

IFC Satellite Seminar on "Post-crisis data landscape: micro data for the macro world", co-organised with the Central Bank of Malaysia and the European Central Bank

16 August 2019, Kuala Lumpur, Malaysia

Cross-border interbank contagion risk to the Malaysian banking system¹

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

Cross-border Interbank Contagion Risk to the Malaysian Banking System¹

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Abstract

The Malaysian banking system is not immune to potential financial instability induced by greater cross-border interconnectedness, a key feature of the recent Global Financial Crisis. In view of this, a comprehensive and reasonably accurate assessment of cross-border contagion risks is crucial to assess risks to financial stability. In this paper, we utilised network analysis and counterfactual simulation to (i) conduct an indepth study of the dynamics of Malaysian banks' cross-border and domestic interbank exposures over a period of 5 years and (ii) assess potential losses arising from contagion induced by external shocks. We find that interconnectivity and solvency contagion risk in the Malaysian banking system to external shocks have declined significantly since 2013, despite the rapid growth in cross-border exposures in value terms. Nonetheless, due to their large size and interconnectedness i.e. importance as a financial intermediator, systemically important banks are more susceptible to induce contagion within the network.

Keywords: Contagion, network analysis, interconnectedness, DebtRank, stress test

JEL classification: D85, G01, G17, G21, G28, L14

¹ This paper has been published as part of The South East Asian Central Banks Research and Training Centre (SEACEN) collaborative research project titled "Cross-border Interbank Contagion Risk Analysis" (SEACEN, May 2019). An additional section has been added since to reflect the extension of our work. The views expressed in this paper are those of the authors and do not necessarily represent those of Bank Negara Malaysia (BNM) or its policies. The authors would like to thank Qaiser Iskandar Anwarudin, Hafiz Abu Samah, Syairah Hanin Shaharudin, and Nik Ahmad Rusydan bin Nik Hafizi for their invaluable feedback.

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1. Introduction

In recent times, more so after the Global Financial Crisis (GFC), regulatory authorities worldwide have taken a keen interest in being better able to assess risks of contagion events from occurring. This is because effects of financial contagion was one of the key features of the GFC as localised distress in specific segments of financial markets rapidly morphed into a crisis of global proportions. The OECD (2012) estimates that contagion shocks induced via bank balance-sheet interconnectedness, which had been an important driver of financial crises, reached unprecedented heights during the GFC. True enough, the extent and nature of international banking integration which contributed to an unprecedented transmission of financial instability, was one factor that made the recent financial crisis so deep and widespread.

While most global banks held back cross-border banking activity in the aftermath of GFC, banks in Asia Pacific stepped up, intensifying their cross-border activities particularly within the region, with financial centres such as Hong Kong SAR and Singapore playing important roles (Remolona and Shim, 2015). Notwithstanding the benefits, Remolona and Shim (2015) go on to highlight three potential source of risks to financial stability caused by greater banking integration in Asia: (i) growing systemic importance³ of foreign banks in host jurisdictions, both as common and concentrated lenders within the region; (ii) high reliance on wholesale and derivative markets for foreign currency funding and (iii) shortening maturity of foreign currency borrowing.

There are several factors which makes the Malaysian banking system susceptible to potential financial instability induced by greater cross-border interconnectedness. First, the Malaysian banking system has one of the highest foreign bank participation among most Asian peer jurisdictions, with foreign banks accounting for 19.8% of total domestic banking system assets as at end-2017. Second, Malaysian banks' cross-border exposures, particularly in the form of short-term borrowings, has increased rapidly in recent times in tandem with growth of domestic banking groups in the regional markets and strong domestic presence of foreign banks. Since 2008, Malaysian banks' external debt almost tripled to RM316.8 billion or 23.4% of GDP as at end-2017. Third, Malaysian banking system is both concentrated and large compared to the domestic economy; with top five largest banking groups by asset size, which also has significant cross-border presence, accounting for 70% of total banking system assets and 231% of Malaysian GDP as at end-2017.

³ Refers to banks whose distress or failure may result in severe negative spillover impact to the financial system and real economy. At the global stage, the Financial Stability Board and Basel Committee of Banking Supervision assess and identify banks that are deemed to be systemically important on an annual basis, referred to as global systemically important banks (G-SIB). Similarly, national authorities identify banks that are systemically important in their respective jurisdiction, commonly referred to as domestic systemically important banks (D-SIB).

2. Literature review

There are two main strands of literature related to our work. The first discusses the use of network analysis to assess contagion risk while the second deals with the use of counterfactual simulation to quantify the impact of contagion risk.

2.1 Network Analysis

Network analysis has been increasingly recognised as a powerful surveillance tool for modelling the interconnectedness of the banking system network, although not widely employed due to data limitations. Hattori and Suda (2007) explored the 'coreperiphery' network of cross-border bank exposures for 215 countries using the Bank for International Settlement (BIS) locational banking statistics data for the period 1985-2006. They found that the network has become more tightly connected with higher average degree, higher clustering coefficient and shorter average path length over time. In addition, network features remain largely undisrupted by any disturbances or crises in the international financial markets. Although systemic risk build-up is inevitable, financial markets are allocating capital and risk more efficiently.

Using similar dataset, Minoiu and Reyes (2011) analysed interconnectivity of the global banking network for 184 countries over 1984-2009. They enhanced existing literatures on network study through the use of cross-border flows data to reflect liquidity conditions and applied the weighted degree approach to capture the heterogeneity in cross-border exposures. The authors posited that network density tends to expand and contract in line with the cycle of capital flows. Furthermore, country centrality decreases during and after banking and sovereign debt crises, with the GFC standing out as an unusually large disruption to the global banking network, contradictory to findings from Hattori and Suda (2007).

Utilising data on bilateral cross-border exposures between 1980 to 2005 for 18 advanced and emerging economies, Kubelec and Sa (2010) found increasing financial interconnectivity over time. The global financial network is clustered among few key nodes with large financial links and lower average path length over time, focusing around the United States and United Kingdom as its central hubs. Due to its robust yet fragile network structure, disturbances to the key hubs would transmit shocks rapidly and widely throughout the network. Comparison with the trade network shows similar increase in interconnectivity over time. Nonetheless, the trade network exhibits strong intracontinental links, concentrating around three clusters, the European cluster (centred on Germany), American cluster (centred on United States) and Asian cluster (centred on China).

2.2 Counterfactual Simulations

While network analysis has aided our understanding on risks posed by greater interconnectedness, actual occurrences of default cascade events (referring to instances of a bank's default impacting or inducing default of other banks via direct balance sheet linkages or indirect linkages such as precipitation of bank run following loss of confidence) remained rare even during the height of GFC, largely due to widespread regulatory intervention. This has led to the lack of reliable empirical evidence, which allows for reasonably accurate estimation of such risks and impact to the financial system and economy upon materialisation of such events. Against this backdrop, counterfactual simulations have emerged as an important approach to assess the likelihood of contagion occurring (Upper, 2011; Elsinger, Lehar and Summer, 2012). Such simulations are increasingly being used by regulators either on a stand-alone basis to assess resilience of a particular financial system or as part of broader macroeconomic stress testing approaches, for example the Bank of England's RAMSI (Burrows et.al., 2012).

Upper (2011), which provides an excellent summary of counterfactual simulation studies of the bank-driven contagion, specifically via the interbank market channel, found two major shortcomings in the reviewed literature: (i) an exaggerated focus involving the idiosyncratic failure of an individual bank in constructing shock scenarios, and (ii) the general neglect of mechanisms that extends beyond direct balance-sheet linkages. Such mechanisms like the amplification of losses by behaviour and asset pricing, which can be significant during crisis periods⁴, can lead to misleading conclusion that contagion risk is small. Therefore, it was not surprising that the early literature on counterfactual simulations using interbank exposures established the following two premises: (i) contagion of insolvency due to interbank exposures are rare and (ii) it is difficult to create realistic scenarios that will induce significant amount of contagion (Summer, 2013). Much recent literature however has emphasised the importance of considering other contagion channels in constructing counterfactual simulations. Glasserman and Young (2015) highlights the importance of mechanisms which goes beyond simple spillover effects (referring to default cascade approaches) to magnify shocks such as (i) bankruptcy costs and (ii) valuation losses resulting from deterioration of counterparty creditworthiness or a loss of confidence. In particular, they found that loss of confidence can lead to widespread losses of value – with their analysis suggesting this channel of contagion is likely to be more important than simple spillover effects.

Put differently, a possible explanation for the general neglect of other forms of contagion mechanisms could have been the reliance on default cascades to propagate distress within networks i.e. distress within the network is only induced upon the failure of a bank in response to either a common shock or idiosyncratic events, a rather common feature across early counterfactual simulation (refer to Upper, 2011; Elsinger, Lehar and Summer, 2012; Glasserman and Young, 2015). Beyond being an unrealistic assumption considering how recent financial crises events have proven⁵, default cascade approach turned out to be problematic as it was difficult to induce contagion having bank defaults as a precondition, limiting the usefulness of such simulation studies. For example, given banks are typically subjected to single counterparty exposure limits which typically falls well below banks' total capital, a simulation study with shock scenario involving a single defaulting bank would neither be sufficient to induce other banks' default nor induce widespread contagion. To induce meaningful contagion in such studies, one has to create a shock scenario with simultaneous instances of bank defaults within the financial system, which are both rare and again, unrealistic in actuality.

In this regard, development of DebtRank methodology motivated by work on distance to default, which enabled propagation of distress within network without

⁴ BCBS (2018) estimates that mark-to-market losses from credit quality deterioration exceeded losses incurred from outright defaults during the GFC.

⁵ For instance, the onset of Global Financial Crisis and ensued contagion were largely driven by sudden and pervasive averseness following a general loss in confidence as opposed to widespread defaults.

assuming defaults (Battiston et. al., 2012) gained prominence as a method to estimate the impact of shocks within financial networks (Aoyama et. al., 2013; Tabak et. al. 2013; Bardoscia et. al., 2015; Fink et. al., 2016; Bardoscia et. al., 2017). Of significance, DebtRank methodology using relative loss of bank equity within a network as a measure of distress, enabled the propagation of distress induced by valuation losses within networks following deterioration of counterparty creditworthiness or a loss of confidence to be incorporated in simulation studies. Consistent with this, the impact of shocks measured using DebtRank is typically larger than the traditional default cascade approach given the ability to induce further losses within the network. Battiston et. al. (2015), which incorporated DebtRank to carry out a stress-test exercise on interbank exposures of 183 listed European banks over the years 2008-2013 found that the second-round and third-round effects of distress dominate first-round effects, further underscoring the importance of taking into account other contagion channels/mechanism in counterfactual simulation. The original DebtRank assumed that (distress and thus) losses are propagated linearly between connected bank. This assumption was subsequently relaxed in later studies (Bardoscia et. al., 2016; Bardoscia et. al., 2017) to introduce other non-linear propagation functions.

3. Malaysian Banking System

The Malaysian banking sector is well-developed and diversified, with a wide range of domestic and foreign financial institutions. At the end-2017, the banking system comprises 27 commercial banks (8 domestic and 19 foreign), 16 Islamic banks (10 domestic and 6 foreign) and 11 investment banks, with total assets worth approximately RM2.5 trillion, or close to 200% of GDP (Graph 1). Commercial banks are the largest providers of funds, performing retail banking services, including acceptance of deposits, supplying loans and providing payment and remittance services. Islamic banks conduct a similar range of banking activities based on Shariah principles. Meanwhile, investment banks are responsible as financial intermediary for capital market activities such as dealing in securities, raising capital and security underwriting besides providing corporate advisory services. In terms of financing, the banking system has about RM1.6 trillion in outstanding loans, equivalent to over 117% of GDP as at end-2017.



Composition of Assets, Financing and Deposits Accepted for the Banking System

Note: Figures in parentheses refer to market share of domestic banks relative to banking system Source: Bank Negara Malaysia

Considerable efforts have been undertaken to strengthen the resilience of the banking system over the last decade, particularly in the aftermath of the Asian Financial Crisis. Realising the needs for stronger and larger domestic financial institutions, an industry-wide restructuring and consolidation programme was introduced by BNM in 1999. This has successfully reduced fragmentation and transformed the banking industry to better equip them with enhanced capacity to serve the domestic economy. The 77 domestic banking institutions that existed in the 1980s have merged to form 8 main domestic banking groups (Graph 2) under the consolidation programme. As highlighted in the introduction, the top five largest domestic commercial banks in Malaysia now account for 70% of total of total banking system assets. 5 out of 8 domestic banking groups have also expanded regionally and emerged as key players within the ASEAN region.



Although banks in advanced economies faltered during the GFC – with some ending in bankruptcy - the Malaysian banking system remained resilient with sound profitability levels and ample capital buffers to absorb shocks in the event of future stressed events. As at end-2017, the capital ratios of all banks were well above the regulatory minima. More than 75% of capital are in the form of highest guality lossabsorbing instruments, which includes equity, retained earnings and reserves, allowing banks to withstand macroeconomic and financial shocks without adversely affecting financial intermediation. A series of macroprudential measures implemented since 2010 and strengthened risk management practices of banks also further mitigated potential risks by reducing banks' exposures to over-leveraged households (Bank Negara Malaysia, 2017), thus improving the asset quality of banks to a low of 1.1%. Liquidity Coverage Ratio (LCR) requirements have been phased in since June 2015 for the banking institution as part of the Basel III reform package, which required all banks to maintain sufficient high-quality liquid assets at a minimum of 100%⁶ of total projected net cash outflows for the next 30 days. Banks have all transitioned smoothly to this requirement.

Key Financial Indicators of Banks		Table 1
Banking System	2000	2017
Capitalisation Risk-Weighted Capital Ratio/Total Capital Ratio (%)	12.4	17.8
Asset Quality Net NPL Ratio (%)	9.9	1.1
Profitability ROA (%) ROE (%)	1.5 19.5	1.5 13.1
Liquidity Liquidity Coverage Ratio (%)	-	134.9
Note: see the Appendix for detailed formulae.		

The nature and extent of financial linkages of Malaysian banking system has evolved and increased steadily since the GFC. While total external exposures⁷ of Malaysian banks remain low, on aggregate accounting for only 10.2% and 17.2% of the total assets and funding of the banking system in 2017 respectively, banks' claims on, and liabilities obligations to, non-resident counterparties grew at a compounded annual growth rate (CAGR) of 11.9% and 12.2% since 2008 (Graph 3). The rapid expansion Malaysian banks' external exposures is driven by the following: (i) the sizeable presence of foreign banks in Malaysia (Graph 4), including operations in

⁶ The LCR requirement was phased-in from June 2015, with an initial transitional requirement of 60%. Full compliance of 100% requirement is in effect starting 1 January 2019.

⁷ We shall be using the term 'external exposures' and 'cross-border exposures' interchangeably in this paper. Both refer to banks' exposures vis-à-vis non-resident counterparties.

Labuan International Banking and Financial Centre (LIBFC)⁸ and (ii) regionalisation of domestic banks, particularly in ASEAN region (Graph 5). In line with this, bulk of the external exposures are in the form of (i) intra-group transactions between banks and related offices⁹ abroad in the form of interbank placements and borrowings and capital funds, (ii) deposits accepted from non-residents and (iii) loans extended to non-resident counterparties.



8 LIBFC, established in 1990 is an offshore financial centre, which offers tax incentives for financial and capital market activities. In lieu of this, LIBFC banks' role as a booking centre is prominent, as onshore banks, primarily domestic banking groups, conduct their FCY intermediation activities via their Labuan offices. We shall be using the terminology LIBFC and Labuan interchangeably in this paper.

Foreign banks market share (%)

9 For foreign banks, related offices refer to overseas parent and regional offices. For domestic banks, related offices refer to overseas subsidiaries and branch operations.

Note: Foreign bank market share data refers to proportion of total banking sector assets held by foreign banks

Note: Refers to total foreign claims of domestic banks in all currencies. Data as at end-3Q 2018.

Source: Global Financial Development Database, Bank Negara Malaysia, Haver Analytics, Bloomberg, IMF World Economic Outlook

Source: BIS International Banking Statistics, Bank Negara Malaysia, Haver Analytics, Bloomberg, IMF World Economic Outlook

Of Malaysian banks' external exposures in 2017 (Graph 6):

- 48% and 31% of external assets and liabilities were attributed to domestic (i) banking groups (DBGs), with significant regional presence. Bulk of the exposures relates to centralised liquidity management practices¹⁰ of DBGs. For DBGs, liquidity is typically managed at the head office to manage maturity and currency mismatches across the group operations. Excess liquidity from related offices along with FCY funding raised in international capital markets as part of the broader funding diversification strategy are redistributed back to related offices.
- (ii) 35% and 30% of external assets and liabilities were attributed to LIBFC banks. External exposures of LIBFC banks predominantly reflect placements by related entities to fund foreign currency (FCY) intermediation activities. Such reliance on funding from related offices is expected for offshore banks, which typically operates as a branch and has limited alternative funding sources.
- (iii) 17% and 39% of external assets and liabilities were attributed to locallyincorporated foreign banks (LIFBs). LIFBs typically leverage on the stronger credit rating of internationally-active parent banks to source cheaper FCY funding. These are primarily channelled towards FCY lending in the domestic interbank market, short-term investments and to manage maturity mismatches in their FCY loan portfolio.



Breakdown of Banking System External Exposures in 2017 by Banks Graph 6

10 For further information on centralised liquidity management practices of Malaysian banks, refer to Chapter 1 of Financial Stability and Payment Systems Report 2017.

Consequently, from a geographical standpoint, Malaysian banks' external exposures are with counterparties situated in (i) regional financial centres; (ii) countries where Malaysian banks have overseas operations; and (iii) countries with internationally active banks, particularly those with locally-incorporated subsidiaries in Malaysia, with significant concentration observed to Asian region (62% and 73% of cross-border assets and liabilities in 2017) (Graphs 7 and 8).



Notwithstanding the low risk profile of banks' external exposures (refer to Bank Negara Malaysia's Financial Stability Review, 2018), Malaysian banks are more exposed to adverse market and geopolitical developments across different economies, particularly within Asia. This being as a natural consequence of the rapid growth and profile of banks' cross-border exposures. Moderate spillover effects were felt in the domestic market during periods of tightened US dollar conditions in 2008, as evident from the increased spreads of onshore USD/RM cross-currency swap rates and the widening of short-term US dollar liquidity mismatch positions of banks in Malaysia (Bank Negara Malaysia, 2013). In addition, with sizeable participation of foreign investors, domestic financial markets are also increasingly susceptible to volatile two-way portfolio flows induced by such regional and global developments. This has added to further concerns on banks' external debt¹¹, which are predominantly in the form of short-term instruments such as deposits and interbank transactions and have evoked concerns of banks also being susceptible to sudden withdrawal shocks.

External debt is a subset of banks' external liabilities, referring to all external liabilities that require payment of principal and/or interest. This is in line with definition of International Monetary Fund (IMF), et al. (2013). In addition to external debt, banks' external liabilities comprise (i) custodial securities held on behalf of non-resident (NR) clients, (ii) capital funds maintained by NR in resident banks, primarily for LIFBs and (iii) financial derivative balances.

4. Data

This paper employs domestic and cross-border interbank exposures data sourced from two separate quarterly reporting submissions: (i) External Assets and Liabilities (EAL) for external cross-border exposures, which can be found in the Bank for International Settlements (BIS) locational banking statistics database for Malaysia, and (ii) Interbank Exposure for information on banks' bilateral exposures in the domestic interbank market. As part of the Interbank Exposure submission, banks are required to submit information on their interbank claims and placements by currencies and counterparties (domestic and external), including placements and borrowings with BNM. Information on bilateral exposures (e.g. counterparty name) to cross-border financial institutions are not readily available for periods before 2017. As such, when looking at cross-border interbank exposures, we use aggregate country level exposures of each bank.

In this paper, we have identified 20 out of 54 banks, comprising domestic and foreign banks, as systemically important to facilitate our analyses. Such banks shall be referred to as systemically important banks (SIBs) hereafter. SIBs are selected based on a combination of balance sheet indicators namely total assets, total deposits and total loans outstanding.

4.1 Network Analysis

There is a total of 54 onshore banks and 24 non-resident countries (including Labuan¹²) in the dataset, forming a network with 78 *nodes*. The network is modelled using interbank lending data and the flow of exposures from a lender to a borrower is considered as a *link*. If credit exposures from one node to another is recorded as 'non-zero', a link is formed between the two nodes. Data was collected on quarterly basis from 2013 to 2017. To ensure consistency in the dataset, the same 54 banks are retained throughout the sample period¹³. Similarly, 21 external counterparty countries have been pre-identified based on their exposures, while the remaining countries clustered accordingly to 3 different regions¹⁴. These nodes form a directed network with a core-periphery structure, with *core* representing banks who are net lenders while *periphery* comprising the non-resident countries who are net borrowers only. Nevertheless, the core-core network structure (comprising both lenders and borrowers in the domestic interbank market) is also analysed.

Following the footsteps of Minoiu and Reyes (2011), we applied the same treatment on the bilateral interbank exposures data by retaining only positive flows in this study (corresponding to net placements or net assets), while negative flows (net liabilities) are replaced with zeros. The total claims and liabilities are not differentiated according to currency (domestic currency (i.e. Ringgit Malaysia) vs

¹² For the purpose of the network analysis, Labuan banks are deemed as non-resident counterparties.

¹³ New (old) banks' entrants (exit) into the domestic banking system are removed from the dataset. Thus, this study does not consider the possibility of new links, except between the nodes fixed in the dataset.

¹⁴ Refer to Table A1 in appendix 1 for full list of countries nodes.

foreign currency) but aggregated as a whole. The resulting matrix is combined with the external cross-border exposures data for each period.

4.2 Counterfactual Simulation Model

For purposes of the counterfactual simulation model, we use annual data of 54 banks between 2013 and 2017. By using actual interbank exposures data, we partly overcome limitations typically associated with use of estimation techniques¹⁵ to construct bilateral interbank exposures. Other balance sheet information such as regulatory capital, placements with BNM and holdings of liquid securities were sourced from monthly reporting submissions by banks. In contrast to Bardoscia et. al. (2015), we use banks' stock of CET1¹⁶ capital in lieu of total equity.

5. Methodology

This section describes the statistical measures used to explain the network topological characteristics and the counterfactual simulation model used to assess contagion risk.

5.1 Network indicators

5.1.1 Connectivity

Network connectivity is the most commonly used topological measure and is defined as the likelihood of connection between nodes. A non-zero exposure between one node and another node, is known as a link. The total number of nodes and links in a network are identified as n and m, respectively. Since the network is a directed network¹⁷, the probability, p that two nodes share a link is defined as

$$p = \frac{2m}{n(n-1)} \tag{1}$$

As the number of nodes in the dataset are fixed, interconnectedness of banks and their respective counterparties is solely influenced by the number of links – the more the number of links, the higher the connectivity.

5.1.2 Clustering Coefficient

Clustering coefficient of a node *i* is calculated as the ratio of the actual number of directed links between the neighbours of node *i* ($m_{nn,i}$) over the number of potential links between them. When the total number of neighbours of node *i* is m_i and the

¹⁵ Referring to techniques utilised to estimate bilateral interbank exposures in absence of actual data. Such techniques tends to distribute aggregate exposures as evenly as possible across institutions given set constraints. A general consensus in the literature is that use of such estimation typically leads to underestimation of contagion effects (Summer, 2013).

¹⁶ CET1 capital is a type of regulatory capital maintained by banks, referring to the highest quality and most loss-absorbing capital instrument under the Basel III capital framework.

¹⁷ For simplification, only directed links (where the edges point in a single direction) are analysed in this paper. Bi-directional links can be considered in future research work.

number of potential links are $(m_i (m_i - 1))$, the likelihood of connection between two neighbours that are directly linked to a node in a directed network is

$$C_{i} = \frac{2m_{nn,i}}{m_{i}(m_{i}-1)}$$
(2)

The neighbours of node *i* are defined as nodes that are directly linked to node *i*. For example, in a directed network of net exposures for the core-periphery structure in Figure A1 (refer to Appendix), if both neighbours, nodes *k* and *j* have a link with node *i*, the likelihood that nodes *k* and *j* are interlinked is known as the clustering coefficient. The clustering coefficient of a network, C can be calculated as the average of the clustering coefficient of each node in the network. Thus, the likelihood of the network to cluster is $C = 1/n \sum C_i$. The higher the coefficient, the more tightly-knit the nodes are together, indicating a 'small-world effect'.

5.1.3 Betweenness Centrality

Betweenness centrality of a node can be defined as the ratio of the total number of shortest paths through node i (σ_{kj} (i)) to total number of shortest paths from node k to j (σ_{kj}). The measure used in this paper has been normalised for comparison purposes between different periods.

$$B_i = \sum_{i \neq k \neq j} \frac{\sigma_{kj}(i)}{\sigma_{kj}} \tag{3}$$

Nodes with high betweenness centrality are often important financial intermediaries as they act as a 'bridge' between nodes in a network. In the network example (Figure A2), bank *G* is recorded to have the highest betweenness centrality between all other banks as it has the most number of times a transaction goes through the node. Being the key financial intermediator, a funding shock to bank *G* would thus be transmitted towards all other nodes connected to it and restricts liquidity for bank *H* and *J*.

5.1.4 Average Degree (Outdegree and Indegree)

The degree of a node computes the number of links for each node. Since the dataset is composed of a directed network, the number of outgoing links from a node, that is the number of counterparties a bank lends to (its debtors), is known as the outdegree (Figure A3). On the other hand, the number of counterparties a bank borrows from (its creditors), also known as the number of incoming links, is referred to as the indegree. The average degree of the network is therefore the ratio of the total number of links, *m* and the total number of nodes, *n*.

Moreover, node strength refers to the value of net interbank exposures originating or terminating at a given node. An increase in the amount of interbank lending by a creditor to its counterparties shows greater node outstrength. Although the number of outward links signals the importance of the bank as a credit provider in the system, the amount of lending should also be emphasised when determining the riskiness of the entity as a credit provider. To put it simply, a bank (A) that lends to a single entity with an amount of RM100 million is more risky than a bank (B) that lends to 5 different counterparties with an amount of RM10 million each. This paper adopted the weighted network approach proposed by Opsahl et. al. (2010) by taking into account the total number of counterparties a bank lends to (outdegree) and their weighted size of exposures (outstrength) using a tuning parameter, α . By assigning α =0.5, both the number of outdegree and weight of the links are given equal relative importance. This centrality measure enables us to more accurately assess the contagion risk of banks with high outdegree relative to their size of interbank placements with their respective counterparties.

5.2 Counterfactual Simulation Model

Bank-driven contagion can take many channels (see Upper, 2011) but this paper focuses on the interbank market, specifically asset-side shocks due to lending and borrowing exposures to financial institutions in the cross-border interbank market (direct effects) and the spillover impacts onto the domestic interbank market via the confidence channel (indirect effects). To assess the resilience of Malaysian banks to susceptibility to shocks induced via the cross-border and domestic interbank markets, a counterfactual simulation adapting the DebtRank methodology developed by Battiston et. al. (2012) shall be utilised. In particular, the DebtRank methodology shall be used to extend the simulation analysis presented in the 2013 Financial Stability and Payment Systems Report (Bank Negara Malaysia, 2013) by attempting to estimate, quantify and track the spillover impact of shocks incurred on banks' crossborder interbank exposures onto the Malaysian interbank system. Results of this extension is explained in Section 8.

5.2.1 Model description

In this section, we introduce and describe the key features of our counterfactual simulation model which had been calibrated by taking into account some of the key insights and shortcomings identified in similar studies highlighted earlier. Detailed information about the process and the main variables of interest can be found in Appendix 2.

Our model envisages a financial system of n banks as a network. Each bank either lends to other banks within the network i.e. domestic interbank lending (A_{dib}), or engage in any of the following (i) cross-border interbank lending to non-resident financial institutions (A_{ea}), (ii) placements with central bank (A_{cb}), (iii) holding of liquid securities (A_{liqs}) and/or (iv) holding of other assets (A_{oth}). Bank assets are assumed to be marked-to-market whereas liabilities are carried at their face value. The rationale being the value of banks' obligations do not change simply because they might not be able to meet the obligations. At any given time, total equity value, E_t of a bank refers to its total assets, A_t less its total liabilities, L.

$$A_t^{dib} + A_t^{ea} + A_t^{cb} + A_t^{liqs} + A_t^{oth} = L + E_t$$
(5)

The model is centred on measuring relative equity loss of each bank or the system as a whole at any given time. Given total liabilities are assumed to be carried at face value, changes in value of total assets would result in corresponding change in the value of banks' total equity. The relative or percentage loss in total equity, denoted by h_i is taken as a proxy for distress for any given bank, also referred to as vulnerability of the bank. When $h_i = 0$, a bank is deemed to be un-distressed. All values between 0 to 1 suggests a bank is under distress.

Relative loss in equity,
$$h_{i,t} = \min\left\{1, \frac{E_{i,t=0} - E_{i,t}}{E_{i,t=0}}\right\}, t = 0, 1, 2...$$
 (6)

At the system level, aggregate vulnerability, H_t refers to the weighted average of each bank's vulnerability, with the weights given by its relative initial equity.

System equity loss,
$$H_t = \sum_i w_i h_{it}$$
 (7)

weights,
$$w_i = \frac{E_{i, t=0}}{\sum_j E_{j, t=0}}$$
(8)

5.2.2 Shock Scenarios

Two types of shock scenarios were used for the simulation. The first scenario assumes banks experiencing a common shock on their cross-border interbank exposures i.e. interbank lending and borrowing exposures to non-resident financial institutions. Specifically, all banks would experience simultaneous credit and funding shocks at time, t=1 (also called the first round for brevity); (i) an effective¹⁸ negative credit shock, r on cross-border interbank lending exposures and (ii) a reversal shock, f on cross-border interbank borrowing exposures. Unable to replace the lost funding in the short-run, banks are forced to deleverage, first withdrawing their excess liquidity placements with the central bank, Acb and then liquidating a portion, z of their holdings of liquid securities, Alias if there are insufficient placements with the central bank. Malaysian banks have high degree of common asset exposures with Malaysian sovereign debt securities forming 40.7% of the banking system's Basel III Liquidity Coverage Ratio High Quality Liquid Assets in 2017. As such, a haircut, x is imposed on all remaining (1-z) stock of liquid securities to replicate the potential price impact of simultaneous asset liquidation to replace lost interbank funding and adverse market movements that may be observed during periods of heavy portfolio outflows that could accompany the interbank funding reversal. This is in part cognisant of the concentration risk posed by emerging markets' limited access to other forms of high quality liquid assets beyond sovereign debt, particularly following the implementation of Basel liquidity frameworks (Basel Committee on Banking Supervision, 2014). Notwithstanding any asset-specific qualities and market dynamics which may offset potential valuation losses during times of rapid deleveraging, we deliberately chose to adopt a conservative approach and impose a haircut on all of banks' liquid assets. The magnitude of the haircut is calibrated based on the historical worst possible adverse yield movement observed on Malaysian government debt.

In the first round, banks will immediately incur the losses following the shocks and there is a corresponding reduction in equity level. The losses in equity at this point is referred to as first order impact. Following this, the likelihood of a distressed bank (referring to a bank suffering from relative loss in equity) repaying its obligations on the domestic interbank market becomes lower as its creditworthiness deteriorates. Here the DebtRank algorithm is adapted to trigger contagion effects in the domestic interbank market whereby banks that lent to distressed banks will incorporate

¹⁸ The effective credit shock on banks' cross-border exposures refers to product of probability of default (PD) and loss-given-default (LGD). For simplicity, the current study only varies the effective credit shock in conducting sensitivity analysis.

information about the reduced creditworthiness into the valuation of their interbank lending exposure thereby incurring losses. We refer to the cumulative loss of equity at this point as second order impact. The value of the interbank asset will lie between its face value (repaid in full) and zero (assuming no recovery in the event of default). In our study, the losses incurred in the second round by creditor banks is proportional¹⁹ to relative loss of equity incurred by debtor banks in the first round. Should a bank have multiple interbank lending exposures to distressed banks in the domestic interbank market, overall losses incurred during the second round refer to total losses incurred on all its domestic interbank lending exposures.

The first scenario is repeated with various values of credit, funding and market shocks to assess sensitivity of impact to set parameters. The second scenario, meanwhile, subjects each bank to similar shocks (as in the first scenario) but individually. This step is then repeated for each bank within the sample. This is intended to decompose systemic risk properties of a bank into (i) its impact on the system and other banks in the event of the bank's distress or default and (ii) its vulnerability with respect to external shocks. Impact of bank *i* refers to the relative equity loss of the system when bank *i* is shocked. Both scenarios are then repeated for data ending 2013 and 2017, respectively.

6. Results

The results in this section are divided into two parts: (i) the topological characteristics of the domestic and cross-border interbank network and (ii) the results of the counterfactual simulation. In highlighting our findings, where applicable, we shall focus on comparing (i) SIBs versus non-SIBs and (ii) domestic versus locally-incorporated foreign banks for greater clarity.

6.1 Network Analysis

Connectivity within the Malaysian banks' interbank exposures has declined over time (Graph 9). Interconnectivity of banks experienced a relatively steep decline in 2015 before reaching 18.2% in 2017, compared to 20.7% in 2013. As the number of nodes in the dataset are fixed, the decline in connectivity is a factor of the total number of links in the network, which dropped to an average of 559 for the year 2017 from 627 in 2013. Further breakdown shows this is largely attributed by lower connections from SIBs, mainly made up by domestic players. The average number of transactions made by these domestic SIBs fell to an average of 281 in 2017 (2013: 349).

¹⁹ Here we would like to highlight that that subsequent works on DebtRank have advanced refined valuation functions for various asset exposures which can more accurately calibrate the distress propagation mechanism (Bardoscia et. al., 2017). In our view, although the extent of the over- and underestimations of using a linear propagation mechanism cannot be rigorously quantified, a reasonable assumption is that they roughly cancel each other out.



Similarly, the likelihood that two neighbouring counterparties are connected are also on a declining trend, with the clustering coefficient estimated at 14.8% in 2017 (Graph 10). There are generally two bouts of decline observed during the period, mainly in 3Q 2014 and mid-2016. This is largely due to outflows, particularly to Labuan. The results above signals that although lesser links are generated within the interbank market over time, the network is prone to movement of flows, observed by the increase in intensity of cross-border flows.

The change in betweenness centrality from 2013 to 2017 confirms that the role of some key SIBs remained important, recording a betweenness centrality of 0.05 to 0.08 as at 4Q 2017²⁰. The four largest parent SIBs remain as key financial intermediaries in the domestic market despite the declining role of their subsidiaries (Figures 1 and 2). Amongst the list of banks with the top ten highest betweenness centrality statistic, two of the banks are LIFBs consistent with the significance of foreign players as a provider of foreign currency liquidity.



²⁰ Refer to Table A2 (Appendix 3).

- 1. Size of the node represents measure of betweenness centrality i.e. the larger the node, the higher the betweenness centrality
- 2. Red nodes represent SIBs, blue nodes represent non-SIBs
- 3. Nodes with green labels represent non-SIB LIFBs, nodes with yellow labels represent non-SIB domestic banks
- 4. *Subsidiaries of SIBs

Source: Author's estimation

The average number of outgoing links has also been on a steadily declining trend, reflecting the decrease in interconnectivity of banks (Graph 11). Specifically, the fall in the average degree is observed since 3Q 2014. Narrowing on the domestic interbank market only (the core-core network), given that there are 54 banks, the maximum number of potential outgoing links in this study would be 1,431²¹. However, given that there are only 169 directed-out links in 2017, only 12% of the potential links are utilised, deeming the domestic interbank system as an incomplete network. This is not much different from 2013, where there were 216 outgoing links, thus exploiting 15% of the potential core-core network. A look at the core-periphery structure, however, shows a slightly more complete network, with 54% of the potential outgoing links and their respective external counterparty countries being utilised as at end-2017. This is reasonable because the greater regionalisation of domestic banks, deep and liquid financial market coupled with strong economic performance attracted a larger presence of foreign banks.

The decline in average outdegree is more apparent for SIBs, albeit remaining higher than non-SIBs (Graph 12). This is largely attributed to the increase in cross-border flows, where more than half of exposures are to non-residents (Graph 13).



Source: Author's estimation

Further breakdown of net interbank exposures of SIBs to non-residents show that the largest exposure of our onshore banks was to the Asian region, specifically Labuan

²¹ The maximum number of potential outgoing links is as follows = $\frac{54 \times 53}{2}$

(Graph 14). Intragroup funding to Labuan expanded in mid-2014 following the increase in foreign currency lending to corporations to support business activities during the period. The general decrease in cross-border exposures observed in 3Q 2016, however, is partly explained by some DBGs' strategy to reduce reliance of overseas operations on parent funding, limiting external exposures.



Table 2 shows the top 10 net exposures of D-SIBs to non-residents by countries. Net interbank placements in Labuan as at 1Q 2013 was recorded at RM5.4 billion. However, this figure ballooned to RM11.7 billion as at end-2017, showing the increasing role of Labuan as a booking centre. Cross-border interbank claims continue to be concentrated within the Asian region, particularly in countries dominated by our domestic banks' regional presence.

SIBs: Top 10 Net Exposures by Countries (1Q 2013 vs 4Q 2017) Table 2				
1Q 2		2013	4Q 2017	
INO	Country	Exposure (RM bil)	Country	Exposure (RM bil)
1	US	7.1	Labuan	11.7
2	Labuan	5.4	Singapore	3.1
3	Hong Kong	2.5	US	2.2
4	Singapore	2.2	China	1.6
5	China	1.2	Philippines	1.1
6	Indonesia	0.9	Hong Kong	0.8
7	France	0.8	Indonesia	0.6
8	UK	0.8	Japan	0.6
9	Vietnam	0.5	UK	0.5
10	Philippines	0.5	Korea	0.5
Course: Pank Nagara Malausia				

Source: Bank Negara Malaysia

The time evolution of the interbank network is illustrated in Figures 3 and 4. The network is shown at the beginning and end of the sample period (1Q 2013 vs 4Q 2017). There is a clear decline in network connectivity in the domestic and cross-border interbank market over time, suggesting a decline in the network susceptibility to contagion events. The decline in interbank connectivity can be explained by the following: (i) greater cross-border flows to specific non-residents by SIBs and (ii) concentration of interbank activities with related counterparties (i.e. intragroup exposures), a less risky source of exposure.

The LCR requirement, which was first announced in November 2014 could have contributed to the diminishing connectivity within the interbank network. To meet the requirements, banks are required to equip themselves with HQLA which includes placements with central banks and holding of liquid debt securities. In this regard, banks would have been incentivised under the requirement to increase placements with BNM (i.e. lending to BNM in the domestic interbank market) as opposed to lend to another financial institution within the domestic interbank market as the former counts as a HQLA, thus lowering interconnectivity. Following the implementation of LCR requirement in June 2015, we did observe a general decline in interbank lending by banks while placements with BNM22 rose and remained at elevated levels thereafter (Graph 15). In addition, the 100% run-off rate attached to interbank borrowings, which effectively means banks have to increase their stock of HQLA by an equivalent amount of their borrowings, could have dis-incentivised banks to borrow from the interbank market, thereby also lowering interconnectivity.



■ SIB 1 ■ SIB 2 ■ SIB 3 ■ SIB 4 ■ SIB 5 ■ SIB 6 ■ SIB 7

Note:

1. Royal blue nodes represent non-SIBs

2. Size of the nodes represent the number of counterparties

3. Direction and thickness of the arrows represent net placement and relative size of exposures

Source: Author's estimation

²² Central bank placements could be argued to be a safer option for banks compared to liquid securities holdings especially during times of volatility in the domestic financial markets with increased two-way portfolio flows, as was the case during 2015.



Using a weighted network approach, we find that the risks for some SIBs have decreased slightly over time in line with diminishing connectivity (Figures 5 and 6). It is interesting to note also that contagion risk used to be widely distributed amongst SIBs, but now the risk is more concentrated within the larger SIBs. Nonetheless, SIBs remain relatively more susceptible to induce contagion compared to non-SIBs due to their large size and important role as a credit intermediator.



Note:

- 1. Red nodes represent SIBs, blue nodes represent non-SIBs
- 2. Size of the nodes represent the degree of interconnectedness, taking into account the number of counterparties and weighted size of exposure
- 3. Direction and thickness of the arrows represent net placement and relative size of exposures

Source: Author's estimation

6.2 Counterfactual Simulation Analysis

In assessing the results of counterfactual simulation model, we start by exploring the losses incurred at the aggregate system level over the five-year period. Recall that

this period also coincides with several key structural changes that took place in the Malaysia banking system: (i) implementation of Basel III capital and liquidity standards and (ii) a significant decline in the aggregate interbank exposures in the domestic interbank market. Graph 16, which offers a deconstruction of the losses according to shock types and rounds the losses were incurred in, shows that aggregate losses due to contagion has decreased significantly from 2013 to 2017. Consistent with findings of lower connectivity in the domestic interbank market, the decline in aggregate losses are driven by lower loss contribution from second round effects. That said, relative losses in equity due to the second round continue to be sizeable, suggesting that disregarding spillover or indirect impact can underestimate the true extent of potential losses. In addition, valuation losses incurred on liquid securities holdings arising from rapid deleveraging to replace lost interbank funding have steadily increased over the years, making up 42% of total aggregate losses at the system level in 2017 as compared to 25% in 2013. While the banking system cross-border interbank funding has grown rather significantly in value terms during the same period, we have maintained the same haircut for liquid securities holdings for simplicity. Given this, the increase in valuation losses is primarily attributable to higher holdings of liquid assets holdings among Malaysian banks (Graph 15) following the implementation of Basel III LCR requirement. On aggregate, Malaysian banks' liquid securities holdings stood at RM433 bil or 17.0% of total assets in 2017, a 32% increase since 2013.

To affirm that improved resilience at the aggregate system level is not down to few large banks alone, we also compared the breakdown of overall losses incurred by each bank over the same period (Graph 17). Consistent with the system level trends, fewer banks suffered from large losses, with only 2 banks suffering from losses exceeding 50% of CET1 capital. Again, during this period, bank capitalisation increased significantly (refer to Table 1) which could in part explain the improved resilience despite higher interconnectedness to cross-border financial institutions.



We then proceed to decompose aggregate losses across the five-year to losses attributable to SIBs and non-SIBs (Graph 18). Similarly, resilience of SIBs have improved over the years. Yet, unsurprisingly system-wide losses induced by SIBs remain significant. However, average vulnerability of SIBs, which reflects the average losses (as proportion of CET1 capital) incurred by SIBs across all iterations in Scenario 2, remain low (Graph 19).



Next, we compare the first-round effects and the second-round effects (Graph 20). Here we observe banks with higher external and domestic interbank leverage suffer greater losses. These tend to be smaller foreign banks who typically operate as foreign currency liquidity provider in the domestic interbank market. As expected, overall impact is lower if related counterparties' exposures are excluded (Graph 21). Comparing with 2013 (Graph 22), we observe a significant reduction in the effects in 2017, with banks being clustered to the bottom left hand corner.





Next, we focus on the two following quantities: (i) losses (as proportion of CET1 capital) incurred by a bank when faced with shocks in the first round and (ii) total loss induced by each bank onto the system when faced with shocks in the first round. The former, a measure of vulnerability to external shocks and the latter, a measure of impact a bank has onto the interbank market sheds light into two separate systemic risk aspects (Graphs 23 and 24). Comparing these quantities for 2013 and 2017, we observe that banks exhibiting relatively high external vulnerability are mostly small banks that also pose limited impact onto the domestic interbank market. Nevertheless, our results show that SIBs continue to exhibit high vulnerability (vulnerability exceeding median vulnerability) and can potentially pose significant impact due to their prominent role in the domestic interbank network. Unsurprisingly, size which is regarded as a key measure of systemic importance appear to be associated with high values of vulnerability and impact.



Note:

1. Marker size represents relative measure of bank assets (the bigger the marker, the larger the bank in terms of asset size)



Source: Author's estimation

7. Conclusion and Policy Implications

We have demonstrated that interconnectivity and solvency contagion risk in the Malaysian banking system to external shocks have declined significantly since 2013, despite the rapid growth in cross-border exposures in value terms. Nonetheless, due to their large size and interconnectedness i.e. importance as a financial intermediator, SIBs are found to be more susceptible to induce contagion within the network. In assessing potential losses arising from contagion induced by external shocks, we incorporated two other channels of contagion that are often disregarded in similar counterfactual simulation studies: (i) valuation losses due to common asset exposures and (ii) mark-to-market losses resulting from credit quality deterioration or a loss of confidence (also known as 'credit quality channel', refer to Fink et.al (2016)).

We believe that network analysis and counterfactual simulation, particularly those which extends beyond simple spillover mechanisms, are good complements to other macroprudential surveillance tools that are being used to monitor financial system vulnerabilities. Such analysis helps to provide useful insights on financial system vulnerability to shock scenarios and the propensity of financial institutions to amplify contagion due to significance within a particular network and/or degree of interconnectedness to other financial institutions i.e. 'too connected to fail' which cannot be gauged by simply looking at the size of balance sheet. In this regard, our study has demonstrated that SIBs continue to exhibit relatively higher vulnerability to external shocks due to their cross-border exposures and can potentially cause significant impact onto Malaysian banking system during times of distress. This serves as a reminder on the need to be cognisant of the risks posed by systemically important banks and have necessary policy measures in place to both manage the risks and reduce the impact of SIBs failure. Furthermore, considering how financial interconnectedness is an increasingly regional and global phenomenon, there is a role for collective efforts by policymakers to improve the monitoring of systemic linkages. This should include having in place effective arrangements for multilateral information sharing and surveillance, and wider coverage of reporting on crossborder financial obligations.

Moving forward, this study could be extended in three key directions. First, with access to more complete information on banks cross-border exposures, particularly identity of counterparties, a more comprehensive and an accurate assessment of contagion risks posed by systemically important banks in other jurisdictions to the domestic financial system and economy can be conducted. Second, calibration of distress propagation mechanism for counterfactual simulation deserves further discussion. In this regard, a more refined and economically accurate mechanism that take into account counterparties' probability of default and the recovery rate of the assets could be explored (refer to Fink et. al., 2016; Bardoscia et.al, 2017). Third, our analysis can be expanded to assess contagion risk to take into account other form of interlinkages through which banks are interconnected with other financial institutions such as a wider set of asset classes e.g. cross holdings of securities or markets like OTC derivative markets. This would allow a more comprehensive assessment of contagion risk within the financial system arising from higher level of interconnectedness.

8. Addendum: Application of counterfactual simulation as part of the broader stress testing toolkit to assess contagion risk

This section is an extension to our earlier paper²³ and demonstrates the application of counterfactual simulation as part of broader stress testing toolkit to assess risk of contagion event in the domestic interbank market. Bank Negara Malaysia conducts a multi-year solvency stress test exercise on a regular basis to assess the resilience of banks under simulated scenarios of severe macroeconomic and financial strains.

The latest stress test exercise for the banking sector²⁴ incorporates the counterfactual simulation model studied in our paper to ascertain the incremental losses incurred by banks from potential contagion via domestic interbank market exposures. Here contagion is induced as banks incur losses from credit, market and external funding risk shocks under each adverse scenario of the macro stress test scenario (Diagram 1). A distressed bank's capacity to repay counterparties in the domestic interbank market is then assumed to decline as its creditworthiness deteriorates. Banks that lend to a distressed bank are then assumed to incorporate information about the reduced creditworthiness into the valuation of their interbank lending exposure to that distressed bank, thereby incurring losses. The losses incurred by the creditor bank is assumed to be proportionate to the relative loss of capital incurred by the debtor bank. For example, if the debtor bank incurs x% of loss in capital, the creditor bank is assumed to experience an equal relative loss of x% on their interbank lending exposure to the debtor bank.

Overall, the potential contagion losses arising from interbank exposures is assessed to be low at 6.3% of total losses in 2018. Unsurprisingly, losses from contagion risks are estimated to be lower if related counterparty exposures are excluded as most interbank market exposures are intragroup in nature.



Source: Bank Negara Malaysia

- ²³ See Harikumara and Lim (2019) "Cross-border Interbank Contagion Risk to the Malaysian Banking System".
- Refer to the Financial Stability and Payment Systems Report 2018, page 31-34 (Bank Negara Malaysia, 2019).

Appendices

List of countries nodes Table A1					
No.	Country Node	Label	No.	Country Node	Label
1	Labuan	LABUAN	13	Japan	JPN
2	Singapore	SG	14	Republic of Korea	KOR
3	Cambodia	КНМ	15	Taiwan	TWN
4	Indonesia	IDN	16	United States	US
5	Thailand	THA	17	United Kingdom	UK
6	Vietnam	VNM	18	Germany	DEU
7	Laos	LAOS	19	France	FRA
8	Brunei	BRN	20	Italy	ITA
9	Philippines	PHL	21	Spain	ESP
10	Myanmar	MMR	22	Other Asia	OTHER ASIA
11	Hong Kong SAR	НК	23	Other Europe	OTHER EU
12	China	CHN	24	Other Non- Residents	OTHER NR

Appendix 1: Network Data and Methodology







Appendix 2: Counterfactual Simulation Model

Description of the ma	ain variables	Table A2
Name	Symbol	Description
Individual bank vulnerability	hi(t)	Relative loss in equity of bank i at time t
System level vulnerability	H(t)	Relative loss of equity for the whole system at time t

Balance sheet dynamics

Bank's assets are assumed marked-to-market whereas liabilities are carried at

their face value

Assets, A_t = Liabilities, L + Equity, E_t

(4)

Table A3

Each bank *i* either lend to other banks within the network i.e. domestic interbank lending (A_{dib}), or engage in any of the following (i) cross-border interbank lending (A_{ea}), (ii) placements with central bank (A_{cb}), (iii) holding of liquid securities (A_{liqs}) and (iv) holding of other assets (A_{oth}).

$$A_t^{dib} + A_t^{ea} + A_t^{cb} + A_t^{liqs} + A_t^{oth} = L_{\Box} + E_t$$
(5)

Total leverage of each bank at time t is the ratio of total assets and its equity, which can be disaggregated into its additive subcomponents as follows

Total leverage,
$$l_t = \frac{A_t}{E_t}$$

$$= \frac{A_t^{dib}}{E_t} + \frac{A_t^{ea}}{E_t} + \frac{A_t^{cb}}{E_t} + \frac{A_t^{liqs}}{E_t} + \frac{A_t^{oth}}{E_t}$$

$$l_t^{dib} + l_t^{ea} + l_t^{cb} + l_t^{liqs} + l_t^{oth}$$
(9)

Contagion stress-test process

At time, t =1 each bank experiences an effective negative credit shock, r on crossborder interbank lending exposures to bank k

$$\sum_{k} r_k A_{i,k}^{ea} = E_t \sum_{k} r_k l_{i,k}^{ea} \qquad \text{where} \qquad A_i^{ea} = \sum_{k} A_{i,k}^{ea} \tag{10}$$

The loss incurred on cross-border interbank lending results in corresponding reduction in equity for each bank i as follows:

$$A_{i,k,t=0}^{ea} - A_{i,k,t=1}^{ea} = \sum r_k A_{i,k}^{ea} = E_{i,t=0} - E_{i,t=1}$$
(11)

Simultaneously, each bank i also experiences a reversal shock, f on cross-border interbank borrowing exposures. Unable to replace the lost funding in the shortrun, banks are forced to deleverage, first withdrawing their excess liquidity placements with central bank, Acb and then liquidating a portion, z of their holdings of liquid securities, Aliqs if there are insufficient placements with the central bank. A haircut, x on banks' remaining holdings of securities replicates the potential price impact of simultaneous asset liquidation to replace lost interbank funding and adverse market movements. The reduction in value of liquid securities results in corresponding reduction in equity is given by:

$$A_{i,t=0}^{liqs} - A_{i,t=1}^{liqs} = x(1-z)A_{i,t=0}^{liqs} = E_{i,t=0} - E_{i,t=1}$$
(12)

Cumulatively, individual relative equity loss at time t = 1 is computed as follows:

Relative loss in equity,
$$h_{i,t=1} = \min \left\{ 1, \sum_{k} r_k A_{i,k}^{ea} + x(1-z) l_{i,t=0}^{liqs} \right\}$$
 (13)

Following this, the likelihood of a distressed bank (referring to bank suffering from relative loss in equity) repaying its obligations on the domestic interbank market becomes lower as its creditworthiness deteriorates. At time t = 2, banks that lent to distressed banks will incorporate information about the reduced creditworthiness into the valuation of their interbank lending exposure thereby incurring losses. The value of the interbank asset will lie between its face value (repaid in full) and zero (assuming no recovery in the event of default). In our study, the losses incurred in the second round by creditor bank is proportional to relative loss of equity incurred by debtor banks in the first round.

DebtRank excludes more than one reverberation, i.e. a bank can only transmit distress once to the network. We adopt similar premise in our study.

Individual relative equity loss at time t = 2 is computed as follows:

Relative loss in equity,
$$h_{i,t=2} = \min \{1, h_{i,t=1} + \sum_{j} l_{ij}^{dib} h_{j,t=1}\}$$
 (14)

Append	ix 3:	Resu	lts
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Betweenness centrality (1Q 2013 vs 4Q 2017)				
SIB/Non-SIB	Betweenness Centrality		Change	
	1Q 2013	4Q 2017	4Q 2017	
SIB 4	0.03	0.08	î	
SIB 2	0.09	0.08	Ļ	
SIB 1	0.08	0.08	\leftrightarrow	
SIB 3	0.11	0.05	Ļ	
NSIB 23	0.01	0.05	1	
SIB 4*	0.01	0.03	1	
NSIB 12	0.00	0.02	1	
NSIB 2	0.01	0.02	1	
SIB 5	0.04	0.02	Ļ	
NSIB 1	0.09	0.01	Ļ	

Note: *Subsidiaries of SIBs

Source: Author's estimations

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IFC-BNM-ECB Satellite Seminar on "New analytics for working with micro data, Al" Cross-border contagion risk to the Malaysian banking system 62nd ISI WORLD STATISTICS CONGRESS 2019 18-23 August 2019, Kuala Lumpur

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Presentation outline

- 1. Setting the scene
- 2. Research objectives
- 3. Data
- 4. Methodologies
 - Network analysis & visualisation
 - Contagion stress test
- 5. Results & policy implications

Setting the scene

Why are we concerned about cross-border contagion risk?



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Research objectives

- 1. Explore properties of Malaysian banks' interbank exposures using network analysis techniques, including assessment of dynamics over time
- 2. Develop a cross-border contagion stress-test that will facilitate the following:
 - Assessment of banks' susceptibility to external shocks at the macro- and micro- level
 - Estimation of contagion path (propagation of shocks) across banks via the domestic interbank market induced by external shocks and potentially vice-versa
 - Identification of potential systemic linkages and cross-border domino effects between systemically-important banks (SIBs), internationally active banks and the Malaysian banking system

Data

Methodology		(i) Network analysis	(ii) Counterfactual simulation
 Banks' bilateral exposures in the domestic interbank market (Bank Negara Malaysia, BNM) Banks' cross-border exposures (BNM, aligned to BIS international banking statistics) 			tet (Bank Negara Malaysia, BNM) mational banking statistics)
Source			 Regulatory capital (BNM) Placements with central bank (BNM) Holdings of liquid securities (BNM)
Frequency	Quarterly (2013-2017)		Annual (2013-2017)
Number of	78 nodes	Core: 54 banks	
observations		Periphery: 24 external counterparty countries	54 banks
	 Does not consider the possibility of new links Only positive flows (net placements/net assets) are retained Negative flows (net liabilities) are zerorised 		(further details in subsequent slides)

Note:

- 1. In this study, we have identified 20 out of 54 banks, comprising domestic and foreign banks, as systemically important banks to facilitate our analyses. On a consolidated basis, these SIBs are part of 7 banking groups. Such banks shall be referred to as systemically important banks (SIBs) hereafter.
- 2. SIBs refers to banks whose distress or failure may result in severe negative spillover impact to the financial system and real economy. At the global stage, the Financial Stability Board and Basel Committee of Banking Supervision assess and identify banks that are deemed to be systemically important on an annual basis, referred to as global systemically important banks (G-SIB). Similarly, national authorities identify banks that are systemically important in their respective jurisdiction, commonly referred to as domestic systemically important banks (D-SIB).
- 3. SIBs for our study are selected based on a combination of balance sheet indicators namely total assets, total deposits and total loans outstanding.

Methodology: Network Analysis

Assessing Topological Characteristics of Networks



Network analysis

Connectivity of banks in the domestic interbank market decreases over time

18.2% of banks are likely to be connected in 2017 (2013: 20.7%)

Connectivity and clustering coefficient



Source: Bank Negara Malaysia

Nonetheless, the role of SIBs as key financial intermediaries remain important

SIBs: Betweenness centrality (1Q 2013 vs 4Q 2017)

SIR/ Non SIR	Betweenness Centrality		Change
31D/ NON-31D	1Q 2013	4Q 2017	
SIB 4	0.03	0.08	1
SIB 2	0.09	0.08	↓
SIB 1	0.08	0.08	\leftrightarrow
SIB 3	0.11	0.05	↓
Non-SIB 23	0.01	0.05	1
SIB 4*	0.01	0.03	1
Non-SIB 12	0.00	0.02	
Non-SIB 2	0.01	0.02	
SIB 5	0.04	0.02	Ļ
Non-SIB 1	0.09	0.01	Ļ

4Q 2017 Network: Betweenness centrality



Note: * indicates subsidiaries or affiliates of the same banking group

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Network analysis Increase in intensity of cross-border flows by SIBs reduces outdegree

SIBs cross-border exposures has increased...

Banking System: Average Outdegree



Source: Bank Negara Malaysia

...with greater exposure to banks in Asian region...

SIBs: Net interbank exposures to nonresidents by region



... amid higher intragroup exposures to non-residents

SIBS: Net intragroup exposure to nonresidents



Network analysis

Decreasing connectivity in the Malaysian banks' interbank market

Key observations:

- Interbank activities are concentrated among intragroup entities
- Increase of high quality liquid assets (central bank placements and securities holdings) to meet Liquidity Coverage Ratio (LCR) requirements

4Q 2017: Network outdegree



1Q 2013: Network outdegree

Note: - Royal blue nodes represent non-SIBs. Other coloured nodes represent SIBs on a consolidated basis (7 in total).

- Size of the nodes represent the number of counterparties
- Direction and thickness of the arrows represent net placement and relative size of exposures

Source: Bank Negara Malaysia

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Network analysis

However, more outgoing links does not always equal greater contagion risk

DSIBs are more susceptible to contagion risk compared to non-DSIBs...





...but the risk for some banks decreased over time



4Q 2017: Weighted network outdegree

Note: - Red nodes represent SIBs, blue nodes represent non-SIBs

- Size of the nodes represent the degree of interconnectedness, taking into account number of counterparties and size of exposures
- Direction and thickness of the arrows represent net placement and relative size of exposures

Source: Bank Negara Malaysia

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Methodology: Contagion stress-test

Assessing contagion risk arising from external exposures



First order impact

- Banks experience losses due to credit and funding shocks on their external exposures, and are deemed to be distressed even if not in default.
- The likelihood of a distressed bank repaying its obligations becomes lower as its creditworthiness deteriorates.

Second order impact

The banks that lent to a distressed bank will incorporate information about the reduced creditworthiness into the valuation of their interbank lending exposure to the that bank thereby incurring losses.

¹ Based on 'DebtRank' methodology developed by Battison et. al (2012) in "DebtRank: Too Central to Fail? Financial Networks, the FED and Systemic Risk" to capture distress propagation in networks without assuming defaults

Scenario & parameters

Credit shock

50% default on cross-border interbank lending

Funding & market shocks

50% withdrawal of

short-term external debt with unrelated counterparties, lost funding is not refinanced

5% haircut on securities

holdings to simulate impact of simultaneous asset liquidation to replace lost funding & adverse market movements

Scenarios

- Common shock affecting all banks simultaneously at time *t*=1
- 2. A single bank is shocked at time t=1. This is repeated for each bank in the system

Contagion stress-test Banks' resilience to external shocks have improved over time

Number of banks

Consistent with lower connectivity in the interbank market, second order impact while sizeable has declined

Banking System: Vulnerability by Type of Shocks and Round



Fewer banks suffered from large losses, with only 2 banks significant losses

> Breakdown of Losses (as % of CET1 capital)



Similarly, resilience of SIBs has improved during the same period



...average vulnerability¹ of SIBs are low

0.46% of CET1 capital

Note:

¹Average vulnerability reflects the average losses (as proportion of CET1 capital) incurred by a bank across all iterations when each bank in the system is shocked individually (Scenario 2)

Contagion stress-test

Banks with higher domestic interbank leverage suffer greater losses

These are largely foreign banks that operate as FCY liquidity provider (and have smaller capital base) 2017: 1st Order Impact vs 2nd Order Impact (% of CET1 Capital)



However, overall impact is lower if related counterparties' exposures are excluded 2017: Excluding Related Counterparties' Exposures



Since, 2013, there has been

reduction in the cumulative

impact of external shocks

2013: 1st Order Impact vs 2nd Order

Impact (% of CET1 Capital)

1. Marker size represents domestic interbank loans leverage (the bigger the marker, the greater the domestic interbank leverage)

2. Marker colour indicates type of bank: Red for SIBs, blue of non-SIBs

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Contagion stress-test SIBs cause significant impact onto system

2017: Vulnerability to External Shocks vs Impact in Domestic Interbank Market

RM million



2013: Vulnerability to External Shocks vs Impact in Domestic Interbank Market

RM million



- Banks exhibiting high external vulnerability are mostly small banks that also pose limited impact onto the domestic interbank market
- However, SIBs continue to exhibit relatively higher vulnerability and cause significant impact onto system
- Unsurprisingly, size (larger dots) appears to be associated with high values of individual vulnerability and systemic impact

Note:

- 1. Marker size represents represents relative measure of bank assets (the bigger the marker, the larger the bank in terms of asset size)
- 2. Marker colour indicates type of bank: Red for SIBs, blue of non-SIBs

Conclusion & policy implications

Results

- 1. Interconnectivity in the domestic interbank market and solvency contagion risk of Malaysian banks to external shocks have declined significantly since 2013
- 2. Nonetheless, due to their large size and interconnectedness i.e. importance as a financial intermediator, SIBs are found to be more susceptible to induce contagion within the network, causing significant impact onto the system

Policy implications

- 1. Network analysis and counterfactual simulation are good complements to other macroprudential surveillance tools that are being used to monitor financial system vulnerabilities
 - Such analysis helps to provide useful insights i.e. 'too connected to fail' which cannot be gauged by simply looking at the size of balance sheet
- 2. Importance of comprehensive and effective arrangements in place for crisis containment, management and resolution
 - Impact of distress or failure of SIBs will impose outsized impact on the system
- 3. Importance of having effective arrangements for multilateral information sharing and surveillance



THANK YOU

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