for both SIB-to-SIB exposures and non-SIB-to-SIB exposures. Allocating using the *LPI* rule may lead to relatively large excess exposure amounts whose role in serving as drivers of new contagion chains is not inconsequential. In turn, these widened key lending links may intervene in other contagion chains. Thus, it is not surprising that the number of both SIBs and non SIBs failures due to contagion increase under a fragile banking system.

Table 8 shows banks' behavioural responses for limit Option 2 (i.e., tighter limits on Non SIB-to-SIB exposures). The Table reveals that tighter limits on Non SIB-to-SIB exposures are not enough to mitigate contagion in a stress scenario. Interestingly, even though the number of bank failures in a single contagion case is larger for the partial than for the full allocation case, the share of assets destroyed by contagious defaults remains larger for the full allocation scheme. This result remains in line with the rationale for having more contagion in the case of full allocation.

Table 9 shows banks' behavioural responses for limit option 3 (i.e, tighter limits for SIB-to-SIB). Interestingly, limiting SIB-to-SIB exposures is effective in reducing contagion risk for both the no allocation and the partial case. In particular, the share of assets destroyed by contagious defaults for 'no allocation' and 'partial allocation' remains low at 2% and 5%, respectively. However, this limit is not useful to constrain contagion risk in the full allocation case. Moreover, we find a non-linear effect as measured by the share of assets destroyed by contagious defaults that starts at 44% under a limit of 20%, then decreases to 19% under a limit of 15%, and finally increases to 44% under a limit of 10%. The outstanding feature about the 15% limit is that we have a single SIB failure, whereas we have two SIB failures for the other two limits (i.e., 20% and 10%). Further analysis on this issue reveals that the turning points for the full allocation occur for a limit of 17.05% and 10.96%, respectively.

The rationale for having a non-linear effect in the full allocation case can be explained as follows. A tighter limit on SIB-to-SIB exposures under full allocation may lead to two cases. In principle, we may allocate the full excess exposure among banks counterparties using the *LPI* rule. According to the *LPI* rule (see Table 4), most of the excess exposure should be allocated among SIBs. However, this approach requires that SIBs have enough capacity to absorb the excess exposure. When this condition is not met, we allocate the remainder evenly among bank counterparties. In so doing, we create artificial links between SIBs-to-nonSIBs exposures. Since the network structure is altered, we may find a case where the diversification of the excess exposure may lead to a decrease, and then back to an increase in contagion risk as we vary the size of the limit. In this case, contagion is induced by SIB exposures to nonSIBs. The failure of a non SIB might not in itself generate material costs for a large bank, but the failure of multiple highly interconnected non SIBs could have a systemic impact. It is important to point out that the survival margin for the SIB that does not fail for the limit of 15% is low in the full allocation case.

Table 10 shows banks' behavioural responses for limit Option 4 (i.e, tighter limits for both SIB-to-SIB and Non SIB-to-SIB). As in the previous case, this type of limits is effective in reducing contagion under both 'no allocation' and 'partial allocation'.

However, this limit is not strong enough to mitigate contagion risk in the full allocation case. Moreover, the non-linearity effect as measured by the share of destroyed assets due to contagion persists in case of a 10% limit in Option 4. Apparently, there is a SIB that fails due to contagion due to its link to a large number of non-SIBs that fail as a result of an initial SIB failure.

Table 11 shows banks' behavioural responses for limit Option 5 (i.e, generalized tighter limit for all banks). The noteworthy feature is that this limit fully eradicates contagion risk even for the case where we have 'full allocation'. Although the benefit (i.e. reduction in contagion risk) of applying this limit is attractive, the cost may be large especially for non SIBs. Moreover, we need to study non SIBs funding to assess the convenience of this type of limit.

We must highlight that lending limits have implications both for the lender and for the borrower. Our analysis is limited in that we are not modelling banks funding behaviour. We are currently extending our simulation framework to incorporate these effects through the borrowing preference index. Finally, the results show that possible unintended consequences might arise if very strict limits are imposed on a banking system.

4.3 Non SIB Funding

In general terms, the probability that a banking crisis arises as a result of a non SIB failure is small.[28] However, non SIBs play a crucial role in traditional financial intermediation services and their importance in the provision of these services may increase during times of financial stress. A tight large exposure limit (i.e. 25% of Tier 1 Capital) may be binding for some non SIBs. Figure 2 shows that non SIB-to-any bank exposures are relatively large.

[28] However, Karas and Schoors (2012, pp.21) describe a case in Russia, where the failure of a single small bank in 2004 caused panic to such extent that the whole interbank market nearly collapsed.

Since the capital base of non SIBs is small, interbank exposures as a per cent of Tier 1 capital are on average larger for non SIBs vis-à-vis SIBs. Figure 2 shows that a 25% limit will be more binding for a large number of Non-SIBs-to-any bank exposures than for SIBs-to-any bank exposures. Figure 6 shows that Non SIBs funding provided by Non SIBs is on average 80%, but may increase beyond 90% in some periods. However, if we apply a 25% limit of Tier 1 Capital, then the Non SIBs funding would be on average 55%. This means that a limit would seriously alter non SIBs funding.

[Insert Figure 6 here]

An exemption of large exposure limits for small banks may be important for the following reasons. First, international standards such as those promoted by the Basel Committee on Banking Supervision apply solely to large internationally active banks. Second, some jurisdictions do not distinguish between non SIBs and SIBs, and apply the same banking regulatory measures alike. In some jurisdictions, there is no room for discriminating between non SIBs and SIBs. Thus, a tight limit may kill the funding of non SIBs to non SIBs. Third, non SIBs in emerging markets may find difficulties in finding alternative sources of funding. Moreover, SIBs may remain reluctant to fund some non SIBs.

5. Concluding Remarks

The well-functioning of the interbank market is of paramount importance for the stability of the financial system. This paper develops a calibration framework based on individual bank idiosyncratic failures to test whether tighter limits on interbank exposures reduce financial contagion in the banking system. In so doing, we test tighter limits on interbank exposures under both regular and stress conditions. The interbank exposure limits serve as a backstop to capital requirements such that their value remains unrelated to the bank’s capital ratio. We assume that the systemic importance of banks within the network can be distinguished solely by their asset size. This is useful in that we can identify four simple types of interconnections (i.e., SIB-to-SIB, SIB-to-non SIB, non SIB-to-SIB, non SIB-to-non SIB) and focus on the best way to limit their degree of interconnectedness. We calibrate the model using proprietary data based on emerging country banking.

Our first finding is that a limit of 25% of Tier 1 Capital is enough from a system-wide perspective to contain the risk of contagion under normal conditions. Unfortunately, a limit of 25% of Tier 1 Capital is not enough from a system-wide perspective to contain the risk of contagion under a severe stress scenario. In particular, we find that there is a number of SIB failing due to contagion. Our second finding is that the risk of contagion in the Mexican interbank market can be significantly reduced by introducing a tighter limit solely for SIB-to-SIB exposures (i.e., 20%) when the banks' behavioral response follows either the 'no allocation' or the 'partial allocation' scheme. Since large banks play a key role as intermediaries of financial resources, we believe that a meeting with the industry would be adequate to assess the costs of implementing this type of limit. Our third finding is that a limit on nonSIB-to-SIB exposures may be regarded as helpful in reducing contagion risk solely when applied jointly with a limit on SIB-to-SIB exposures. Our fourth finding is that a tighter LE regulation may increase the risk of contagion under both 'partial' and 'full' allocation scheme. Finally, our stress test results also show that a generalized 10% limit fully eradicates contagion risk and this applies for the three types of banks' behavioral responses that we analyze.

Regarding banks' behavioral responses when the excess exposure is partially or fully allocated among bank counterparties according to the *LPI*, we find that the benefits of introducing tighter limits and the corresponding diversification of interbank exposures are counterbalanced by the fact that each bank establishes a large number of financial linkages that may increase the impact of a domino effect. A thorough simulation of banks' behavioral responses in the presence of tighter limits (i.e. the funding response of the bank towards a tighter limit) is a task that we leave for future research.

The calibration results also indicate that more research is needed for introducing tighter limits for small banks. A number of reasons support this view. First, tighter limits on non SIB-to-SIB exposures are not as effective in reducing contagion risk as a tighter limit on SIB-to-SIB exposures. Second, funding requirements of small banks are large due to their relatively small capital base as compared to that of SIBs. Besides, level playing field conditions and the promotion of a competitive environment require the exemption of tighter limits for small banks to promote their competitive survival. Mergers and acquisitions may reduce the number of banking institutions and this may be especially harmful in small banking systems. Regulators should promote the development of small banking institutions, especially in countries where non-bank financial service providers have become increasingly important participants in the financial services sector. Third, we agree in that the failure of a small bank does not bear the same cost as the failure of a large bank.

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Table 1 Interconnection in the Inter-bank network for the worst contagion chain

	Network Structure		
	Complete	Incomplete	Proportion
Number of bilateral exposures	1560*	263†	16.85%
SIB-to-SIB exposures	42[a]	37	88.09%
SIB-to-non SIB exposures	231[b]	46	19.91%
Non SIB-to-SIB exposures	231[b]	55	23.80%
Non SIB-to-non SIB exposures	1,056[c]	125	11.83%

*The network comprises 40 banks. The interbank market can be represented as an $N \times N$ matrix. The matrix of bilateral exposures may have up to 1600 elements. Since banks don't have claims on themselves, the number of exposures in a complete structure reduces to 1560.

†This number refers to the number of bilateral exposures observed for the day where the worst contagion chain was found.

[a] Since the Mexican Banking System has seven SIBs, there are 42 (i.e., 7×6) SIB-to-SIB exposures

[b] Since the Mexican Banking System has seven SIBs and thirty-three non SIBs, there are 231 (i.e., 7×33) SIB-to-non SIB exposures and 231 (i.e., 33×7) non SIB-to-SIB exposures.

[c] Since the Mexican Banking System has thirty-three non SIBs, there are 1,056 (i.e., 7×33) non SIB-to-non SIB exposures.

Table 2. Lending Preference Index for the Mexican interbank market

Bank	Lending Preference Index					Sum
	Bank Counterparts*					
	1	2	3	4	5	
SIB 1	76.5%	15.0%	3.1%	2.2%	1.3%	98.0%
SIB 2	49.6%	27.3%	5.9%	5.2%	4.1%	92.1%
SIB 3	34.5%	26.1%	16.6%	15.7%	3.5%	96.4%
SIB 4	27.4%	26.6%	19.6%	19.3%	5.5%	98.4%
SIB 5	37.1%	16.1%	13.3%	11.2%	10.4%	88.2%
SIB 6	52.5%	20.4%	11.5%	8.4%	4.8%	97.6%
SIB 7	63.2%	12.1%	7.5%	5.6%	5.0%	93.4%
Non SIB 1	46.3%	18.5%	6.9%	6.6%	5.7%	84.1%
Non SIB 2	34.3%	13.0%	9.5%	7.1%	6.6%	70.5%
Non SIB 3	49.4%	15.0%	13.2%	6.0%	5.6%	89.2%
Non SIB 4	23.7%	18.5%	13.7%	11.8%	5.9%	73.6%
Non SIB 5	14.5%	13.0%	12.6%	12.2%	11.6%	63.9%
Non SIB 6	42.0%	13.4%	13.2%	11.1%	6.6%	86.3%
Non SIB 7	26.8%	20.3%	13.7%	9.7%	7.6%	78.2%
Non SIB 8	28.9%	16.6%	16.3%	11.0%	6.6%	79.4%
Non SIB 9	40.7%	34.1%	17.8%	6.2%	0.7%	99.5%
Non SIB 10	40.2%	20.6%	11.4%	9.0%	6.3%	87.5%
Non SIB 11	78.6%	18.3%	1.6%	0.7%	0.3%	99.6%
Non SIB 12	42.9%	27.1%	12.7%	9.9%	5.0%	97.6%
Non SIB 13	45.0%	26.2%	10.9%	5.9%	5.0%	93.0%
Non SIB 14	27.3%	20.3%	19.4%	15.7%	5.2%	87.9%
Non SIB 15	54.7%	21.3%	12.4%	3.0%	1.4%	92.9%
Non SIB 16	33.4%	26.8%	20.7%	10.9%	4.0%	95.8%
Non SIB 17	98.6%	0.9%	0.2%	0.1%	0.1%	99.8%
Non SIB 18	42.3%	33.6%	12.9%	8.6%	1.0%	98.4%
Non SIB 19	36.4%	34.0%	17.9%	5.8%	2.2%	96.2%
Non SIB 20	38.1%	17.1%	16.8%	10.2%	7.9%	90.2%
Non SIB 21	91.0%	6.0%	1.7%	0.6%	0.3%	99.5%
Non SIB 22	43.6%	32.0%	7.4%	6.4%	5.4%	94.8%
Non SIB 23	46.5%	36.5%	4.4%	3.7%	3.7%	94.8%
Non SIB 24	39.2%	32.6%	10.5%	5.9%	3.3%	91.6%
Non SIB 25	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Non SIB 26	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non SIB 27	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Non SIB 28	36.6%	35.5%	16.7%	6.1%	5.2%	100.0%
Non SIB 29	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non SIB 30	37.0%	13.5%	12.2%	10.1%	9.1%	81.8%

Non SIB 31	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non SIB 32	96.9%	3.1%	0.0%	0.0%	0.0%	100.0%
Non SIB 33	88.7%	10.7%	0.5%	0.1%	0.0%	100.0%

*Bank counterparts are ordered from left to right according to their importance as measured by the lending preference index.

Table 3. Descriptive statistics for the Mexican Interbank System per Bank Type

Sum of banks' assets / GDP	41.66%
Sum of SIBs assets / GDP	36.13%
Sum of non-SIBs assets / GDP	5.53%
Sum of interbank exposures / Sum of banks' assets	2.64%
Sum of SIB interbank exposures / Sum of SIBs assets	2.45%
Sum of non-SIBs interbank exposures / Sum of non-SIBs assets	3.87%
Sum of interbank liabilities / Sum of banks' liabilities	2.94%
Sum of SIBs interbank liabilities /Sum of SIBs liabilities	3.07%
Sum of non-SIBs interbank liabilities / Sum of non-SIBs liabilities	2.10%
Average regulatory capital ratio	31.12%
Average SIBs regulatory capital ratio	15.85%
Average non-SIBs regulatory capital ratio	34.36%
Standard deviation of regulatory capital ratio	34.32%
Standard deviation of SIBs capital ratio	3.46%
Standard deviation of non-SIBs capital ratio	37.03%
Average Tier 1 Capital Ratio	23.50%
Average SIBs Tier 1 capital ratio	7.98%
Average non-SIBs Tier1 capital ratio	26.79%
Standard Deviation of Tier 1 capital ratio	34.87%
Standard deviation of SIBs Tier 1capital ratio	3.52%
Standard deviation of non-SIBs Tier 1 capital ratio	37.63%
Average leverage ratio	5.02%
Average SIBs leverage ratio	4.97%
Average non-SIBs leverage ratio	5.35%

Table 4. Descriptive Statistics for the shock that arises from the idiosyncratic failure of each individual bank

	Benchmark	Option 1	Option 2			Option 3			Option 4			Option 5
	Mexican Regulatory Limit	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank (25%)			SIB-to-Non SIB, Non SIB-to-any bank			SIB-to-Non SIB, Non SIB-to-Non SIB			SIB-to-any bank, Non SIB-to-any bank
			Non SIB-to-SIB			SIB-to-SIB			SIB-to-SIB, Non SIB-to-SIB			
Limit as a % of Tier 1 Capital	100%	25%	20%	15%	10%	20%	15%	10%	20%	15%	10%	10%
Panel A (all figures in per cent (%))												
Number of exposures exceeding limit as per cent of the number of exposures in banking system	0%	8%	8%	9%	10%	8%	8%	9%	8%	10%	11%	16%
Number of SIB-to-SIB exposures exceeding limit as per cent of the number of SIB-to-SIB exposures	0%	5%	5%	5%	5%	5%	11%	14%	5%	11%	14%	14%
Number of SIB-to-Non SIB exposures exceeding limit as per cent of the number of SIB-to-Non SIB exposures	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Number of Non SIB-to-SIB exposures exceeding limit as per cent of number of Non SIB-to-SIB exposures	0%	20%	20%	25%	31%	20%	20%	20%	20%	25%	31%	31%
Number of Non SIB-to-Non SIB exposures exceeding limit as per cent of number of Non SIB-to-Non SIB exposures	0%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	15%
Panel B (all figures in per cent (%))												
Size of exposure exceeding the limit as per cent of sum of exposures of all banks	0%	20%	21%	22%	23%	23%	30%	41%	23%	32%	43%	45%
Size of exposure exceeding the limit as per cent of regulatory capital	0%	6%	6%	6%	6%	6%	9%	12%	7%	9%	12%	13%

Table 5. Loss Statistics for the shock that arises from the idiosyncratic failure of each individual bank

	Benchmark	Option 1	Option 2			Option 3			Option 4			Option 5
	Mexican Regulatory Limit	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank (25%)			SIB-to-Non SIB, Non SIB-to-any bank			SIB-to-Non SIB, Non SIB-to-Non SIB			SIB-to-any bank, Non SIB-to-any bank
			Non SIB-to-SIB			SIB-to-SIB			SIB-to-SIB, Non SIB-to-SIB			
Limit as a % of Tier 1 Capital	100%	25%	20%	15%	10%	20%	15%	10%	20%	15%	10%	10%
Panel A												
Number of cases where contagion occurs out of 40 idiosyncratic failures	5	0	0	0	0	0	0	0	0	0	0	0
Number of contagion cases where at least one SIB fails	1	0	0	0	0	0	0	0	0	0	0	0
Maximum number of SIB failures per contagion case	1	0	0	0	0	0	0	0	0	0	0	0
Maximum number of bank failures in a single contagion case	4	0	0	0	0	0	0	0	0	0	0	0
SIB failures due to contagion	1	0	0	0	0	0	0	0	0	0	0	0
non-SIB failures due to contagion	3	0	0	0	0	0	0	0	0	0	0	0
Panel B*												
Avg inter-bank loss as per cent of regulatory capital	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
S.D. of loss as per cent of regulatory capital	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
VaR (95%) as per cent of regulatory capital	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Maximum loss as per cent of regulatory capital in the system	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ratio of the maximum value of failed bank assets to sum of bank assets**	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

*Loss is computed only when contagion occurs

**The sum excludes the assets of the trigger bank

Table 6. Comparison of the size of exposure exceeding the limit for the three different type of banks’ behavioural responses

	Benchmark	Option 1	Option 2			Option 3			Option 4			Option 5
	Mexican Regulatory Limit	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank (25%)			SIB-to-Non SIB, Non SIB-to-any bank			SIB-to-Non SIB, Non SIB-to-Non SIB			SIB-to-any bank, Non SIB-to-any bank
			Non SIB-to-SIB			SIB-to-SIB			SIB-to-SIB, Non SIB-to-SIB			
Limit as a % of Tier 1 Capital	100%	25%	20%	15%	10%	20%	15%	10%	20%	15%	10%	10%
Type of banks’ behavioural responses												
From <u>Table 4</u>: **No Allocation and no stress**												
Size of exposure exceeding the limit as percent of sum of exposures of all banks	0%	20%	21%	22%	23%	23%	30%	41%	23%	32%	43%	45%
Size of exposure exceeding the limit as percent of regulatory capital	0%	6%	6%	6%	6%	6%	9%	12%	7%	9%	12%	13%
No Allocation under stress												
Size of exposure exceeding the limit as percent of sum of exposures of all banks	10%	39%	40%	41%	41%	46%	52%	59%	46%	53%	61%	63%
Size of exposure exceeding the limit as percent of regulatory capital	3%	10%	10%	10%	11%	12%	13%	15%	12%	14%	16%	16%
Partial Allocation under stress												
Size of exposure exceeding the limit as percent of sum of exposures of all banks	10%	12%	13%	13%	14%	16%	20%	29%	17%	22%	31%	34%
Size of exposure exceeding the limit as percent of regulatory capital	3%	3%	3%	3%	4%	4%	5%	8%	4%	6%	8%	9%
Full Allocation under stress												
Size of exposure exceeding the limit as percent of sum of exposures of all banks	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Size of exposure exceeding the limit as percent of regulatory capital	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 7. Stress testing and banks' behavioural responses for limit option 1

	Benchmark	Option 1	Option 1:Partial	Option 1:Full
	Mexican Regulatory Limit	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank, Non SIB-to-any bank
Limit as a % of Tier 1 Capital	100%	25%	25%	25%
Panel A				
Number of cases where contagion occurs out of 40 idiosyncratic failures	10	7	11	14
Number of contagion cases where at least one SIB fails	2	2	2	2
Maximum number of SIB failures per contagion case	2	1	2	2
Maximum number of bank failures in a single contagion case	11	6	15	15
SIB failures due to contagion	2	1	2	2
non-SIB failures due to contagion	9	5	13	13
Panel B				
Avg loss as per cent of regulatory capital**	4%	3%	4%	4%
S.D. of loss as per cent of regulatory capital	7%	4%	5%	5%
VaR (95%) as per cent of regulatory capital	19%	10%	14%	15%
Maximum loss as % of regulatory capital in the system	19%	10%	14%	15%
Maximum value of failed bank assets to sum of assets**	43%	27%	44%	44%
Panel C				
Total number of arcs	263	263	467	902
Average degree	9	9	15.3	31
Completeness index	23%	23%	39%	80%

Table 8. Stress testing and banks' behavioural responses for limit option 2

	Benchmark	Option 2			Option 2: Partial			Option 2: Full		
	Mexican Regulatory Limit	SIB-to-any bank (25%)			SIB-to-any bank (25%)			SIB-to-any bank (25%)		
		Non SIB-to-SIB			Non SIB-to-SIB			Non SIB-to-SIB		
Limit as a % of Tier 1 Capital	100%	20%	15%	10%	20%	15%	10%	20%	15%	10%
Panel A										
Number of cases where contagion occurs out of 40 idiosyncratic failures	10	6	6	6	8	10	10	11	11	11
Number of contagion cases where at least one SIB fails	2	2	2	2	2	2	2	2	2	2
Maximum number of SIB failures per contagion case	2	1	1	1	2	2	2	2	2	2
Maximum number of bank failures in a single contagion case	11	5	5	5	14	13	10	12	11	13
SIB failures due to contagion	2	0	0	0	2	2	2	2	2	1
non-SIB failures due to contagion	9	5	5	5	12	11	8	10	9	12
Panel B										
Avg loss as per cent of regulatory capital**	4%	3%	3%	3%	4%	3%	3%	4%	4%	5%
S.D. of loss as per cent of regulatory capital	7%	5%	5%	4%	6%	5%	5%	5%	5%	5%
VaR (95%) as per cent of regulatory capital	19%	9%	9%	9%	14%	13%	13%	14%	14%	14%
Maximum loss as % of regulatory capital in the system	19%	9%	9%	9%	14%	13%	13%	14%	14%	14%
Maximum value of failed bank assets to sum of assets**	43%	26%	26%	28%	43%	43%	42%	43%	48%	48%
Panel C										
Total number of arcs	263	263	263	263	405	414	414	685	720	746
Average degree	9	9	9	9	13.8	14	14	25.3	26.2	27.1
Completeness index	23%	23%	23%	23%	35%	36%	36%	65%	67%	70%

Table 9. Stress testing and banks' behavioral responses for limit option 3

	Benchmark	Option 3			Option 3: Partial			Option 3: Full		
	Mexican Regulatory Limit	SIB-to-Non SIB, Non SIB-to-any bank (25%)			SIB-to-Non SIB, Non SIB-to-any bank (25%)			SIB-to-Non SIB, Non SIB-to-any bank (25%)		
		SIB-to-SIB			SIB-to-SIB			SIB-to-SIB		
Limit as a % of Tier 1 Capital	100%	20%	15%	10%	20%	15%	10%	20%	15%	10%
Panel A										
Number of cases where contagion occurs out of 40 idiosyncratic failures	10	7	7	7	11	11	11	14	14	14
Number of contagion cases where at least one SIB fails	2	0	0	0	0	0	0	1	2	3
Maximum number of SIB failures per contagion case	2	0	0	0	0	0	0	2	1	2
Maximum number of bank failures in a single contagion case	11	5	5	5	10	10	10	15	14	15
SIB failures due to contagion	2	0	0	0	0	0	0	2	1	2
non-SIB failures due to contagion	9	5	5	5	10	10	10	13	13	13
Panel B										
Avg loss as per cent of regulatory capital**	4%	3%	2%	2%	3%	3%	2%	4%	4%	5%
S.D. of loss as per cent of regulatory capital	7%	3%	3%	2%	3%	2%	2%	4%	4%	4%
VaR (95%) as per cent of regulatory capital	19%	7%	6%	5%	8%	7%	6%	14%	12%	14%
Maximum loss as % of regulatory capital in the system	19%	7%	6%	5%	8%	7%	6%	15%	12%	15%
Maximum value of failed bank assets to sum of assets**	43%	2%	2%	2%	5%	5%	5%	44%	19%	44%
Panel C										
Total number of Arcs	263	263	263	263	394	405	409	661	675	694
Average degree	9	9	9	9	13.4	13.7	13.8	24.3	24.7	25.3
Completeness index	23%	23%	23%	23%	34%	35%	35%	62%	63%	65%

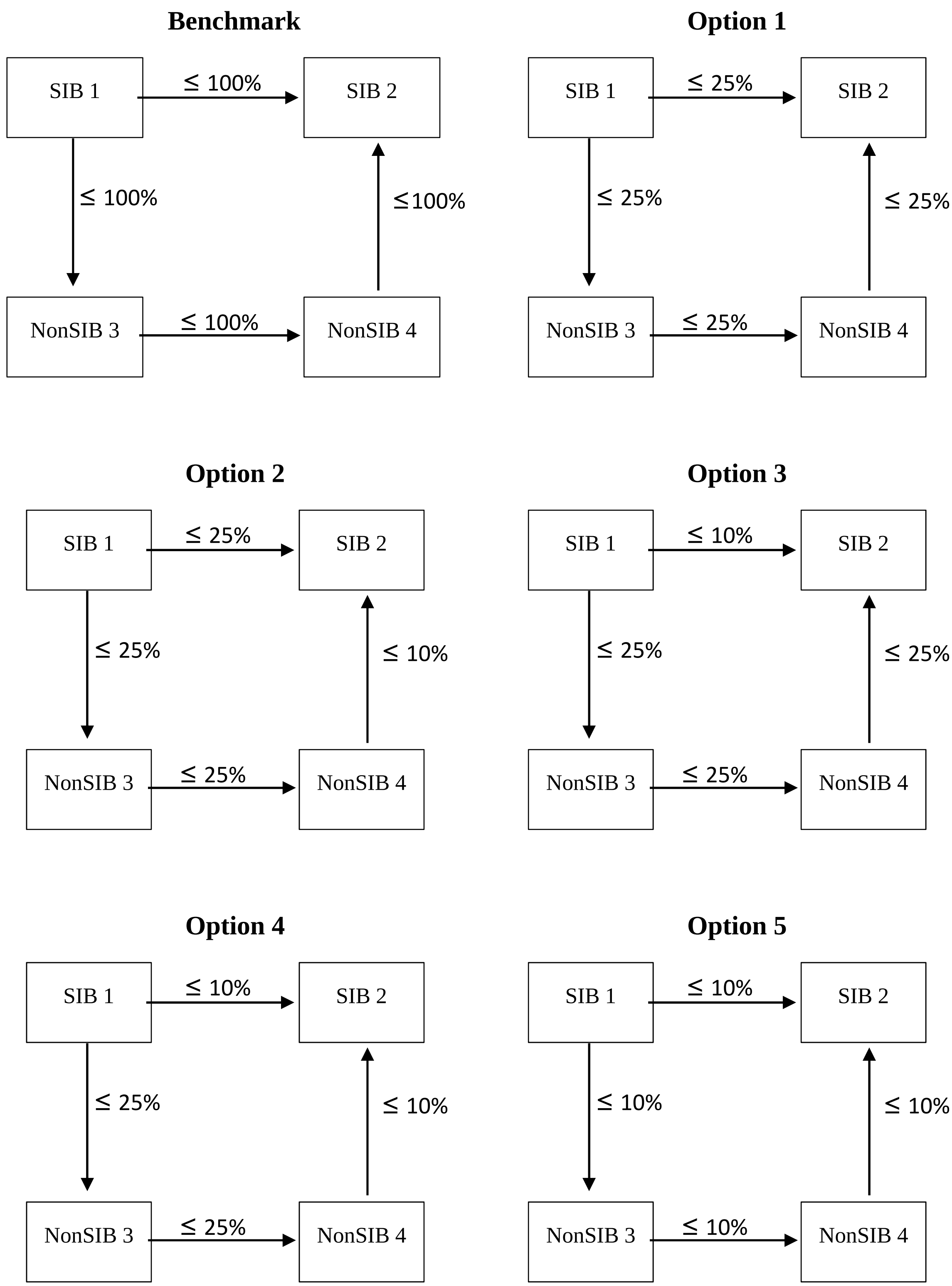
Table 10. Stress testing and banks' behavioral responses for limit option 4

	Benchmark	Option 4			Option 4: partial			Option 4:Full		
	Mexican Regulatory Limit	SIB-to-Non SIB, Non SIB-to-Non SIB (25%)			SIB-to-Non SIB, Non SIB-to-Non SIB (25%)			SIB-to-Non SIB, Non SIB-to-Non SIB (25%)		
		SIB-to-SIB, Non SIB-to-SIB			SIB-to-SIB, Non SIB-to-SIB			SIB-to-SIB, Non SIB-to-SIB		
Limit as a % of Tier 1 Capital	100%	20%	15%	10%	20%	15%	10%	20%	15%	10%
Panel A										
Number of cases where contagion occurs out of 40 idiosyncratic failures	10	4	4	4	6	8	8	9	9	9
Number of contagion cases where at least one SIB fails	2	0	0	0	0	0	0	0	0	1
Maximum number of SIB failures per contagion case	2	0	0	0	0	0	0	0	0	1
Maximum number of bank failures in a single contagion case	11	5	5	5	6	6	7	10	10	13
SIB failures due to contagion	2	0	0	0	0	0	0	0	0	1
non-SIB failures due to contagion	9	5	5	5	6	6	7	10	10	12
Panel B										
Avg loss as per cent of regulatory capital**	4%	0.4%	0.4%	0.4%	0.9%	0.8%	0.9%	1.8%	2.6%	4.3%
S.D. of loss as per cent of regulatory capital	7%	0.3%	0.3%	0.3%	0.7%	0.7%	0.7%	1.3%	1.4%	2.7%
VaR (95%) as per cent of regulatory capital	19%	0.8%	0.8%	0.8%	2%	2%	2.1%	4.1%	4.9%	9.8%
Maximum loss as % of regulatory capital in the system	19%	6.8%	5.6%	4.5%	6.9%	5.7%	4.7%	6.9%	5.7%	9.8%
Maximum value of failed bank assets to sum of assets**	43%	1.5%	1.5%	1.5%	1.5%	1.5%	3.1%	3.8%	3.8%	15.7%
Panel C										
Total number of Arcs	263	263	263	263	405	425	429	685	734	779
Average degree	9	9	9	9	13.9	14.3	14.4	25.3	26.5	28
Completeness index	23%	23%	23%	23%	36%	36.5%	37%	65%	68%	72%

Table 11. Stress testing and banks' behavioral responses for limit option 5

	Benchmark	Option 5	Option 5:Partial	Option 5:Full
	Mexican Regulatory Limit	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank, Non SIB-to-any bank	SIB-to-any bank, Non SIB-to-any bank
Limit as a % of Tier 1 Capital	100%	10%	10%	10%
Panel A				
Number of cases where contagion occurs out of 40 idiosyncratic failures	10	0	0	0
Number of contagion cases where at least one SIB fails	2	0	0	0
Maximum number of SIB failures per contagion case	2	0	0	0
Maximum number of bank failures in a single contagion case	11	0	0	0
SIB failures due to contagion	2	0	0	0
non-SIB failures due to contagion	9	0	0	0
Panel B				
Avg loss as per cent of regulatory capital**	4%	0%	0%	0%
S.D. of loss as per cent of regulatory capital	7%	0%	0%	0%
VaR (95%) as per cent of regulatory capital	19%	0%	0%	0%
Maximum loss as % of regulatory capital in the system	19%	0%	0%	0%
Maximum value of failed bank assets to sum of assets**	43%	0%	0%	0%
Panel C				
Total number of Arcs	263	263	394	661
Average degree	9	9	13.4	24.3
Completeness index	23%	23%	34%	62%

Figure 1: Illustrations of the different options



An arrow represents an exposure of any bank ‘A’ to any other bank ‘B’. The value of the large exposure limit as a % of Tier 1 capital appears at the side of each arrow.

Figure 2. Interbank exposures to Tier 1 capital for the period of March 2008 to July 2012

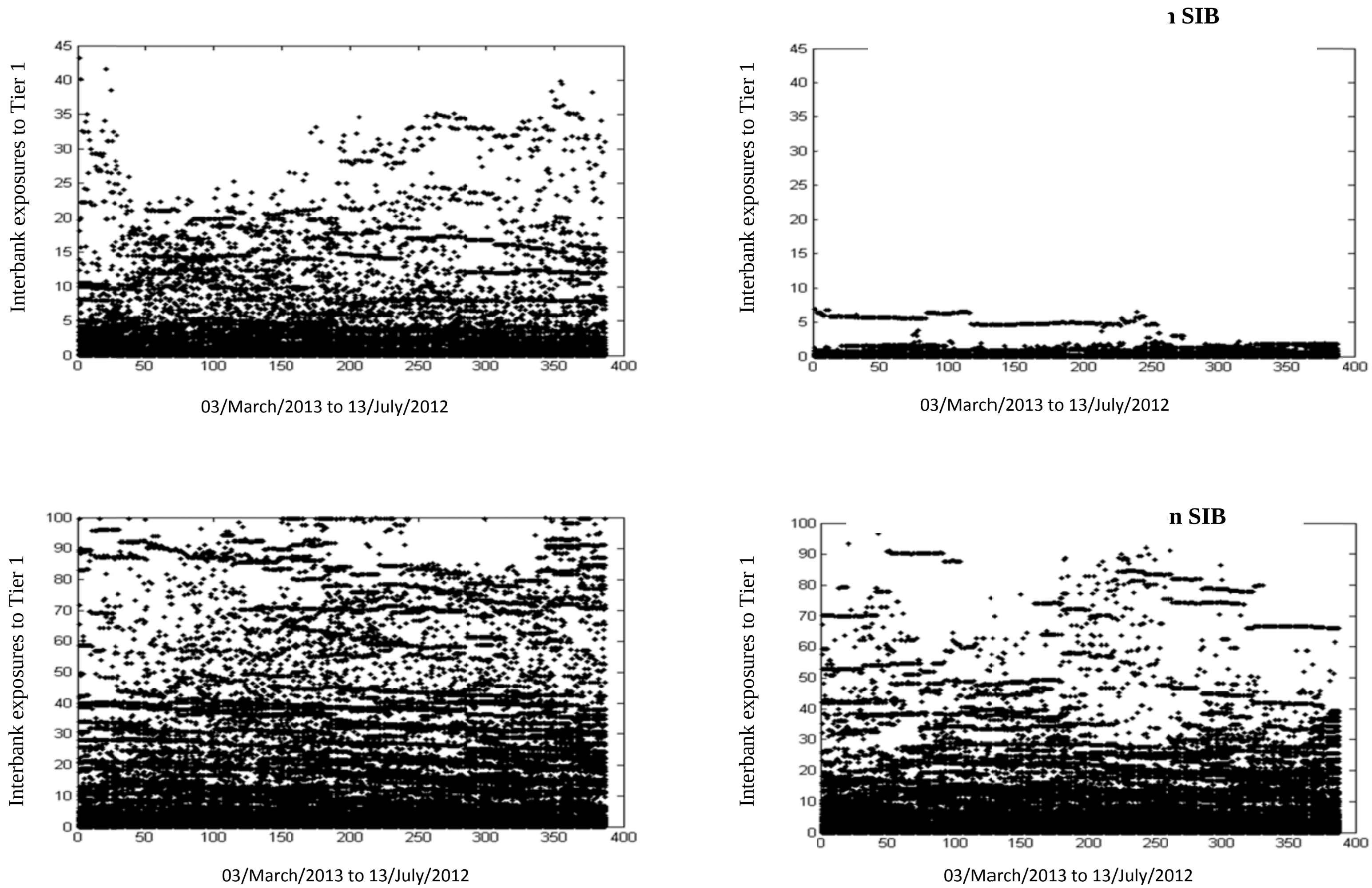
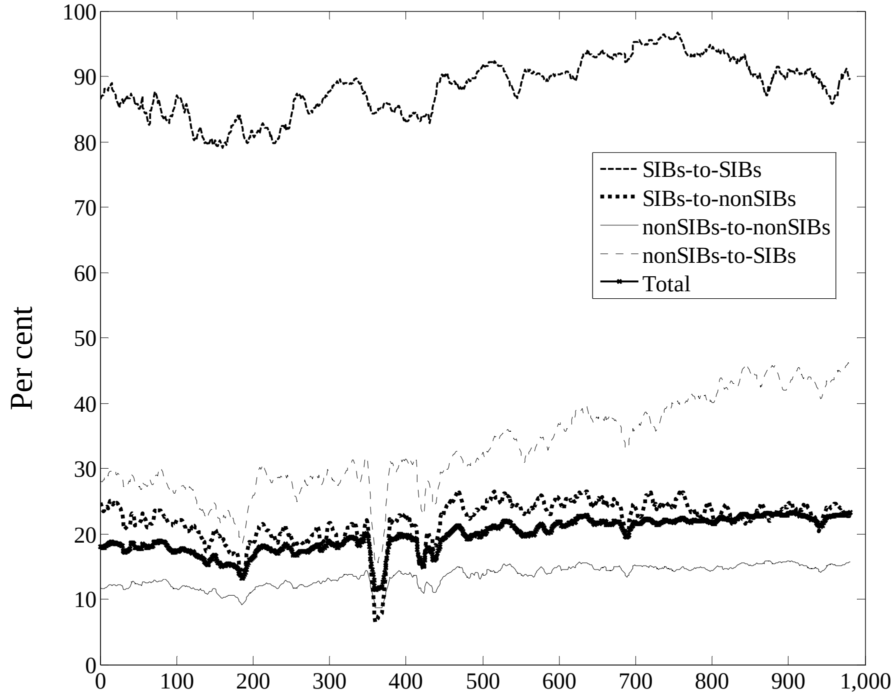


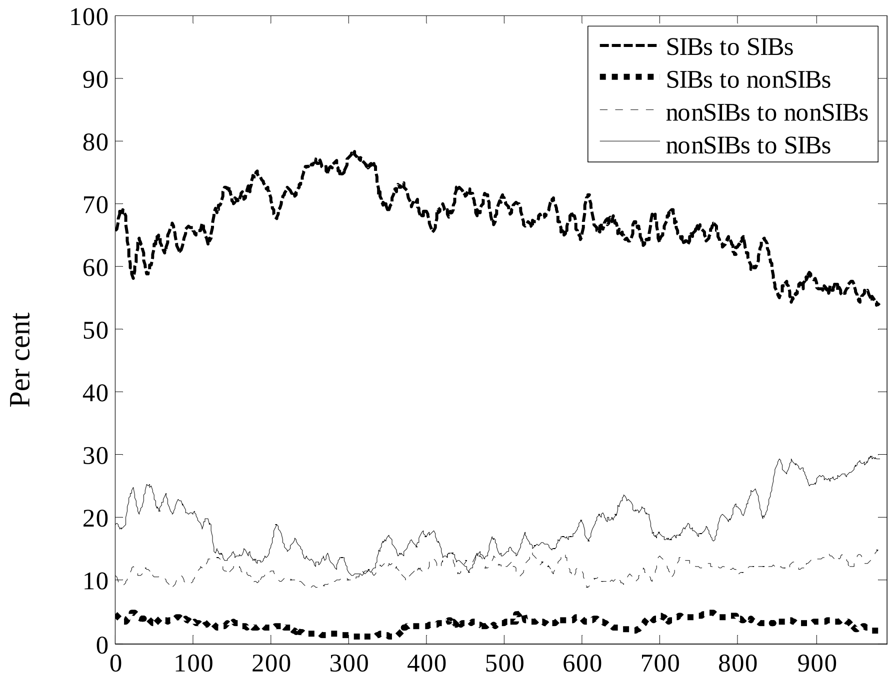
Figure3. Completeness Index for the period of March 2008 to February 2012

Panel A. Completeness Index per Bank-to-Bank transaction



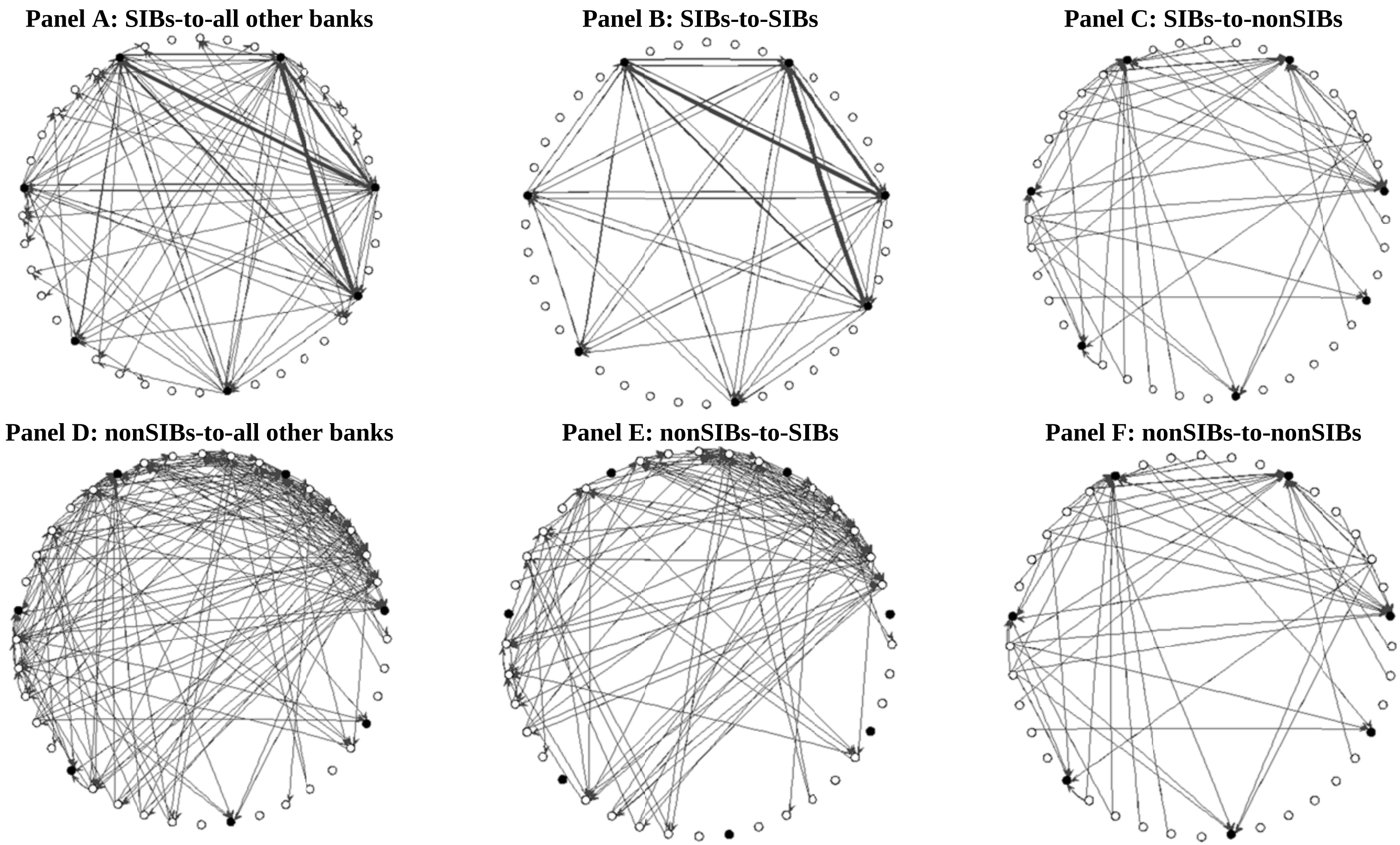
Number of observations for the period of March 2008 to February 2012

Panel B. Sum of Bank-to-Bank exposures as per cent of Total Interbank Exposure



Number of observations for the period of March 2008 to February 2012

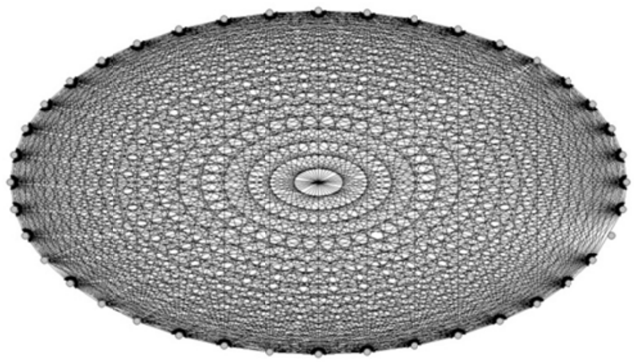
Figure 4. Structure of the network of interbank exposures for the point in time under analysis*



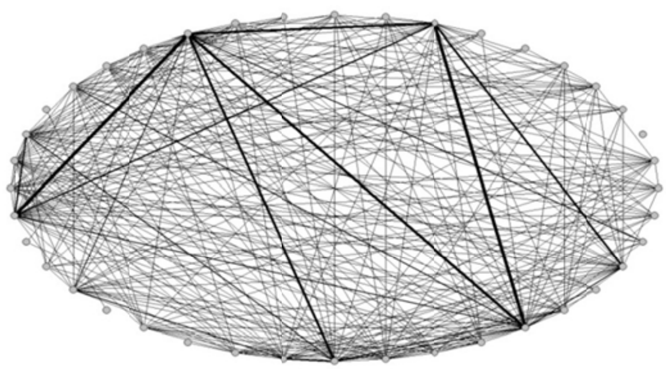
*In figure 4, each node represents a single bank, while the width of each ‘arc’ or ‘link’ reflects the size of the gross bilateral interbank exposure. The network comprises 40 banks. The size of the node does not represent the size of the bank. However, each panel has seven ‘black nodes’ or ‘black filled nodes’ that represent the SIBs.

Figure 5. Comparison of a network based on ME and a network based on actual inter-bank exposures

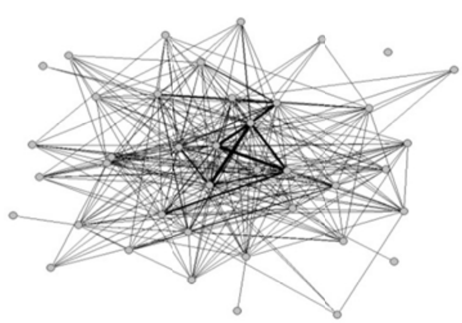
Panel A: Structure of a network generated by ME



Panel B: Structure of a real network of inter-bank exposures



Panel C: Core-Pheriphery of an inter-bank network



These graphs were made using Pajek software (Available at: http://vlado.fmf.uni-lj.si/pub/networks/pajek/).

Figure 6. Non SIBs funding provided by Non SIBs as a percent of total available funding for Non SIBs