## Chapter 2

# A CONTAGION RISK ANALYSIS THROUGH VISUAL NETWORK: AN OVERVIEW OF THE ASIA-PACIFIC REGION

By

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## 1. Introduction

This study outlines a detailed overview of the structural changes in the Asia-Pacific region from the 1990s onwards, and we also review the most relevant literature on this important topic. The second part of the paper then provides the descriptive analysis of the financial structures in the region including the role of the G7 countries, Luxembourg and Switzerland. The following chapters in this volume then focus on the specific characteristics of the individual countries with deeper insights about their financial structures.

A number of recent empirical studies by central banks and the academic literature have focused on the impact of the Great Financial Crisis (GFC) and the role of systematically important banks (SIBs) on the systemic stability of the financial system as a whole. These studies unambiguously show that cross-border interbank exposures affect the systemic stability of individual banking systems through the transmission of shocks, see, for example, Haldane and May (2011), Allen and Gale (2000), Yellen (2013) and Cerutti (2015), among others.

This contagion risk through cross-border interbank activities has not been easy to detect. The opaqueness of the linkages is even more pronounced when banks are linked through off-balance sheet financial activities. The complex financial cross-border interbank linkages conceal possible idiosyncratic shocks that may cause spillovers to other financial systems.

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As Genberg (2017) shows, cross-border financial integration in Asian emerging market economies (AEME) has become rather complex. Following a lengthy period of high economic growth, which has been primarily financed through bank lending, cross-border interbank linkages in the AEMA have a prominent global network component. On the one hand, this type of interconnectedness has a positive effect on the efficient allocation of funds in terms of innovation activities and competition. On the other hand, cross-border interconnectedness poses higher contagion risk in terms of systemic instability within the banking system and financial institutions. Glasserman and Young (2015) further show that strongly interconnected financial systems report higher losses due to, and caused by, this contagion risk.

So far empirical research on systematic stability of the banking sector in AEME has been rather limited. It is imperative that financial regulators deploy models that allow them to monitor not only the soundness of SIBs but also the potential contagion risk caused by cross-country interbank linkages in AEME. In this paper we predominantly focus on the following two research objectives. First, we propose to analyse cross-border interbank claims and liabilities of the individual countries located in the Asia-Pacific region by deploying visual network analysis (VNA). Such an analysis evaluates interbank exposure to SIBs within the specific market. VNA allows us to also explore the 'hierarchical' cross-country interbank contagion risk that seems to have been neglected in similar studies. In doing so, we evaluate the contagion risk of the individual countries emanating from the financial centres in Hong Kong, Singapore, Tokyo, New York and London. A number of studies have shown that the network analysis is a suitable method in analysing the links between financial institutions (countries). It allows us to unveil links and statistical factors that could be used as a key tool for detecting the potential triggers of systemic risk and contagion effects. Overall, the visual network analysis is able to capture the very complex and extensive interconnectedness of financial institutions (countries). The pros and cons of such a methodological approach have been extensively assessed in a number of studies published by academics and researchers from central banks, the International Monetary Fund (IMF) and the Bank for International Settlement (BIS), e.g., Allen and Gale (2000), Upper (2007), Chau-Lan et al. (2009), Espinosa-Vega and Sole, (2010) and Changmo et al. (2014), among others.

Second, by creating a detailed mapping of cross-border interbank linkages in AEME, we may uncover possible weak links of an adverse credit event or liquidity contraction. Since we do not have data on SIBs through cross-border interbank linkages, as was applied, for example, by Upper (2007), we will explore these links at the country level. The analysis should also provide some insights into potential idiosyncratic shocks, including the impact of 'home bias'. This type of analysis may identify whether the triggers of contagion risk are market shocks or country specific shocks. We also address an important question regarding solvency and liquidity contagion risks. This is of crucial importance and the findings may direct policy makers towards effective prudential management policies.

In doing so, we deploy bilateral data on cross-border bank lending for 28 countries. The sample includes nine global core countries, that is, the G7[5] plus Switzerland and Luxembourg; as well as six core economies in South-East Asia and the Pacific region, namely Australia, Hong Kong, Chinese Taipei, South Korea, Macau and the Philippines. We further include 13 periphery economies. The detailed discussion can be found in Section 4 on data and methodology. The visual network analysis allows us to capture the dynamics and structural changes across these economies including the Great Financial Crisis. Our analysis spans from 2000 Q4:to 2018 Q1.

5. The G7 countries include Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

In this particular study, we adopt the methodological framework proposed by Minoiu and Reyes (2013). The adoption of this methodological framework allows us to compare the finding for AEME with previous research and detect commonalities of the issues across economies. In addition, the execution of the model is relatively feasible even for those who have little knowledge in the field of network simulations systems.

The study contributes to current research in the following ways. To begin with, this is the first study that is exclusively focused on the Asian-Pacific economies, while taking into consideration the effect of the most developed countries and key financial centres. Second, the visual network analysis allows us to capture the flows of funds. This is a particularly important issue in the case of the liquidity constraint to which the financial institutions in the region were exposed to during the financial crisis. A relatively long sample period of our analysis also helps to understand the significant structural changes that took place across the economies in our analysis. We further follow the weighted approach applied by Minoiu and Reyes (2013) to identify the potential intensity of capital flows across the selected economies.

Furthermore, our study provides both qualitive and quantitative analyses through VNA about cross-border contagion risk in the selected Asian-Pacific economies. The key objective of such an analysis is to equip policy makers with the alternative scenarios of potential triggers of cross-border interbank contagion risk. An integral part of this analytical study is to provide recommendations on how to mitigate possible contagion risk within the specific economies and the Asia-Pacific region as a whole.

This chapter is organised as follows. Section 2 overviews the financial markets in the Asia-Pacific region. Section 3 reviews related literature and Section 4 summarises the data and methodology used in our chapter. Section 5 reports and explains the empirical results and Section 6 concludes.

## 2. Financial Markets in the Asia-Pacific Region: An Overview

### 2.1 Systemic Changes in the Asian Economies since 1997

Since the late 1990s, we have observed significant structural changes in terms of the systemic stability of financial markets. In particular, the activities of financial institutions have become more closely linked and interconnected. In 1997, Asian countries experienced one of the most protracted crisis in their recent history, and the financial systems in many countries were almost brought to a complete standstill. The crisis revealed not only the significant structural problems in their domestic economies, but also showed the extensive interconnectedness with financial institutions in advanced economies and global financial centres. The lesson that financial markets learnt during the Asian financial crisis was that domestic and/or external shocks can significantly undermine the systemic stability of the banking system if financial institutions are undercapitalised and face liquidity problems.

Nevertheless, there was a remarkable revitalisation of the financial systems immediately after the crisis. That is in a sharp contrast with what we saw during the Great Financial Crisis (GFC) after 2007-2008. One of the possible explanations why the GFC was much more severe and lasted for such a prolonged period was that since 1997, global financial markets have become even more 'integrated'. Emerging and less developed economies have become extremely dependent not only on their own state of the economy but on the economic stability and the phase of the business

cycles in the advanced economies as well. This link could easily undermine their economic and financial stability and thus affect their further development. The common lesson from the financial crises is that it is important to maintain sound macroeconomic fundamentals along with financial stability underpinned by appropriate financial regulations. These are the basic measures that have to be implemented by regulators and policy makers. Nevertheless, as we argue later, it is not sufficient that these measures focus only on the soundness of purely domestic markets. Bank or even systemic failures can be 'imported' through contagion effects from other countries. Anecdotal evidence further shows that these effects are not necessarily limited to geographically neighbouring countries but can actually be transmitted across continents.

The international bank lending market, which has substantially expanded in the last two decades, has become more vulnerable to external shocks. For example, in 2007, net cross-border bank lending stood at US$4.3 trillion. One year later, the same net cross-border lending was reduced to minus US$1 trillion. This was a consequence of the financial market turbulences and uncertainty when the GFC fully unfolded. Such unprecedented volatility clearly indicates how financial liquidity can suddenly go into reverse. Because of the complexity and extensive linkages across global financial markets, changes in one dominant financial market can have a significant knock-on effect on even relatively sound banking systems. This problem is more pronounced in emerging and less developed economies that are more vulnerable to sudden inflows/outflows of short-term capital including speculative capital. Furthermore, countries' extreme dependence on external finances combined with an underdeveloped financial infrastructure and insufficient financial regulations may lead to unfavourable conditions and an inability to withstand different forms of adverse effects. Such adverse effects can be further reinforced by the higher complexity of financial products. It has become more difficult to detect possible systemic risks within the financial system and/or across the financial systems. The systemic stability of the banking system has therefore become an imperative task for bank regulators.

### 2.2 Cross border Activities in the Asia-Pacific Region

As Genberg (2017) shows, cross-border financial integration has become rather complex in Asian emerging market economies (AEME). Following many years of relatively high economic growth that was predominantly financed by banks, cross-border interbank linkages in the AEME now contain a strong global network component. We have witnessed a dramatic expansion of cross-border activities, predominantly in the form of cross-border bank lending. This acceleration of cross-border activities was driven particularly by international banks from the more advanced economies, including the G7 countries and both global as well as regional financial centres – Singapore, Hong Kong and Kuala Lumpur. Von Peter (2007) provides a detailed analysis of how international banking activity has changed since 1990s. His analysis unambiguously shows that international lending activities are dominated by only a handful of global banks from advanced economies. For example, in [period], the United Kingdom held 20.4% of international bank assets and 22.8% of international bank liabilities. With a share of 12.6 (9.2)% in terms of bank liabilities (assets), the United States constituted the second largest financial centre. Japan, by contrast, has seen a contraction in terms of international lending activities, most likely on account of the long-standing banking restructuring process. It is also of interest to note that Japanese banks do not provide lending directly to less developed economies, but rather allocate their assets to the financial centres in Hong Kong and Singapore (see Section 5 for a broader discussion). The other G7 countries, such as Germany, France and Switzerland, have significantly lowered their exposures to international lending activities to single-digit percentages.

The current global economic and political uncertainty could undermine the fragile stability in emerging and less developed economies. In particular, the recent interest rate increases by the Federal Reserve, as well as the termination of quantitative easing in the USA and Europe, could put extra pressure on the financial liquidity position of financial institutions in Southeast-Asian economies. A resulting capital outflow combined with currency depreciation could have an adverse effect on systemic stability. The recent global outflow of funds from the emerging economies to the tune of US$12.3 billion has undermined the stability of domestic currencies. And a global economic slowdown could aggravate the situation even more. Furthermore, countries also face the problem of political and economic uncertainty. The current trade disputes between the USA and China could have adverse consequences for Asian economies as a whole. It is well documented that a reduction of China's export could negatively affect supply chains across Southeast Asia, as regional trade with China is based on the trade of intermediate goods, which accounts for more than 50% of overall trade. In terms of internal economic and political issues, many Southeast Asian economies exhibit a high share of household debt that is linked to aggressive competition among the retail banks and non-financial institutions expanding their business activities into the retail banking sector.

On the other hand, countries are better equipped to withstand shocks coming from contagion effects. Asian-Pacific economies have put a lot of effort into the key factors that should alleviate potential contagion effect compared to the Asian financial crisis in 1998, including changes to exchange rate regimes. Many economies have abandoned the fixed currency pegs that prevented a devaluation of their currencies in the case of sudden financial market turbulence. That should prevent the sharp, crisis-led devaluations that we witnessed in 1998 when, for example, the Indonesian rupiah devaluated by more than 75% against the US dollar and the Malaysian ringgit devalued by more than 50%. The current setting of the exchange rate regime, such as a managed float that Southeast Asian economies have consequently adopted, should considerably reduce the problem of sudden and rapid devaluations of their currencies.

A further important step that should significantly contribute to the reduction of possible contagion effects is the fact that most economies in the region have substantially boosted their foreign exchange reserves. In fact, some economies have increased their foreign exchange reserves tenfold since 1998. That should help to protect them from short-term speculative attacks on their domestic currencies. Moreover, many economies have addressed the problematic aspects of fiscal deficits, and fiscal discipline has been documented in a number of emerging and less developed economies in the region. This goes hand in hand with curbing inflationary pressures that might undermine overall financial and economic stability and cause unwanted contagion damage if financial market turbulences were to materialise.

### 2.3 The Asia-Pacific Region after the Great Financial Crisis

The emerging and less developed economies in Southeast Asia have undergone significant structural changes in terms of their cross-border activities and financial exposures. Although they still rank rather low in terms of the volume of transferred funds, linkages with countries have changed. A general expansion of the volume of transactions is mostly due to the increased number of international banks that have established operations in these economies. Undoubtedly, these stylised facts can be regarded as an early benefit of the extensive linkages across banks in the Asia-Pacific region. These activities also reflect the banks' business strategy of diversifying their portfolio to limit potential risks. But increased cross-border financial linkages may have potential

negative externalities in terms of systemic stability, including the case of sudden capital outflows that many countries have recently faced as a reaction to the phasing out of quantitative easing in the USA and Europe.

A number of studies have recently tried to identify the links between quantitative easing (QE) and capital flows to Asia. The outcomes are rather inconclusive. For example, Cho and Rhee (2013) argue that the first round of QE (QE1) substantially contributed to capital inflows to Southeast Asian economies after the GFC. Their argument is based on the notion that QE1 lowered US yields, which 'helped' to redirect capital flow to Asia. The authors do not share the view that QE2 and QE3 had similar effects to QE1. They also point to the housing market in some Asian economies and the fact that many residential house prices have risen sharply. It appears that housing prices went up in those economies where the domestic currency has not appreciated. These observations might be also be ascribed to the prolonged QE policies and the resulting effects on global capital flows.

Overall, the turbulence in international financial markets during the GFC disrupted the flows of credit from advanced countries to emerging and less developed economies in Asia and Latin America. Based on the data from the BIS Banking Statistics, we may observe a decline in cross-border claims, which undoubtedly had an adverse effect. This was mainly caused by a retrenchment by global and multinational financial institutions. The structural changes that financial institutions and financial markets have undergone in the last three decades or so caused financial markets at different stages of their development to react differently to external shocks.

## 3. Related Literature

There has been an extensive number of empirical research studies that analyse potential systemic crises and contagion risk using VNA, which has become a well-recognised tool for mapping potential risk within the financial system. The key advantage is that financial linkages can be mapped on a truly global scale. A number of studies have been published by central bankers, financial regulators, practitioners and academics that focus on the factors that may trigger contagion risk. In particular, special attention has been given to the issues of systemic risk, intra- and cross-border contagion risk and the role of systematically important banks (SIBs). These studies unambiguously show the vulnerability of systemic banking stability to the transmission of shocks, see, for example, Allen and Gale (2000), Haldane and May (2011), Yellen (2013), Cerutti (2015), Minoiu and Reyes (2013) and Yilmaz (2017), among others.

### 3.1 Contagion Risk in the Financial Markets

Prior to starting the discussion about contagion risk and bank cross-border interconnectedness, it is important to look at how the term systemic risk is established and positioned within the economic literature that deals with contagion risk. Undoubtedly, the term systemic risk is broadly applied and its definition varies. We adopt the definition that is used by the Group of Ten (G10, 2001, p. 126). They propose the following definition:

> *"Systemic financial risk is the risk that an event will trigger a loss of economic value or confidence in, and attendant increases in uncertainty about, a substantial portion of the financial system that is serious enough to quite probably have significant adverse effects on the real economy.*

> *Systemic risk events can be sudden and unexpected, or the likelihood of their occurrence can build up through time in the absence of appropriate policy responses. The adverse real economic effects from systemic problems are generally seen as arising from disruptions to the payment system, to credit flows, and from the destruction of asset values. Two related assumptions underlie this definition. First, economic shocks may become systemic because of the existence of negative externalities associated with severe disruptions in the financial system. If there were no spillover effects, or negative externalities, there would be, arguably, no role for public policy. [...]*

Gerlach (2009) shows that this definition provides three key factors that provide important characteristics of systemic risk. First, it must impact on a "substantial portion" of the financial system. Thus, it is risk to the financial system as a whole. Second, systemic risk has multiple spillover effects, i.e., a single bank facing severe financial distress can undermine the financial stability and soundness of other banks that are connected to it. Such a situation requires that the effects of this risk are somehow measured and the potential impact is quantified if possible. It is important to mention that systemic risk could be triggered by adverse macroeconomic conditions as well.

Degryse and Nguyen (2004) provide an additional way of detecting potential triggers of interbank contagion risk. They use the following three fundamental explanations. First, interbank contagion attains its momentum in the case of insufficient financial liquidity for a specific financial market. They correctly underline the fact that domestic and cross-border interbank markets provides liquidity only through the redistribution channel, which on its own fails to create new financial assets (liquidity). It is commonly observed from a number of financial crises that the key element that causes a liquidity crisis is the fact that an individual bank, or even the entire banking system, relies too much on the liquidity provided within domestic or cross-border markets. This can also be a reflection of the adopted business model by the bank in question. A further factor that often causes a liquidity constraint occurs when banks suddenly change their exposure to the interbank market due to their own liquidity problems or business activities. It is important to note that the withdrawal from the interbank market is a much easier and cheaper option for a bank than the liquidation of its long-term position. Hoggarth et al. (2010) show that large international banks respond to a liquidity problem by reducing their exposure on the interbank market rather than reshuffling their liquidity across their branches and subsidiaries.

The next factor that can contribute to systemic turbulences within the banking system is a change in market expectations. This can cause contagion and have spillover effects across the entire market and/or the cross-border interbank market. Such a situation occurred during the Asian financial crisis in 1997, for example, when banks faced unprecedented asset-liability mismatches. The latter became even more pronounced when the currencies of those countries depreciated, which led to runs on banks in some countries. The interbank market almost froze overnight, aggravating the problem. Finally, the third way in which systemic contagion can occur is through the failure of systematic important banks (SIB). The failure of a SIB may cause not only a systemic crisis of the banking system in the specific country, but an ensuing spillover effect can be contagious for the banking systems of neighbouring countries. The degree of contagion depends on the linkages across banks through domestic (cross-border) interbank markets. The main area of our concern is therefore to evaluate the linkages of those SIBs within the domestic and cross-border interbank markets that are key players in terms of both liquidity provision and asset activities.

### 3.2 Network Models: Theoretical Concepts

The seminal paper by Allen and Gale (2000) derived a contagion model within a financial market equilibrium framework, where financial contagion is modelled as an equilibrium phenomenon. They show that because liquidity preference shocks are imperfectly correlated across regions, financial institution hold precautionary claims on other regional financial institutions. Such a mechanism is perceived to reduce risk against liquidity preference shocks. Allen and Gale (2000) further argue that the key factor that triggers contagion across the financial institutions (markets) is determined by the structure of the claims within the financial market system. It is then evident that systemic changes within the financial (banking) market can affect systemic changes within both the core-periphery and the core-core network. It is then further shown that such interconnectedness can have a positive effect on the efficient allocation of financial funds by improving financial innovation and competition.

In the economics literature, there is prevailing empirical support that a well-developed global financial network contributes to accelerated economic growth. Anecdotal evidence indicates that economic growth in emerging and less developed economies depends significantly on bank lending. Undoubtedly, competitive pressures within a global network of financial institutions can have a favourable effect on how capital is allocated. At the same time, a number of financial (banking) crises demonstrate that the network across global and multinational financial (banking) institutions undermines the stability of an individual banking system through adverse contagion risk. The latter occurs through systemic instability within the banking system and financial institutions. Glasserman and Young (2015) indicate that strongly interconnected financial systems report higher losses caused by contagion risk. The threat of contagion risk has multidimensional effects on emerging and less developed economies that have rather limited economic stabilisers to withstand the adverse effects of contagion risk, which can be escalated via cross-border interbank activities. Glasserman and Young (2015) further show that this is even more reinforced in cases where bank activities are linked through off balance sheet financial activities. In this regard, possible turbulences in terms of lending disruptions involving quite complex cross-border interbank linkages may contribute to a spillover effect on other financial institutions.

Frexias et al. (2000) model systemic risk in an interbank market. Their research question is on how the banking system is capable of withstanding the insolvency of one bank. They also explore whether or not the closure of one bank could cause a knock-on effect on the rest of the system. An integral part of their model is the investigation of how the central bank can coordinate to avoid the negative consequences on the payment system, including the doctrine of too-big-to-fail. Mirroring Allan and Gale (2000), Leitner (2005) also argues that an interconnectedness of financial institutions improves the allocation of scarce resources through innovation and competitiveness. Leitner (2005) shows that interconnectedness across banks is beneficial if it can push banks in a crisis to provide financial support for one another (bailing them out). This effect is, however, subject to their ability to coordinate such events. Gai and Kapadia (2010) argue that models with endogenous network formation, such as Leitner (2005), impose strong assumptions. They also state that the existing literature fails to differentiate between the probability of contagious default and the potential way it is propagated. Gai and Kapadia (2010) expanded existing analytical models of contagion in financial networks by allowing an arbitrary structure. In particular, they assessed two key channels of contagion in financial systems through which default may spread from one institution to another. The primary focus is on how losses can potentially spread via a complex network of direct counterparty exposures, following an initial default. They argue that the probability of contagion is generally low, but that the effect, once contagion occur, tends to be widespread.

### 3.3 Empirical Research

The empirical research on interbank linkages and contagion risk is rather voluminous. Representative studies include Sheldon and Maurer (1998), Furfine (1999) and Wells (2002). While Boss et al. (2004) focus on case studies in European countries, Upper and Worms (2004) analyse contagion risk in the USA. Undoubtedly, they help policy makers to better understand the complexity of the financial network, although they fall short on providing general policy recommendations and policy actions needed to deal with an eventual manifestation of contagion risk. A further notable study involving VNA was published by Nier et al. (2007). The study is underpinned by the seminal paper by Allen and Gale (2000). However, Nier et al. (2007) provide much deeper insights into the area of contagion risk by exploring possible financial contagion effects. They show that banks that are well capitalised compared to their peers, are more resilient against possible contagious effects. They also show that a relatively marginal change in bank connectivity can trigger disproportional contagion effects. At the same time, if connectivity reaches a threshold value, bank connectivity can help banks that are mutually connected to withstand possible shocks. Nier et al. (2007) also find that the size of interbank liabilities can have a negative impact on bank stability through domino effects. That can occur despite sufficient capital reserves. In terms of competition, they provide evidence that a higher degree of concentration within the banking system can trigger larger systemic risk.

Minoiu and Reyes (2013) provide a comprehensive analysis of the global banking network using data on cross-border banking flows for 184 countries over the period from 1978 to 2010. They show that the density of the global banking network is pro-cyclical. They also provide interesting evidence that country connectedness increases before financial crises and drops afterwards. In the paper, they further argue that the network density in 2007 was comparable to earlier peaks. A more recent study by Korniyenko et al. (2018) further explores the global financial network.

## 4. Data and Methodology

### 4.1 Data Description

As Fender and McGuine (2010) argued, the GFC ably demonstrated that the type of available information that would be needed by regulators to identify international funding risks is inadequate. Cerutti et al. (2012) pointed out that the quality of data is an important issue in the analysis about systemic risk. McGuire and Wooldridge (2005) review the currently available data sources for research on contagion effects and systemic risk. As highlighted in McGuire and Wooldridge (2005), the BIS currently provides three types of statistics on international banking activity: locational banking statistics (LBS), consolidated banking statistics (CBS) and syndicated loan statistics (SLS). LBS provides information on the external debt measures that use national accounts or balance of payments. LBS are generally used by national statistical offices for the construction and evaluation of balance of payments statistics, while CBS and SLS contain information regarding cross-border borrowing sourced from individual banks.

It is important at this stage to point out the differences of how the data are reported. McGuire and Wooldridge (2002) provide a detailed explanation of how these two sets of statistics differ from conventionally applied measures of external debt. The locational statistics cover cross-border positions of all banks domiciled in the reporting area, including positions vis-à-vis their foreign affiliates. But the consolidated statistics report the nationality of the reporting bank as well as their net out intragroup positions (McGuire and Wooldridge, 2005). Minoiu and Reyes (2013) advocate the use of LBS as the appropriate statistics if the aim is to explore linkages across countries.

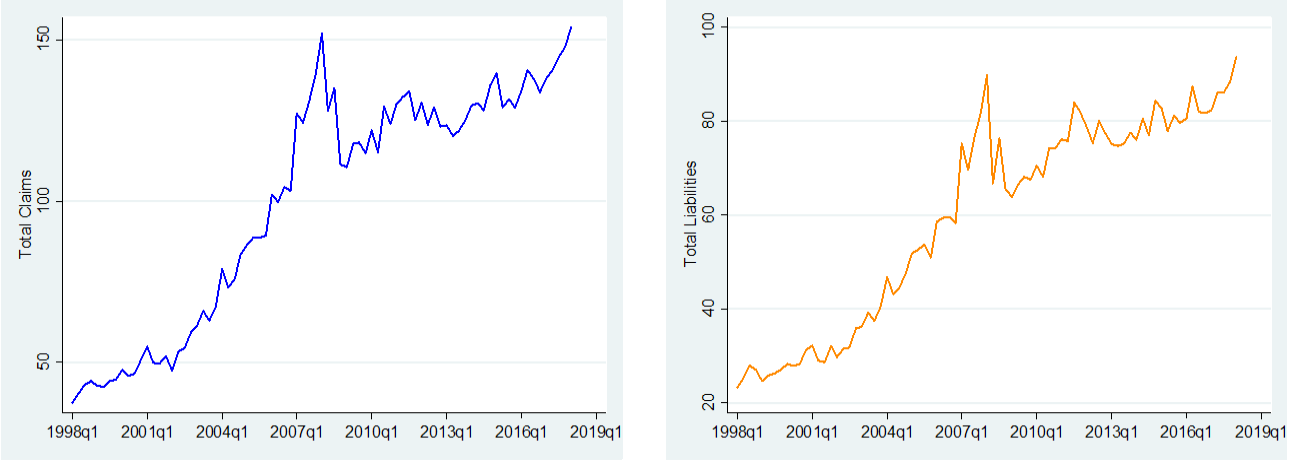
The focus of our analysis is an exploration and capture of the global financial network structure as it pertains to the Asia-Pacific region. In doing so, we use the LBS data set that is available from the BIS. We should note that LBS data are unconsolidated, which means the data sample includes positions vis-à-vis affiliates of foreign banks that reside in different countries. We only use data on loans and deposits on banks' balance sheet.

The sample period runs from 1998 Q1 to 2018 Q1 for nine core countries (Australia, Canada, France, Germany, Japan, Luxembourg, Switzerland, the United Kingdom, and the United States). Six other economies, namely Hong Kong, Italy, Macau, South Korea, Chinese Taipei and the Philippines, started reporting their banking flow statistics to the BIS after 1998. Therefore, the number of core and periphery economies varies over time.[6]

The different types of claims on reporting economies include loans and investments to counterparty economies (borrowers). Liabilities of a reporting economy include deposits, and borrowings from counterparty economies (lenders). As we may observe from Figure 1, both total claims and liabilities increased over time, reaching a peak in 2008 Q1 before plummeting during the financial crisis. Cross-border banking flows have gradually recovered since 2009 Q1. We find similar trends for total claims and liabilities of the G7 countries, Switzerland and Luxembourg. However, they exhibit different development after the GFC. Both total claims and liabilities stagnated and have not yet recovered to their pre-crisis level.

**Figure 1. Total Amounts of Cross-border Bank Flows**

**(a) Total Claims** **(b) Total Liabilities**




Source: BIS Locational Banking Statistics.

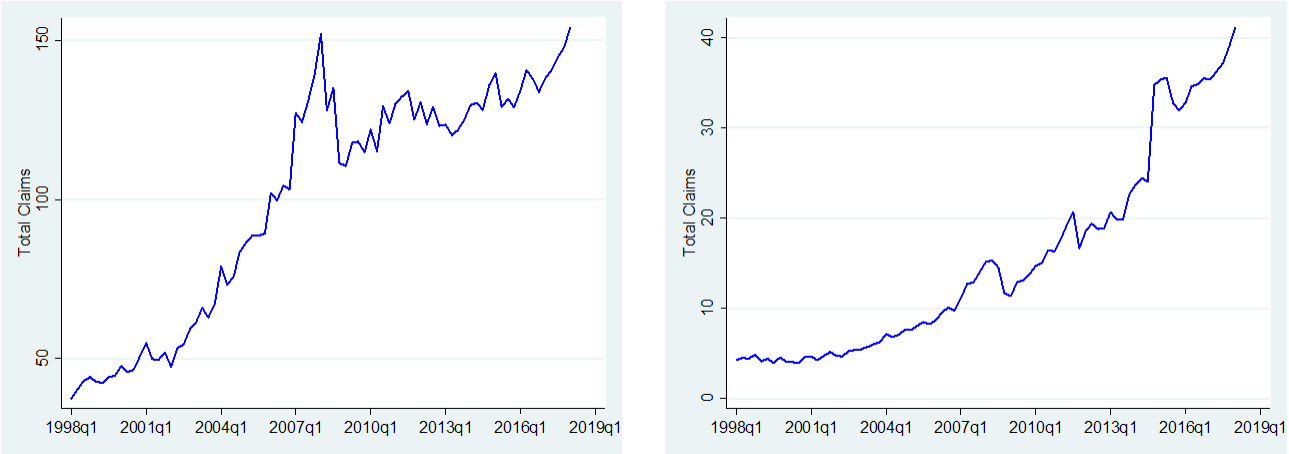
Notes: Total claims (liabilities) is the sum of all cross-border banking claims (liabilities) between reporting and counterparty countries. The data is modified using exchange rate and break adjusted changes based on BIS calculation. Total claims and liabilities are in 100 billion USD.

6. The number of each category is as follows: [1998q1-2000q3]: Core (10), Periphery (18), [2000q4-2003q3]: Core (11), Periphery (17), [2003q1-2005q3]: Core (12), Periphery (16), [2005q4-2014q3]: Core (13), Periphery (15), [2014q4-2016q3]: Core (14), Periphery (14), [2016q4-]: Core (15), Periphery (13).

Figure 2a provides a comparison of the volume of cross-border flows by taking into consideration the full network and contrasting it with Figure 2b, which shows the flows when bilateral transactions between the G7 countries, Luxembourg and Switzerland are excluded.

**Figure 2**
**Cross-border Bank Flows (Claims)**

**(a) Full network** **(b) Excluding bilateral transactions of G7+2**




Source: BIS Locational Banking Statistics.
Notes: Total claims is the sum of all cross-border banking claims between reporting and counterparty countries. The data is modified using exchange rate and break adjusted changes based on BIS calculation. Total claims and liabilities are in 100 billion USD.

## 4.2 Network Settings

Our sample includes major economies in the Asia-Pacific region and other globally systemically important economies. In total, we collected data for 28 economies. We have nine global core countries (the G7countries as well as Switzerland and Luxembourg), six regional core economies (AU, HK, TW, KR, MO and PH) and the remaining 13 have been designated as periphery economies (BD, CN, IN, ID, MY, MM, NP, NZ, PK, SG, LK, TH, VN).[7] Core economies are defined as reporting economies to the BIS Locational Banking Statistics. As mentioned above, the available data set imposes certain restrictions that have to be taken into consideration. We need to map the network structure of core economies. However, some economies do not report these data so these are treated as periphery economies.

As Chan-Lau et al. (2007) show, by using the network simulation approach, we may assess direct and indirect cross-border interbank contagion risk caused by liquidity and/or solvency problems. In order to establish cross-country interbank linkages, we have to project a matrix that captures the exposures of individual banks. Working with central banks would allow us to collect data on bilateral exposures that provide a more detailed understanding of the potential contagion risks.

7. See Table A1 in Appendix for the complete list of economies and their abbreviations.

Our network consists of a set of nodes that are represented by the 28 economies in our sample. Thus, each node represents an individual economy. A link to another economy then represents financial claims on the total banking system in that economy. The proposed network is constructed as follows: economies represent nodes and edges capture the flows of money. The orientation of links runs from source to target economies. Our network structure is a directed network that includes both in-coming and out-going links. Specifically, the evidence based on the links from sources to targets provides valuable information about which economy holds claims (liabilities) of other economies (through nodes). In our network structure some nodes (economies) are positioned as a source, but also as a target of bank flows. Other nodes (economies) represent a target only.

The individual linkages contain numerical values that capture the volume of claims (liabilities) across the entire network. The weights of edges represent the amount of bank flows for each edge. In our VNA, we can also define the size of nodes, the colour of nodes and the thickness of arrows to reflect different network features. The pattern and size of linkages in our VNA contain a wealth of information and provide a comprehensive picture that may help to fully understand the complexity of the captured linkages. The resulting structure also allows us to identify the key economies that dominate the system in terms of the flows of money to periphery economies.

### 4.3 Network Measurements: Applied Indicators

The next part of our discussion focuses on the fundamental network indicators that are vital for our analysis.

The *node degree* provides fundamental information about the number of links associated with a given node. As Kolaczyk (2009) explains, we can easily calculate the number of in-coming (in-degree) and out-coming links (out-degree) in a directed network structure. In other words, in-degree captures claims and out-degree liabilities. The concept of node degree indicates the number of edges connected to a node (economy). An economy with a high node degree has a large number of cross-banking contracts among the region. For a directed network, in-degree can be defined as the number of bilateral links to a target economy, while out-degree refers to those from a source (reporting) economy. We can further obtain information about the total amount of cross-border flows by using the *weighted node degree (node strength)*, giving rise to the weighted out-degree and/or weighted in-degree for a given node (economy). The latter two capture the intensity of financial flows for a particular economy (node). We should note that in our network, out-degree and weighted out-degree for periphery economies, is equal to zero. We may interpret the node degree as follows: a higher node degree refers to the number of bilateral cross-border bank transactions. In the case of the complete network, the decrease in weighted out-degree reflects the reduced bilateral transactions among advanced countries.

A further important network indicator is *connectivity*, which is measured as the ratio of the total number of links (edges) that exist in the network to the number of total possible links (edges). In other words, connectivity measures network density or, alternatively, it can be interpreted as the likelihood of a connection between two economies (Minoiu and Reyes, 2013).

*Betweenness centrality* is a measure for the relative frequency of a node appearing in the shortest paths between every other pair of nodes in the network. This measure is intended to show the place of a node in the network and reflects how influential an economy is as an intermediary of flows in the network. A higher centrality value of an individual node (economies) indicates a higher importance of an economy in the network. This measure captures the transmission of contagion effects: nodes with higher centrality values have a larger influence on other nodes (economies).

Two additional summary statistics include *closeness centrality and eccentricity.* The former is defined as the average distance from a given starting node to all other nodes in the network. Closeness centrality therefore measures the mean distance from a node to other nodes. This quantity has a low value for nodes that are separated from others by only a short distance on average. Such nodes could have better access to information at other nodes or a more direct influence on other nodes. Newman (2010) shows that this indicator is a natural measure of centrality and is often used in social and other network studies. There is one issues with this indicator that is related to the fact that its values tend to span a rather small dynamic range from largest to smallest. As Newman (2010) further shows, this problem has practical implications, because it is difficult to distinguish between central and less central nodes using this measure. The second summary statistic, *Eccentricity*, measures the distance from a node to the farthest node from it.

Fagiolo (2007) expands the standard clustering coefficient of Watts and Strogatz (1998) for unweighted and undirected networks to binary directed networks and weighted directed networks. Tabak et al. (2011) show in the case of the Brazilian banking system that the directed clustering coefficient is a suitable indicator for measuring systemic risk in complex networks. The *clustering coefficient* measures the completeness of a neighbouring node. In our analysis, we apply the binary clustering coefficient, the value for which ranges from 0 to 1. This coefficient is calculated as the ratio between the total number of complete triangles to the total possible number of such triangles.

## 5. Empirical Results

### 5.1 Network Connectivity Measurements

In this section, we try to capture the dynamics of lending relationships in the selected economies over the observed period. Such a detailed analysis will disclose the potential for partially hidden problems that might trigger a banking crisis through contagion effects.

Table 1 provides a basic overview of the various network indicators. We can see that the selected economies in our sample borrow from 7.3 lenders on average and up to 15 lenders in total. In each quarter, the borrowed volume is on average equal to US$54.4 billion, with a range from zero (minimum) to US$934 billion (maximum). Core economies lend on average to 18.29 economies and the maximum number of the economies that receive loans is 28. The volume of flows in core economies ranges from US$0.79 billion to US$1,378 billion. The bottom panel of Table 1 provides information regarding network density. We observe that the likelihood of two economies being connected through cross-border flows falls in the interval from 59.5 to 71.9%. As for the binary clustering coefficient, we find that two economies having a connection with one another if they both have a relationship with a third economy is on average 36.0% for all economies and 21.6% for reporting economies. *Betweenness centrality, i.e.,* the relative frequency of a node appearing in the shortest path between every other pair of nodes in the network, is on average 8.96. The indicator of closeness centrality varies from 0.692 to 0.813.

**Table 1**
**Summary Statistics of Network Indicators**

**Claims**

| | Obs | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| **Measures of country centrality** | | | | | |
| **Network excluding transactions among advanced economies** | | | | | |
| In-degree | 2268 | 7.308 | 3.697 | 0 | 15 |
| Weighted in-degree | 2268 | 54460.7 | 104178.5 | 0 | 934564.8 |
| Out-degree | 906 | 18.295 | 4.694 | 4 | 27 |
| Weighted out-degree | 906 | 136332.2 | 177590.3 | 709 | 1378037.0 |
| **Measures of network density** | | | | | |
| **Network excluding transactions among advanced economies** | | | | | |
| Connectivity | 81 | 0.659 | 0.031 | 0.595 | 0.719 |
| Clustering coefficient (all) | 81 | 0.366 | 0.132 | 0.064 | 0.480 |
| Clustering coefficient (reporting) | 81 | 0.216 | 0.087 | 0.050 | 0.352 |
| Betweenness | 81 | 8.967 | 1.287 | 6.867 | 12.667 |
| Closeness | 81 | 0.761 | 0.033 | 0.692 | 0.813 |

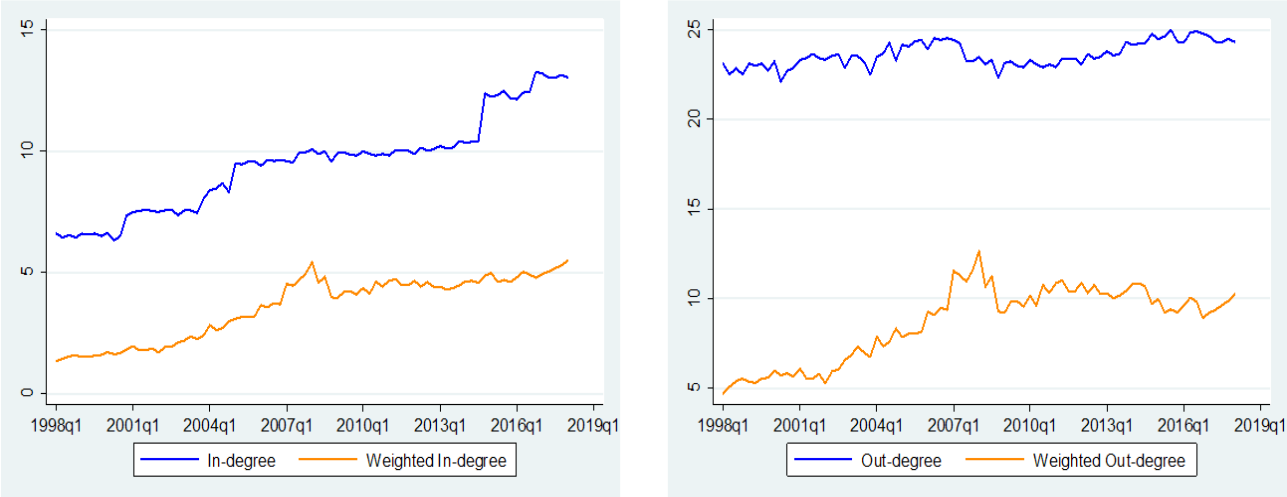
Source: Authors' calculations.

Figure 3 provides information about cross-banking contracts. Figure 3a captures the changes in bilateral links to a target economy. We observe that the average number of links to target economies increased steadily since the early 2000s. Over this period, we observe several significant adjustments in terms of the quantity of bilateral cross-border activities, which may reflect structural changes after the dot-com bubble and the period before the GFC. However, a significant change can be seen shortly after the peak of the GFC. The number of cross-border in-coming links has increased from 2013Q2 and has continued to grow. We observe that the volume of cross-border lending has increased consistently over the entire period, which is reflected in node strength, which captures total flows (orange line in Figure 3a). We find a structural break shortly after the GFC in 2008.

By contrast, cross-border links from source to target economies display a steady pattern with a brief drop during the period of the GFC (Figure 3b). The strength of the nodes, however, increased from the relatively low values observed in 1998 and reached US$1,137 billion shortly after the GFC.

**Figure 3**
**Time Series Graphs of Network Metrics (Claims; full network)**

**(a) In-degree** **(b) Out-degree**

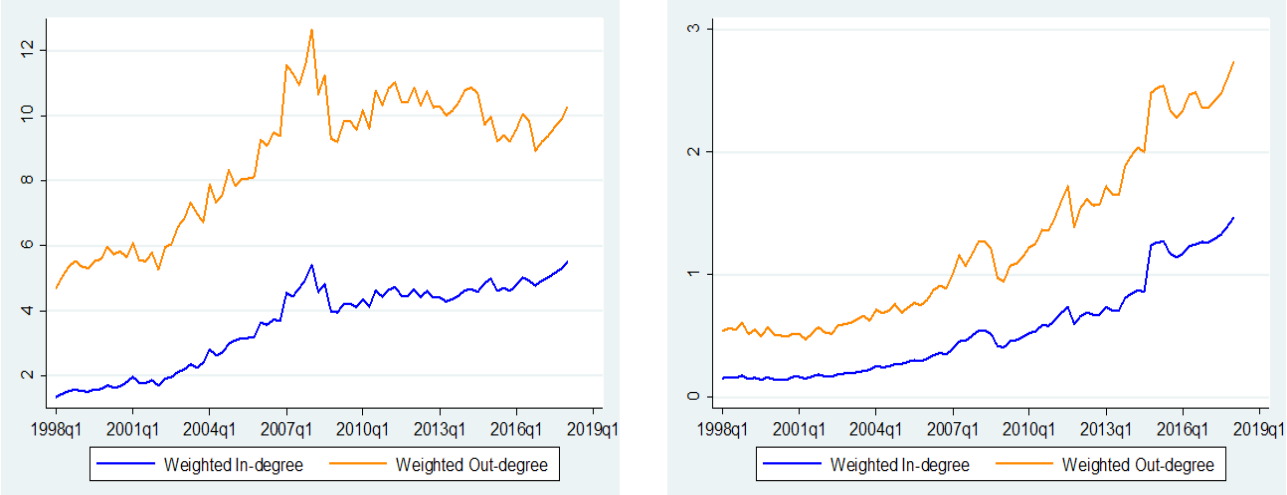



Notes: The unit of cross-border banking transactions is 100 billion USD.

In order to provide information about cross-border banking transactions in selected Asia-Pacific economies, we plot two panels in Figure 4. Figure 4a shows the strength of nodes for our full network. We observe that there has been a clear drop in the volume of cross-border activities shortly after 2007, which most likely reflects credit contractions faced by individual financial systems, predominantly in the USA and Europe. However, Figure 4b demonstrates that once we exclude the bilateral links within the G7 countries, Luxembourg and Switzerland, regional economies in Asia have not been significantly affected by the crisis. We can see a gradual growth in terms of the volume of bank loans, with only a partial adjustment shortly after the GFC. Nevertheless, this fall was reversed very quickly. We may argue that financial markets in advanced economies have shifted to emerging markets and less developed economies as a consequence of the increased uncertainty in the USA, UK and the rest of Europe. We might also speculate whether QE could have contributed to the increased liquidity in those economies. So far, the evidence of empirical research studies is rather inconclusive. A more intuitive explanation and discussion is provided by visual network graphs below.

**Figure 4**
**Node Strength**

**(a) Full network** **(b) Network excl. bilateral links of G7+2**

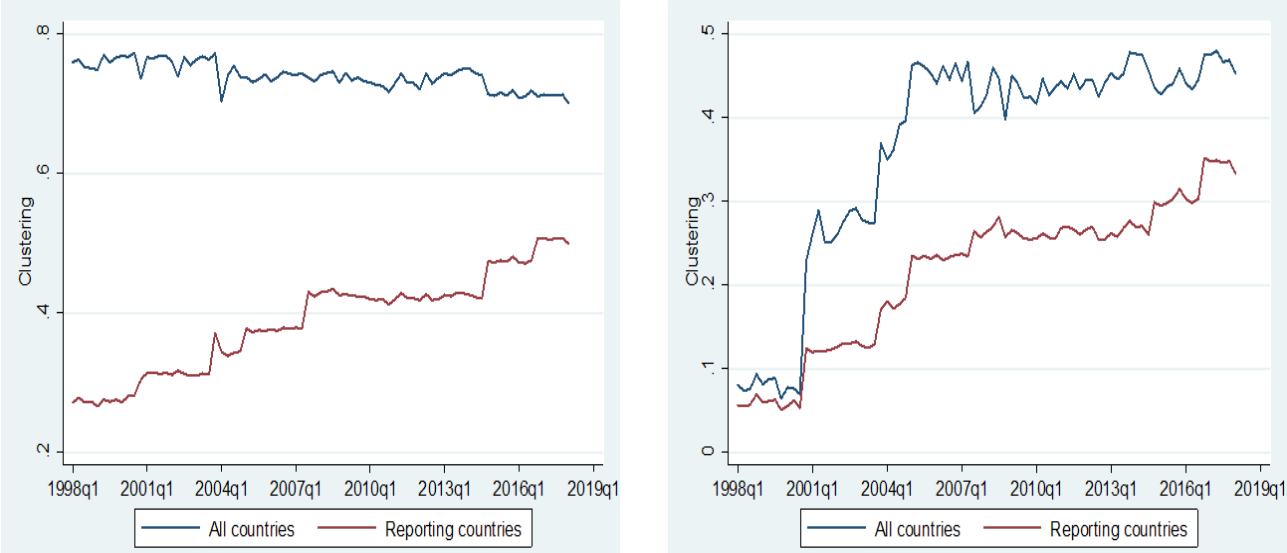



Notes: The unit of cross-border banking transactions is 100 billion USD.

In Figure 5, we turn our attention to the clustering coefficient. As we have discussed earlier, the clustering coefficient is a possible indicator for providing valuable information about systemic risk in complex networks. From Figure 5b, we observe a structural change in the early 2000s, when the value of the coefficient jumped up over the subsequent periods, indicating a higher probability that two economies are connected through a third economy. In other words, increased values of the coefficient indicate that there has been a tendency for higher clustering in the network over the period. Since we observe that increase from early 2000, i.e., before the GFC, we may surmise that there has been a tendency for the financial markets to create regional clusters and that financial markets have become more connected.

**Figure 5**
**Clustering Coefficient**

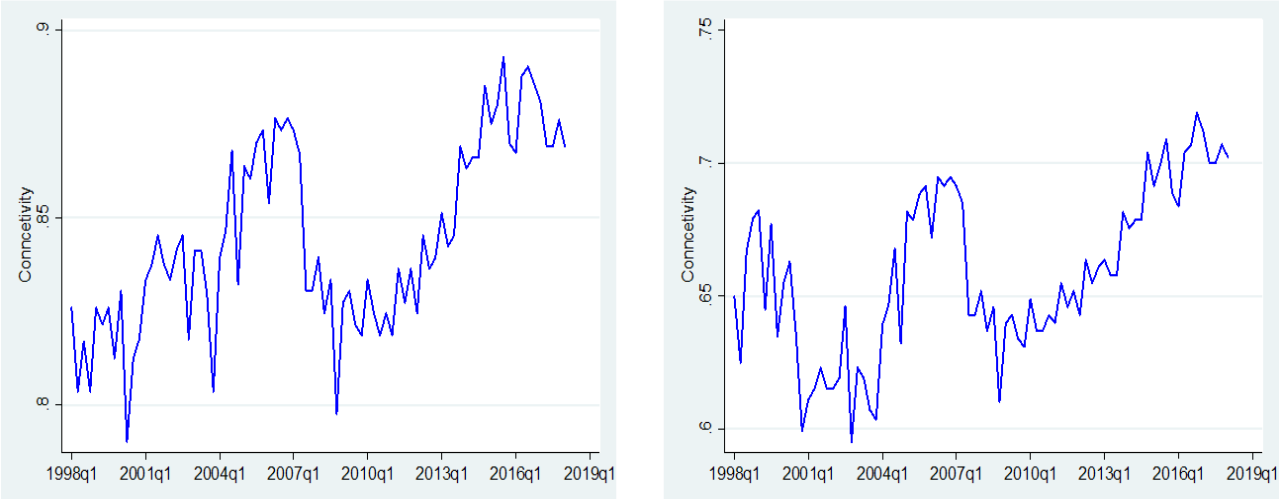
**(a) Full network** **(b) Network excl. bilateral links of G7+2**



We can further explore the issue of how the network is mutually linked – connected by using the network connectivity coefficient. Let us recall that connectivity measures network density. If we focus just on Figure 6a, we observe that the coefficient has increased over the analysed period, which suggests that cross-border activities within the region have increased. This lends support to our earlier conclusions based on changes in the clustering coefficient.

**Figure 6**
**Connectivity**

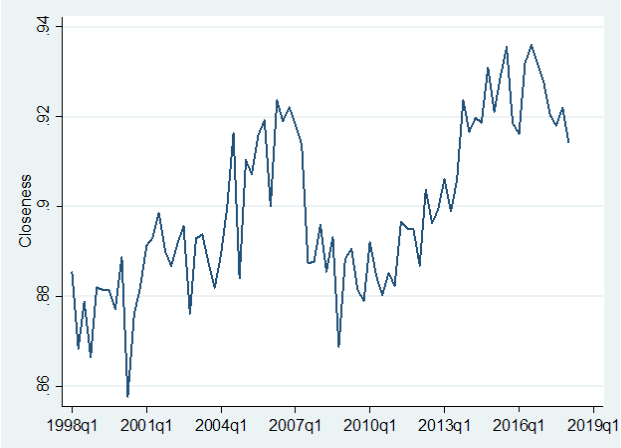
**(a) Full network** **(b) Network excl. bilateral links of G7+2**



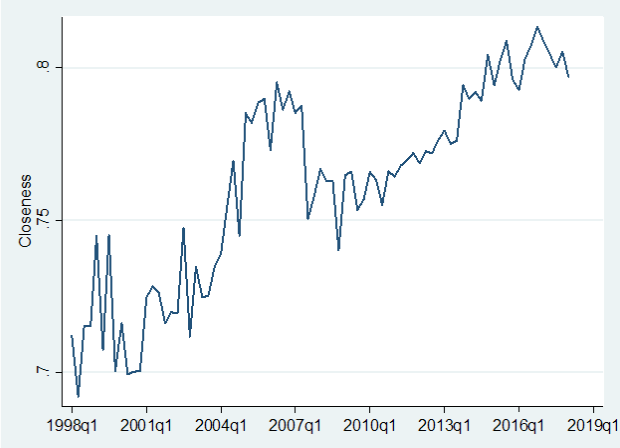

In Figure 7, we look at the closeness centrality network coefficient. We again provide two panels, that is, the full network and the full network without the bilateral links of the G7 countries, Luxembourg and Switzerland. There is strong evidence that the coefficient that measures closeness dropped sharply at the outset of the GFC. We can observe a similar sharp decrease in 2000-2001 during the dot-com crisis. While Figure 7b provides a similar pattern, the drop in the coefficient values over the period is less pronounced than in Figure 7a. By contrast, we find an increasing trend. We recall that low values for nodes that are separated from others by only a short geodesic distance on average indicate that such nodes may have better access to information at other nodes or more direct influence on other nodes. Thus, the low value of the coefficient indicates that the distance of individual (economy) node has increased, which can be interpreted as large financial centres playing a key role in the network. However, Newman (2010) argues that there is a problem with this practical implication since it is difficult to distinguish between central and less central nodes using this measure.

**Figure 7**
**Closeness Centrality**

**(a) Full network**



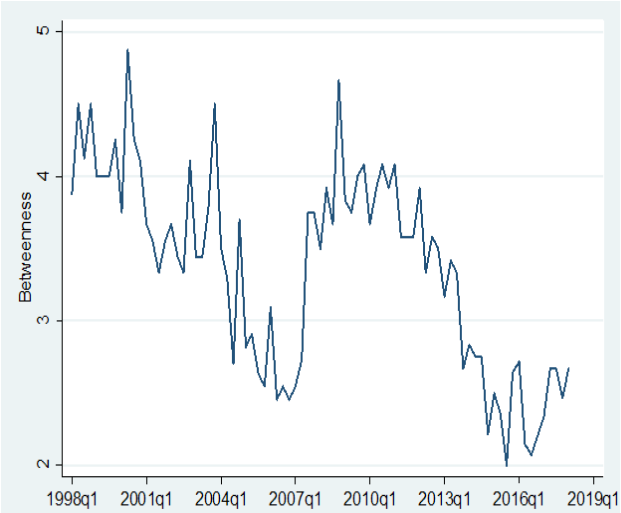

**(b) Network excl. bilateral links of G7+2**




Last but not least, the final network coefficient is the betweenness centrality, which provides information about the influence of an individual economy as an intermediary of flows in the network. A closer look at Figure 8 indicates that coefficient values have gradually declined. This corresponds to our previous discussion that the system has become more clustered and none of the economies maintain a dominant position within the market compared to the period of the late 1990s and early 2000s. We can further observe some degree of volatility of the coefficient during the GFC, but since 2010 there has been a clear tendency of a diminishing role for a few key players. This outcome will also be observable in the network graphs that we discuss later. This trend is further supported by Figure 9, which focuses on the influence of advanced economies (the G7, Luxembourg, and Switzerland) on regional network only. Based on the presented figures, we conclude that financial markets have been undergoing substantial changes that were further reinforced or amplified by the GFC.

**Figure 8**
**Betweenness Centrality**

**(a) Full network**




**(b) Network excl. bilateral links of G7+2**

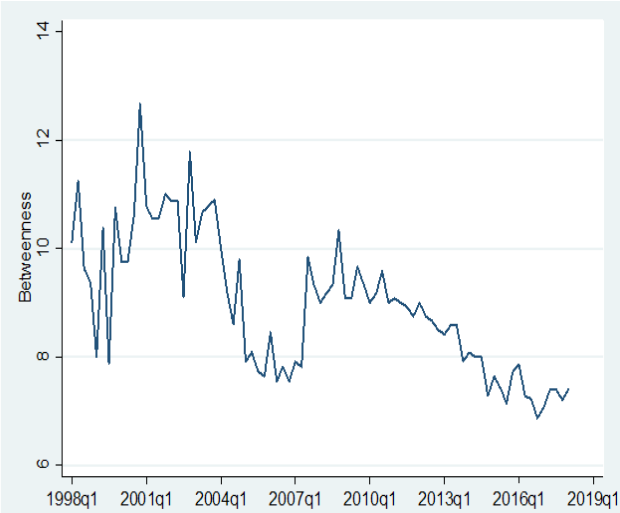
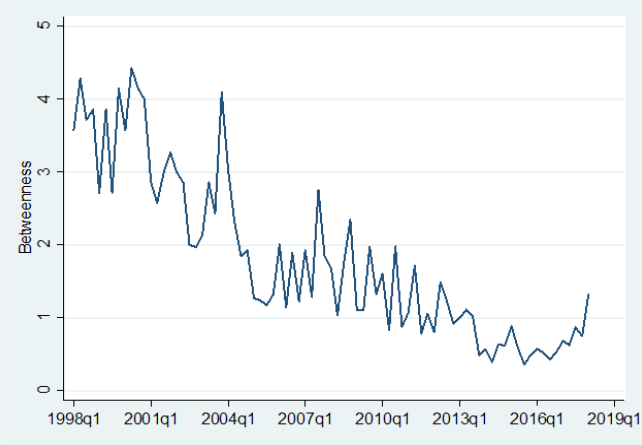


**Figure 9**
**Betweenness Centrality of Advanced Economies in Regional Network**

**Regional Network**




## 5.2 Visual Network Analysis

In this section, we extend our discussion by providing a visual presentation of network analysis. The graphs were obtained by using Gephi, which is a publicly available visualisation software (https://gephi.org/). Our results are presented in the following way. First, we plot graphs that provide information about the network structure for the complete network. Then, we analyse the regional network, which means that we exclude the bilateral links between the G7 countries, Luxembourg and Switzerland. Finally, we present the ranking of network measures by focusing on in- and out-weighted summary statistics.

Graph 1 provides a detailed analysis of how the flows of money have changed during the entire period. It highlights the complete picture of bank flows in the Asia-Pacific region including bilateral transactions between advanced economies (the G7, Luxembourg and Switzerland). In addition, Graph 1 provides information about the weighted out-degree, which is represented by the size of a node. The colour of nodes indicates the betweenness centrality coefficient and the size of bilateral bank flows is reflected in the thickness of the edges. We analyse each period from 1998 Q1 to 2018 Q1 and show graphs for the first quarter of selected years.[8] What we can observe from Graph 1 is that, based on the betweenness centrality measure and the thickness of edges, Great Britain and Japan played a key role in terms of money flows over the period from 1998 to 2014. Since then, however, Hong Kong has taken the lead along with Japan and Australia, while Great Britain's dominance in the network has fallen significantly. South Korea also plays an important role in cross-border banking activities, while Chinese Taipei's position in that market has remained more or less unchanged. The colour of nodes, which represent betweenness centrality, become brighter over time, reflecting the growing importance of economies like Chinese Taipei, South Korea, Macau and China.

8. We show graphs for the first quarter of every fourth year between 1998 and 2006. To highlight the changes during the GFC period, we show network graphs of the first quarter of 2008, 2009, 2010. Then, we present graphs biennially from 2012 up to 2018.

In Graph 2, we focus exclusively on the regional network, excluding the bilateral transactions between advanced economies (the G7, Luxembourg, and Switzerland). We present measures of weighted out-degree (the size of nodes), betweenness centrality (the colour of nodes) and the size of bilateral bank flows (the thickness of the edges). The Graph reveals that Japan played an important role from 1998 to 2002, attaining a dominant position in terms of overall money flows as well as bilateral bank flows. It is worth noting that money from Japan went above all to Singapore and, to lesser extent, to Australia. The same links can be observed for Great Britain, which was also connected with Singapore, Australia and Hong Kong. The betweenness centrality metric, which provides information about the influence of an economy in the region, indicates that Chinese Taipei took the lead, followed by Singapore. Graphs after 2006 indicate that the regional network has undergone some significant changes. Great Britain became the key country in terms of the flows of money, still followed by Japan. At the same time, Australia, Chinese Taipei and South Korea became the most influential economies in the region.[9] In 2016, Hong Kong and Australia overtook Japan and Great Britain in terms of the flows of money (out-degree). Hong Kong also increased its influence in the region with its extensive links to China, as can be clearly observed during 2016. South Korea (dark green colour) also strengthened its position within the region. In 2018, the Philippines also became an influential economy in the region based on the betweenness centrality coefficient, the overall flows of money and bilateral bank flows. Hong Kong has a dominant position in the market by having the largest flows of money, the largest amount of bilateral flows and an influential position in the region based on the betweenness centrality coefficient. More specifically, it increased the number of bilateral bank flows with Great Britain and Japan. The most notable phenomenon is that the activities between Hong Kong and China strengthened. Hong Kong's position in the region significantly increased along with other financial hubs.

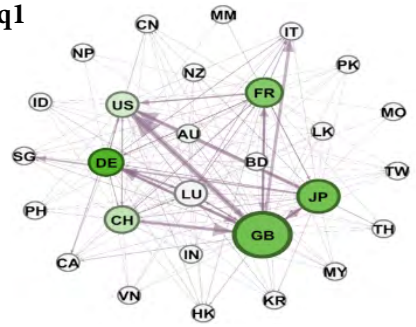
Graph 3 maps the regional network in terms of incoming links. In this regard, Singapore plays a pivotal role in the system not only with the largest volume of flows of money but also in terms of the size of bilateral bank flows. The position of Singapore remained unchanged until 2012. There is also a fair number of other economies with the relatively low coefficient of betweenness centrality, indicating their influence in the region. These economies include Singapore, Hong Kong, New Zealand, Australia, South Korea, China, Chinese Taipei, India and Thailand. However, there have been later structural changes similar to those we discussed for Graph 2. In 2004, China overtook Singapore as the largest economy in terms of flows of money, followed by Hong Kong. We can also observe from 2014 onwards that a number of economies in the region have become more influential in terms of the betweenness centrality measure. These economies include, among others, Vietnam, Myanmar, Bangladesh, India and Thailand.

The changes in the importance of individual economies find further support in Tables 3 and 4. Table 3 shows the ranking in terms of the weighted out-degree measure. Table 4 presents the ranking of the weighted in-degree. Table 3 shows a marked a shift in positions since 2014. In particular, Great Britain is only the fourth-ranked economy measured on the basis of overall flows of money in 2018 Q1. Hong Kong, Japan and Australia remain the key centres in the regional network. Table 4 ranks the top ten economies measured by weighted out-degree metric. Singapore was overtaken by China in 2014, and remains in second rank, followed by Hong Kong and Australia.

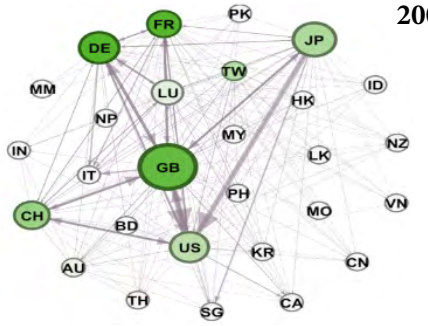
9. Out-going bilateral bank flows data for Hong Kong is only available from 2014 Q1 and the same data for Singapore is unavailable throughout the sample period. Therefore, it should be noted that our analysis is based on the data with limited availability. See Table A1 in Appendix for the sample period of individual economy.

**Graph 1**
**Complete Network**

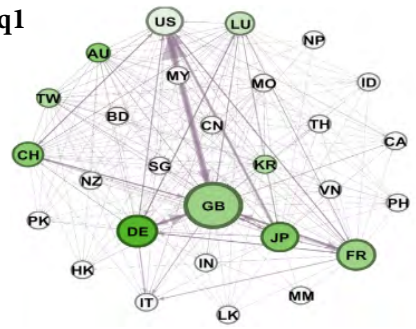
1998q1



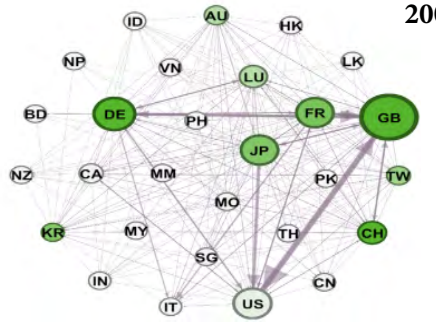

2002q1



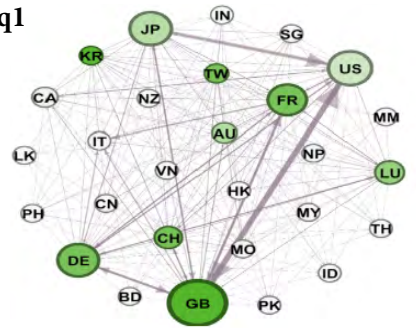

2006q1



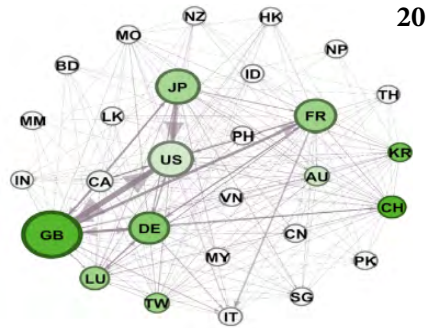

2008q1



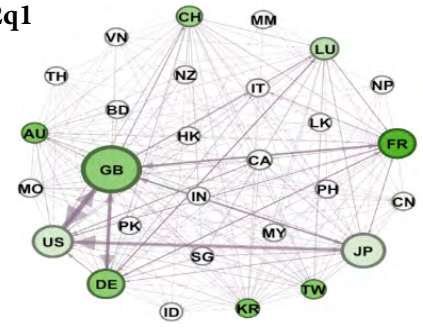

2009q1



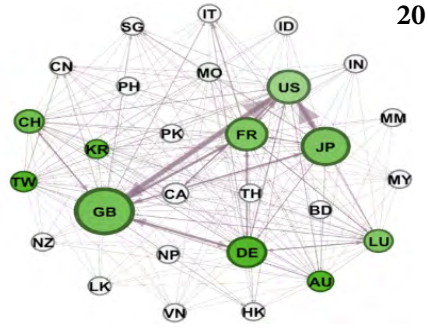

2010q1



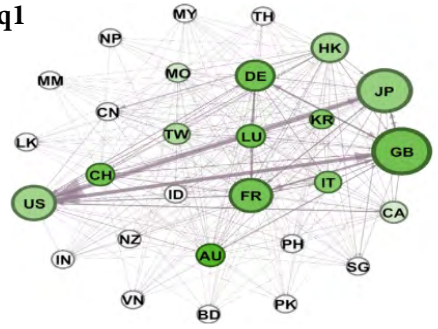

2012q1



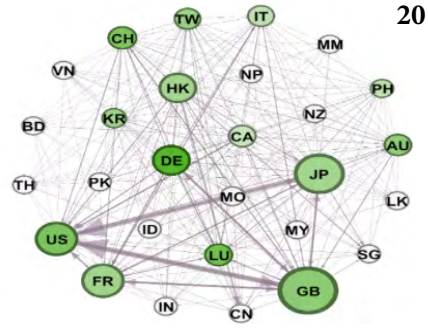

2014q1




2016q1

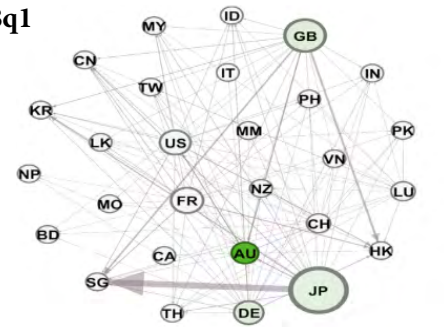



2018q1

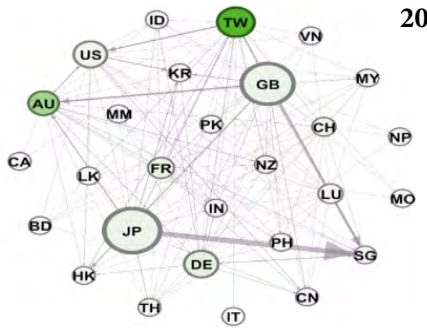


## Graph 2
## Regional Network (Weighted Out-going Links)

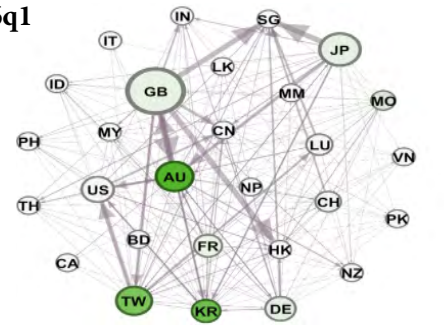
1998q1



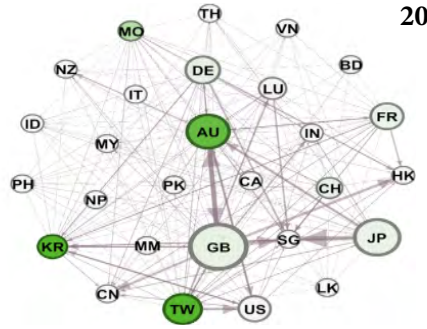

2002q1



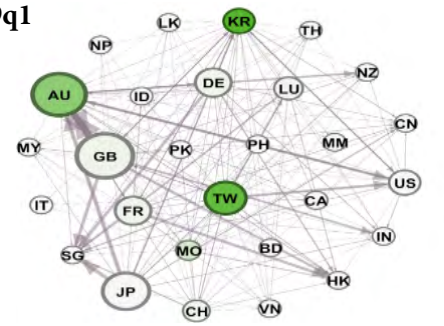

2006q1



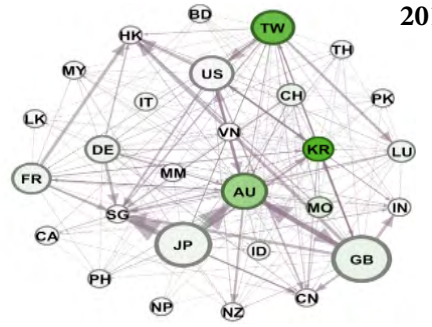

2008q1



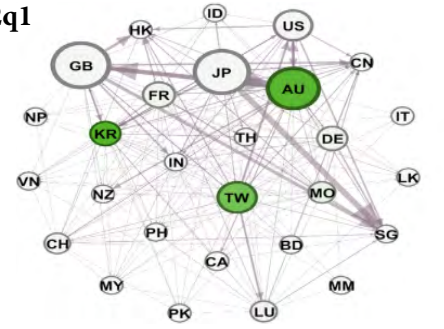

2009q1



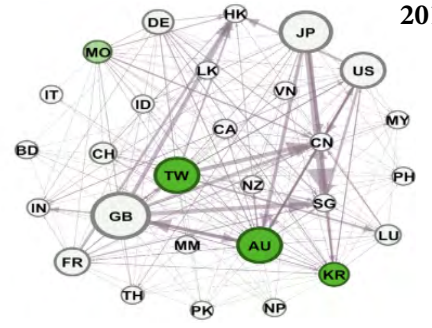

2010q1



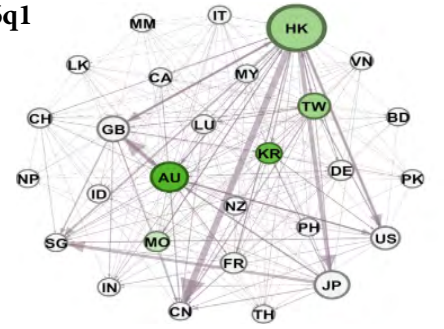

2012q1



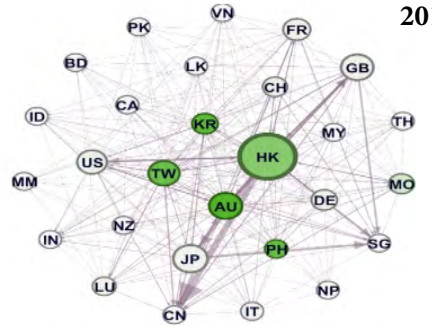

2014q1




2016q1

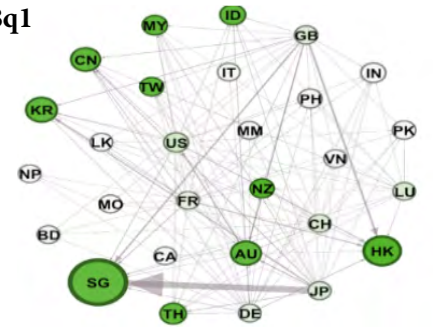



2018q1

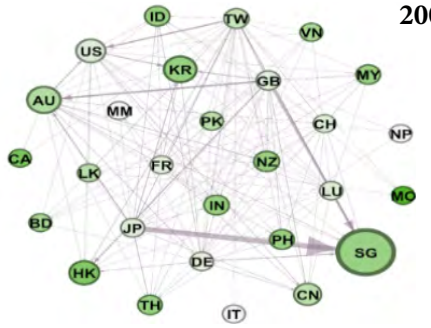


**Graphs 3**
**Regional Network (Weighted In-coming Links)**

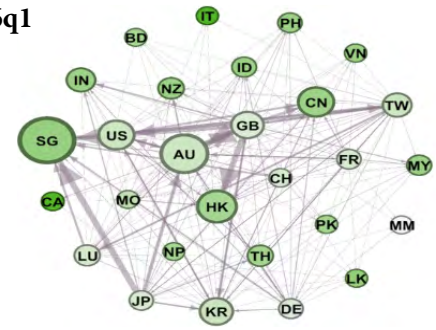
1998q1



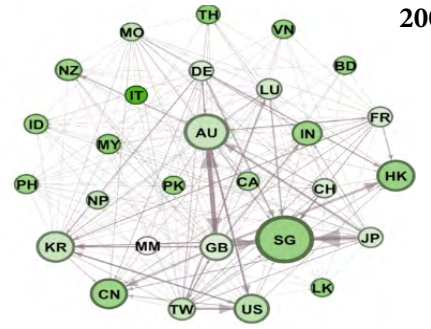

2002q1



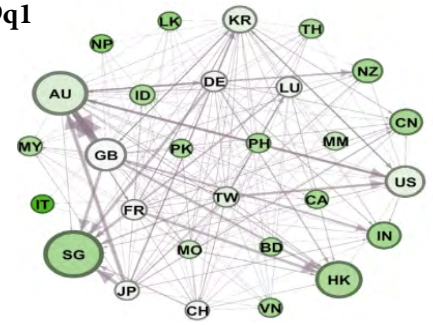

2006q1



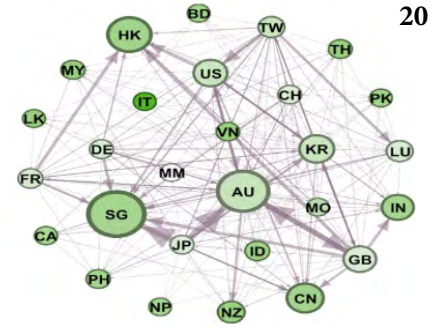

2008q1



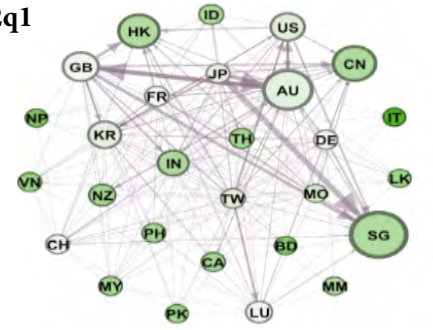

2009q1



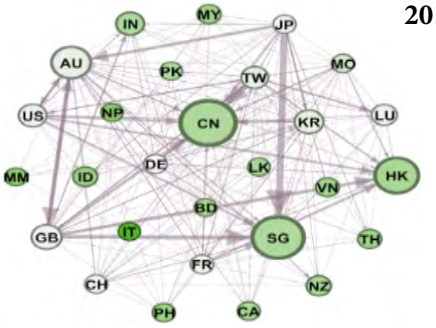

2010q1



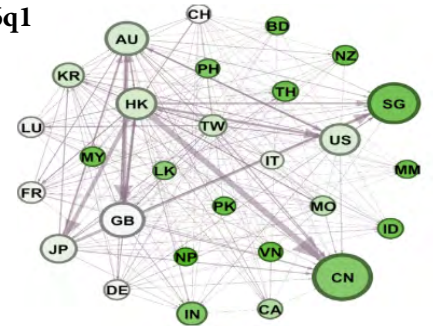

2012q1




2014q1




2016q1




2018q1

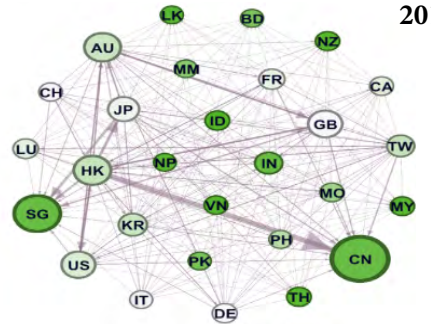


**Table 3**
**Ranking of Network Measures (Weighted Out-degrees)**

| 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| SG | SG | SG | SG | SG | SG | SG | SG | CN | CN | CN |
| HK | AU | AU | AU | AU | AU | AU | AU | SG | SG | SG |
| KR | KR | KR | KR | HK | KR | HK | CN | HK | GB | HK |
| AU | HK | HK | HK | CN | HK | CN | HK | AU | AU | AU |
| CN | CN | US | US | US | CN | KR | GB | GB | HK | GB |
| TH | TH | CN | CN | KR | US | US | US | KR | US | US |
| ID | ID | NZ | TW | GB | GB | GB | KR | IN | JP | JP |
| IN | IN | IN | GB | TW | IN | IN | IN | US | KR | KR |
| MY | NZ | ID | NZ | IN | TW | NZ | NZ | TW | IN | IN |
| US | GB | TW | IN | NZ | NZ | LU | LU | LU | TW | TW |

**Table 4**
**Ranking of Network Measures (Weighted In-degrees)**

| 1998 | 2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 | 2018 |
|---|---|---|---|---|---|---|---|---|---|---|
| JP | JP | JP | GB | GB | GB | GB | GB | GB | HK | HK |
| GB | GB | GB | JP | JP | JP | JP | JP | JP | AU | JP |
| FR | DE | TW | AU | AU | AU | AU | AU | US | JP | AU |
| US | US | DE | US | TW | TW | US | TW | TW | TW | GB |
| DE | AU | US | TW | US | DE | TW | US | AU | GB | TW |
| AU | FR | AU | DE | DE | FR | FR | FR | FR | US | US |
| LU | LU | FR | FR | KR | US | DE | DE | DE | FR | FR |
| CH | CH | LU | LU | FR | KR | KR | KR | KR | KR | KR |
| IN | PH | CH | CH | LU | LU | CH | MO | MO | DE | DE |
| IT | CA | SG | MO | CH | CH | LU | LU | CH | MO | MO |

## 6. Conclusions and Policy Implications

This study provides a comprehensive analysis of development in cross-border banking activities over the last 20 years. The analysis is based on the BIS' Locational Banking Statistics. In order to provide an overall picture of how banking systems are interconnected, we deploy the visual network analysis (VNA). We explain in great detail how this methodological framework can contribute to a better understanding of the issues under investigation. This technique clearly demonstrates not only the complexity of cross-border bank activities within the Asia-Pacific region but also the connectedness with advanced economies.

The data sample from 1998 to 2018 allows us to trace the structural changes that have occurred, particularly during the financial turbulences that occurred either in the region or in the advanced economies. The analysis investigates the characteristics of cross-border activities in the Asia-Pacific region. Reported network summary statistics include measures such as closeness centrality, betweenness centrality, connectivity and clustering. The analysis of these coefficients over the sample period help us to better understand structural changes over time. We have also evaluated the role of individual economies in our network over time. Our network analysis shows that the volume of transactions has dramatically increased, particularly after 1997. This change was accompanied by an increased number of bilateral links across banks. We note that many of the periphery economies became increasingly influential in the overall network. We also show that the connectedness of economies in the Asia-Pacific region since 1997 has changed completely, specifically that the structure of how economies are connected now is significantly different. There is evidence that the links have become much closer and the volume of credit transactions has increased severalfold.

The economies within the region surpassed the importance of many of the G7 countries (Great Britain and Japan, in particular). Since 2016, we observe the dominance of Hong Kong and China in the system. This type of structural change will necessarily have implication on system stability not only in terms of regional stability but also on a global scale. The dominance of Hong Kong and its extensive links with China are remarkable, but not surprising. Nevertheless, this extremely close link could have serious contagion effects if the Chinese economy faces turbulence. Our network analysis shows that the flows of money terminates in China and is not diversified further. This is very different from the 2000s, when Japan played the key role in the network. At that time, the flows of money from Japan were directed mainly at Singapore, but Singapore widely diversified the received financial resources. Based on our results, there is a need to further explore economies' (banks) portfolio diversification in the region.

We also conclude that a more comprehensive analysis of contagion risk with the help of more complex methodological frameworks can be conducted only if the reported statistics are improved, as studies capable of detecting possible triggers of systemic risk require much more disaggregated statistical information.

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**Appendix**

**Table A1**
**List of Economies**

| Economy | Abbreviation | Type (Core/Periphery) | Sample period (Core economy) |
|---|---|---|---|
| Australia | AU | C | 1998 Q1 – 2018 Q1 |
| Bangladesh | BD | P | - |
| Canada | CA | C | 2007 Q3 – 2018 Q1 |
| China | CN | P | - |
| Hong Kong, SAR | HK | C | 2014 Q4 – 2018 Q1 |
| India | IN | P | - |
| Indonesia | ID | P | - |
| Japan | JP | C | 1998 Q1 – 2018 Q1 |
| Macau, SAR | MO | C | 2004 Q1 – 2018q1 |
| Malaysia | MY | P | - |
| Myanmar | MM | P | - |
| Nepal | NP | P | - |
| New Zealand | NZ | P | - |
| Pakistan | PK | P | - |
| Philippines | PH | C | 2016 Q4 – 2018 Q1 |
| Singapore | SG | P | - |
| South Korea | KR | C | 2005 Q1 – 2018 Q1 |
| Sri Lanka | LK | P | - |
| Chinese Taipei | TW | C | 2000 Q4 – 2018 Q1 |
| Thailand | TH | P | - |
| UK | GB | C | 1998 Q1 – 2018 Q1 |
| US | US | C | 1998 Q1 – 2018 Q1 |
| Vietnam | VN | P | - |
| Germany | DE | C | 1998 Q1 – 2018 Q1 |
| France | FR | C | v |
| Italy | IT | C | 2014 Q4 – 2018 Q1 |
| Switzerland | CH | C | 1998 Q1 – 2018 Q1 |
| Luxembourg | LU | C | 1998 Q1 – 2018 Q1 |

Notes: C denotes core (reporting) economies of which the data for individual counterparty economies are available, P denotes periphery (non-reporting) economies.