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The Changing Roles of China and Japan in Cross-Border Banking Credit Network in Asia

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Abstract: We measured the credit linkages between the banking sectors of 14 Asian economies by constructing Euclidean distances from quarterly data on cross-border claims and liabilities for 2016-2021, thus constructing the Asian regional cross-border credit network. Then we used the network analysis method to analyse the dynamic characteristics of the network structure and study the role and importance of Chinese banking and Japanese banking. The results showed that from 2016 to 2020, the cross-border credit network structure in Asia presented the characteristics of high density and high clustering coefficient. China, Japan, Hong Kong, and Singapore are the core of the network, while peripheral economies tend to converge to the core. From the perspective of the dynamic characteristics of the network and the importance of nodes, Chinese banking played an increasingly important role as a lender of funds, which increased its importance significantly. The economies most closely linked to Chinese banking are Australia, Turkey, and India, but Hong Kong, Macao, and Taiwan are less linked than expected. Japanese banking has been a vital lender, with close links to Hong Kong, Macao, and Singapore. In addition, the banking of Singapore, Australia and Bahrain play a significant intermediary role in the Asian regional network. In particular, cross-border credit linkages across Asian banking have weakened significantly since 2021, which may be related to the impact of the global pandemic. This paper provides policy enlightenment for developing the cross-border credit business of Chinese banking and promoting regional financial integration in Asia.

Keywords: Cross-Border Credit Network; Asian Regional Banking; Cross-Border Linkages; Network Analysis Method

JEL: F34; F36

1. Introduction

Before 2008, the competition for the international market share of the banking sector of various economies led to the sharp growth of cross-border credit scale and credit bubble, which was an important cause of the global financial crisis (McCauley et al., 2021). The global financial crisis

led to the collapse of major financial institutions, government bailouts of banks, and a plunge in stock markets worldwide. Since the global financial crisis outbreak, the international banking landscape has changed significantly. Cross-border banking in Europe has gradually shrunk, Asian banking has expanded outside the region, and the cross-border banking business in Asia has grown steadily.

The Asian region lacks a developed capital market, and most economies have been dominated by the banking sector which monopolises most financial resources. With the advancement of RMB internationalisation and the opening of China's capital account, Chinese banking has continued to expand overseas. Till 2018, Chinese banking had become the largest cross-border creditor for nearly half of the emerging market economies worldwide (Cerutti et al., 2020). The cross-border claims of Japanese banking on Asian economies had changed significantly after the Southeast Asian financial crisis. According to Bank for International Settlements (BIS) statistics before 2000, the cross-border claims of Japanese banking on the banking sector in Hong Kong and Singapore were much larger than those on other economies in Asia. After 2000, the gap between bilateral cross-border claims of Japanese banking on other Asian economies narrowed significantly, showing a trend of diversification. Its cross-border claims on banking in Australia and China had risen most dramatically. This indicated that Chinese and Japanese banking were playing an increasingly important role in Asian banking.

However, due to the lack of data on bilateral cross-border claims of Chinese banking to other economies, it is impossible to directly measure its cross-border credit linkages and importance in Asian banking. In recent years, the complex network method has been widely used to study cross-border financial linkages, and most scholars have applied it to risk spillovers or systemic financial risk contagion on capital markets (Liu et al., 2017; Shimada et al., 2021; Yang et al., 2022). Few studies have examined cross-border financial linkages based on the perspective of economic banking. Therefore, based on the above background, we took cross-border banking in the Asian region as the object and used the cross-border claims and liabilities data of the reporting economies in Asia from the BIS's Locational Banking Statistics (LBS) to construct the cross-border credit network in Asia. Then we used the network analysis method to measure and analyse the cross-border linkages of the banking sector in Asian economies and the role of the Chinese and Japanese banking industries. The findings of this paper provide policy recommendations for the promotion of cross-border credit business and the openness of Chinese banking.

The remainder of this paper is organised as follows. Section 2 reviews the literature related to this paper. Section 3 analyses the typical facts of cross-border claims in major Asian economies. Section 4 introduces the method of constructing the cross-border credit network of the banking industry, the indicators of network topology analysis and sample selection. The results have been analysed in Section 5. Section 6 concludes this paper.

2. Literature Review

2.1. The Size and Flow of Cross-Border Credit in Global Banking

The outbreak of the global financial crisis in 2008 caused a comprehensive and detailed study of this crisis by scholars all over the world, a large part of which focused on credit conditions in cross-border banking. Cross-border banking has a significant feature, which is a high concentration. In other words, bilateral lending and borrowing relationships in banking with large funds but a relatively small number of economies account for the vast majority of total cross-border bank credit. This is mainly due to strong cross-border linkages between advanced economies, with just five major creditor economies: France, Germany, Japan, the UK and the US, accounting for 55% of total global cross-border credit (Aldasoro & Ehlers, 2019).

Before the global financial crisis, there was a sharp rise in international bank claims, including cross-border bank loans and local loans from foreign banks' overseas subsidiaries. The concentration of cross-border banking has been on an upward trend, with many European economies being major lenders of cross-border funds and most emerging market economies being net recipients of cross-border funds (Claessens, 2017). During this period, rapid financial globalisation led emerging markets and developing economies to open their capital markets further. Their banking sectors had begun to expand abroad and some banks had become significant cross-border banking players (Horen, 2011; Beck et al., 2014; BIS, 2014; Claessens & Horen, 2014). In the aftermath of the global financial crisis, the size of cross-border credit began to contract, and global banking became more fragmented than before the crisis (McCauley et al., 2019; Wang & Deng, 2019). Eurozone banks sharply reduced their overseas business, and the level of banking integration was lower than before the crisis (Enoch et al., 2013; Bologna et al., 2014; ECB, 2014). However, at the same time, the banking sector in emerging market economies continued to expand overseas, most typically in the Asia-Pacific region. It exhibited significant bank regionalisation, coupled with the adoption of a regional banking integration framework by ASEAN, further deepening regionalisation

(Claessens & Horen, 2014; Ehlers & Wooldridge, 2015). It has been argued that Asian emerging market economies weathered the global financial crisis relatively well because of the region's limited cross-border linkages with the outside world, which weakened the exposure of the region's economies to adverse shocks from individual creditor countries outside the region (Curcurù et al., 2012; Ehlers & Wooldridge, 2015). Ten years after the 2008 financial crisis, epidemic outbreaks had once again plunged the global economy into great uncertainty. Still, cross-border credit conditions have remained largely stable due to government responses (Hardy & Takáts, 2020). Chinese banking is the largest cross-border creditor for nearly half of emerging market and developing economies and its global reach is similar to that of developed economies (Cerutti et al., 2020).

2.2. The Role of Banking in Cross-Border Financial Network

Before the 2008 global financial crisis, there was little literature on cross-border banking based on a complex network perspective, and static analysis of the international banking network structure was the main focus. International banking statistics (IBS) from the BIS are the most important source of data for constructing cross-border linkage networks in banking. The use of LBS and CBS data allows the study of cross-border linkages in the banking of reporting economies and the risk transmission pathways of financial crises (Avdjiev et al., 2015). Hattori and Suda (2007) used cross-border claims data from 16 reporting economies in the CBS database (all developed economies in the European and American area) to construct the global banking risk network from 1985 to 2006. They found that the cross-border linkages became stronger, and the network structure showed higher connectivity, shorter mean path lengths, and higher clustering coefficients over time. Peter (2007) identified international banking centres based on a network analysis perspective. He found that the U.S. and the Cayman Islands had a high share of the global credit market but ranked low in network centrality, while Canada, Macao, and India had substantially higher network centrality rankings compared to their market share rankings, i.e., actual international banking centres were not necessarily at the centre of the network structure.

After the financial crisis in 2008, the large-scale financial institution failures and bank runs led more scholars to realise that banking played an important role in cross-border financial linkages. First, the most critical literature focused on constructing the cross-border claim risk network for banking and conducting cross-border financial risk contagion analysis. Billo et al. (2012) used monthly return data from different financial institutions to construct the Granger Causality Network and found that

banking played a more significant role in transmitting shocks than hedge funds, brokerage firms, or insurance companies. Tonzer (2013) constructed networks using credit data from the LBS database for major European economies as well as the U.S., Canadian, and Japanese banking from 1993 to 2009. They found that economies linked to a more stable banking system abroad through foreign borrowing positions experienced more significant positive spillover effects. As complex network theory continues to evolve, the modularity approach has been widely applied to studies analysing risk contagion in banking. For example, Garratt et al. (2014) studied the modular structure among cross-border banks before the 2008 global financial crisis using the Map Equation approach and analysed the inter-module risk contagion. They found that the U.S., the U.K., Japan, and the Cayman Islands were on the same plate, which had the strongest risk contagion ability during the crisis. Based on the same approach, Chen et al. (2020) found that the U.S., Japan, Switzerland, and Canada were on the same plate during the European debt crisis. The plate had elevated risk spillovers both within and between the plates, and the risk contagion between the U.S. and the U.K. had remained closest over time. Some other scholars have used banking stock indices to construct cross-border banking networks or spillover matrices to analyse the spillover effects of cross-border financial risks. Demirer et al. (2015) constructed networks using stock return volatilities of 96 systemically important banks from 2003-2014 and found that during the global financial crisis and the European debt crisis, the North American and European banking systems were net transmitters of equity yield volatility, while the Asian banking systems were net receivers. Tabak et al. (2022) also found a similar conclusion by constructing the DY (2015a) spillover index of stock index volatility of banking from 35 economies in The Americas, Europe, Asia, and South Africa. They also found that Italy had the strongest spillover effects during the global pandemic, while China had the weakest external cross-border links. Using the same spillover index model, Foglia et al. (2022) found that the epidemic strongly impacted the structure of the Eurozone banking system, with banks reaching historical peaks in volatility correlations during the crisis. Large banks played a key role in risk transmission, while small and medium-sized banks were only the participants.

2.3. The Impact of Financial Crisis on Cross-Border Banking Network

Some scholars focus on the impact of the global financial crisis on the structure of international banking networks. Spelta and Araújo (2012b) constructed a banking network based on a spatial vector model using cross-border liability data from the banking of 20 European and American

economies and four Asian economies. They found an upward trend in the network's connectivity from 1997 to 2011, with banking "clustering" most evident in Europe (except Germany and Switzerland), Denmark, Sweden, and Finland losing their key positions in the network to Hong Kong and the Netherlands Antilles. Minoiu and Reyesÿ2013 ÿconsidered the reporting economies in the LBS as "lenders", all of whom had developed economies, and were at the core of the network, while the non-reporting economies were considered "borrowers" and were at the periphery of the network. Thus, constructing the global banking network of 184 economies, they found that the network's density was pro-cyclical, expanding and contracting with the global capital flow cycle; the network's connectivity increased before the global financial crisis and decreased after the crisis. Chen and Zhao (2019) used cross-border claims and liabilities data from the banking of 30 economies in Asia, Europe, and the United States to construct the banking network through the European distance indicator. They then found that the global financial crisis caused the importance of banking in Europe and the United States to decline and the importance of banking in Asia to rise.

Other scholars focused on the regionalisation trend of cross-border banking expansion after the global financial crisis. McCauley et al. (2019) argued that the contraction of international banking networks after the global financial crisis was limited to European banking, while Japanese, Canadian, and U.S. banking all expanded outward. On this basis, Cerutti and Zhou (2017) and Cerutti and Zhou (2018a) combined the LBS and CBS databases to construct the global banking network. They found that after the crisis, the importance of banking in non-major European economies declined, while the importance of banking in emerging markets increased. The increased level of regionalisation in banking is most notable in peripheral network positions, driven by the banking in emerging markets and non-core banking systems such as Australia, Canada, Hong Kong, and Singapore.

As can be seen, most of the existing studies based on the cross-border banking network focus on the developed economies in global banking or European and American banking, and relatively little literature focuses on Asian banking. The marginal contributions of this paper are as follows: first, we focused on the Asian banking, which showed a strong tendency to expand overseas. We constructed the Asian cross-border credit network by drawing on the European distance indicator using actual data on cross-border claims and liabilities of Asian economies. Then we used network topology indicators to analyse the network structure's dynamic characteristics. Second, based on the perspective of the linked network,

we measured and analysed the role, importance, and linkages of Chinese and Japanese banking in Asian banking. This study provides a theoretical basis and relevant policy insights for China to promote financial openness from this new perspective.

3. Typical Facts

In this part, we have shown the cross-border claims of banking in major Asian economies. The cross-border claims indicator[2] here refers to the total cross-border positions of all banks registered within each economic region, including cross-border positions with their foreign subsidiaries, specifically including loans, deposits, debt securities and other bank financial assets. Most of the reporting economies in the Asian region in the LBS database only report their total cross-border claims on other counterparties in the world, e.g. China, India, etc., so this is a multilateral figure.

Multilateral Cross-Border Claims of Chinese Banking[3] and Japanese Banking

Banking on the Chinese mainland has been reporting its multilateral cross-border claims to BIS since 2016. Therefore, for comparison purposes, Figure 1.1 clearly shows the trends in the cross-border claims of Japanese banking and Hong Kong banking since their data became available, and Figure 1.2 illustrates the cross-border claims of the above three, Chinese, Hong Kong and Japanese banking since the data was reported by Chinese mainland banking.

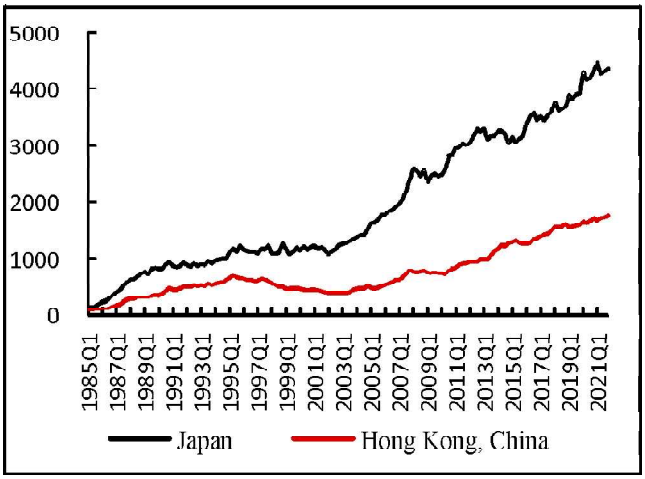

Figure 1.1: Multilateral cross-border claims of banking in Hong Kong and Japan (1985-2021) (in billion USD)

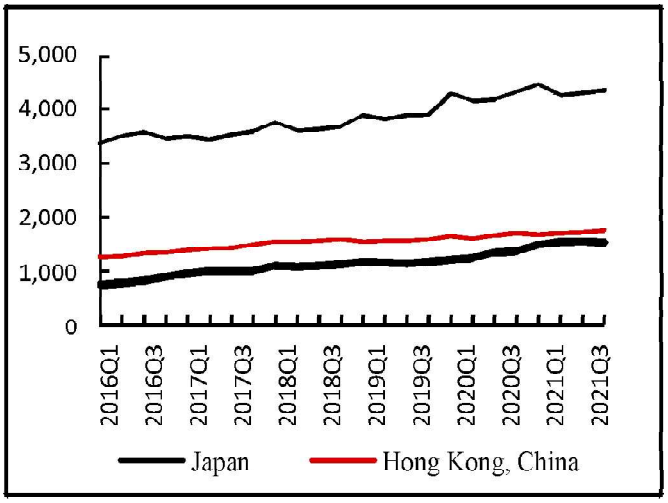

Figure 1.2: Multilateral cross-border claims of banking in Chinese mainland, Hong Kong and Japan (2016-2021) (in billion USD)

Source: Bank for International Settlements.

Japanese banking cross-border claims have been on a steady upward trend year after year, reaching $4349.2 billion by the end of 2021, an increase of about 30 times from $139.5 billion in early 1985. Specifically, it has experienced three stages of rapid rise. The first was from 1985 to 1990 when cross-border claims rose from $139.5 billion to $949.9 billion, an almost seven-fold increase in six years. During this period, Japan signed the Plaza Agreement in September 1985, and the yen began to appreciate steadily, which greatly facilitated the development of Japanese outward investment. The next period was 2002-2008, with six-year growth of $1514.8 billion, which was the most rapid growth in cross-border claims, and Japanese banking expanded sharply overseas during this period. Later, due to the negative impact of the global financial crisis in 2008 and the subsequent European debt crisis, the amount of cross-border lending by Japanese banks showed a slight decline until the end of 2010, when it gradually rebounded. The third phase, from 2015-2021, did not show a significant trend of credit contraction even under the impact of the global epidemic and reached an all-time peak of $4459.1 billion in the second quarter of 2021.

Multilateral cross-border claims for banking in Hong Kong have been slowly rising with small fluctuations, growing nearly 19 times from $86.3 billion in 1985 to $1742.9 billion in 2021. Specifically, it continued to rise from 1985 to 1995, reaching a peak of $701 billion in 1995. Then began a sharp decline due to the significant impact of the Southeast Asian financial

crisis until 2003, when cross-border claims fell by almost half to $391 billion. The global financial crisis in 2008 also caused a slight decline in cross-border claims on Hong Kong's banking, but it began to rebound at the end of 2010 and has been steadily rising since then.

The scale of cross-border claims for banking on the Chinese mainland doubled in 2021 compared to 2016, rising from $748.3 billion to $1,531.1 billion, showing an overall steady upward trend. Over the same period, this could be compared with 29% and 38% increases in Japanese banking and Hong Kong banking, respectively. During this period, the most significant rise was seen in 2016-2018 with the implementation of the Shanghai-Hong Kong Stock Exchange and the Shenzhen-Hong Kong Stock Exchange. The period 2020-2021 also remained steady, being less affected by the global epidemic.

3.1. Multilateral Cross-Border Claims of Banking in Other Major Asian Economies

The five economies shown in Figure 2 are from different sub-regions of Asia[4] and rank high in terms of the size of their cross-border claims within their sub-regions.

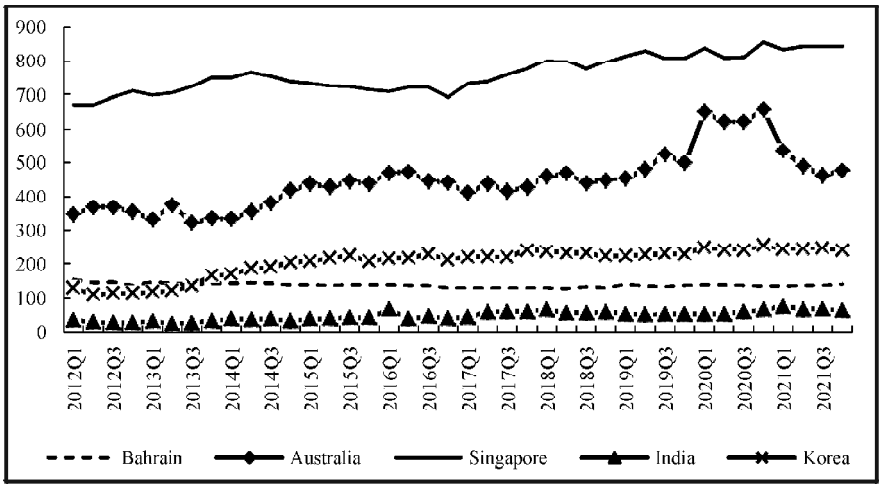

Figure 2: Trend of multilateral cross-border claims of banking in other major Asian economies 2012-2021 (in billion USD)

Source: Bank for International Settlements.

Cross-border claims in Singapore banking have mainly been stable over the last decade and rank first among the five economies. By the end of 2021, the size of cross-border claims was $842.2 billion, an increase of 26% compared to 2012. Cross-border claims in Australian banking have

fluctuated considerably. Specifically, it reached a peak of $650.3 billion at the end of 2019, after which its volatility increased significantly due to the impact of the global epidemic and is in a state of continuous decline, with its cross-border claims standing at $475.2 billion at the end of 2021. The sizes of cross-border claims of banking in Korea, Bahrain and India have been stable over the last decade.

Based on the above typical facts, we find that the cross-border claims of the banking of various Asian economies are quite different and Chinese banking and Japanese banking rank at the top. However, the bilateral cross-border claims data of Japanese banking shows that it plays an important role as a cross-border creditor in Asian banking. Due to the lack of access to bilateral cross-border claims data for banking in China and most Asian economies, it is not possible to directly analyse their importance and cross-border linkages within the Asian region. Therefore, it is necessary to measure the linkages of banking in each economy through the network analysis method.

4. Network Analysis Approach

4.1. Construction of a Cross-Border Banking Credit Network

To construct the network, it is first necessary to measure the interrelationships between the banking sectors of the economies. Because banking sectors in most Asian economies don't report bilateral or cross-border claims and liabilities data, networks cannot be built from actual credit data directly. The use of Euclidean distance to measure interrelationships was first used in the stock market to measure the correlation between the returns of two stocks (Mantegna, 1999; Arajo & Lou, 2007). Later, the method was applied to the cross-border banking credit market to measure the correlation between the banking of two economies (Spelta &Araújo, 2012b; Chen & Zhao, 2019). The methodology in this paper was based on the assumption of a fully connected network structure (any node in a network is connected to other nodes) and refers to the Euclidean distance calculation method in the literature above to study the correlation between cross-border banking in Asian economies. The specific process is as follows:

First, we calculated the net claims $p_{i,t}$ of economies i in quarter t. Specifically, claims ($Cred_{i,t}$) minus liabilities ($Liab_{i,t}$) is the net claims.

$$\vec{p}\,(i) = \overrightarrow{Cred}\,(i) - \overrightarrow{Liab}(i) \tag{1}$$

Second, the above vector of net claims $p_{i,t}$ was standardised as follows.

$$\vec{P}(i) = \frac{\vec{p}(i)}{|\vec{p}(i)|} \tag{2}$$

Third, we substituted the normalised net claims into equation (3) to calculate the Euclidean distance between them.

$$d_{ij} = \left|\vec{P}(i) - \vec{P}(j)\right| \tag{3}$$

Fourth, we calculated the correlation strength s_{ij} between economy i and economy j; its value is equal to the reciprocal of the Euclidean distance (Spelta & Araújo, 2012a).

$$S_{ij} = \frac{1}{d_{ij}} \tag{4}$$

According to the formula, the closer the two economies are to each other, the stronger their correlation is. When an economy's banking changes, economies closer to it are more vulnerable. The opposite happens when economies are further apart.

Fifth, we used the correlation strength s_{ij} between two economies to construct the intensity matrix.

$$S = (s_{ij})_{N\times N}$$

Sixth, we set thresholds for each element in the intensity matrix. Due to the wide disparity in the scale of net claims in the banking sector of Asian economies, some relatively weak correlations in the fully connected network would interfere with the overall distribution and topology of the network. Therefore, it was necessary to filter out the edges with relatively low correlation strength from the strength matrix S to construct the network adjacency matrix in a real sense. Based on the above reasons, we used the threshold method to specify the highest point of the probability distribution of correlation strength as the threshold (Zhang et al., 2014). The elements larger than the threshold value are retained, which means that there are connected edges between economy i and economy j, and the weights of the edges are equal to the correlation strength values of the two. If the elements are smaller than the threshold value, there is no edge between economy i and j. Then based on the threshold results a new network adjacency matrix: $A = (a_{ij})$ $N\times N$ is constructed. This matrix is used as a network matrix to represent the cross-border banking credit network.

The last step of constructing cross-border banking credit networks is based on the network matrix. The network matrix identifies the edges of the network and the economies are the nodes, which together form the network. The arrows between the nodes indicate the direction of the flow

of credit funds. Therefore, the network constructed in this paper is directed and weighted.

4.2. Network Structure Analysis

In this part we analyse the topology of the network from the whole to part, from the network level to the important node level, including binary and weighted network indicators.

4.2.1. Overall Network Structure Analysis Indicators

1. Network density: Network density refers to the closeness of connected edges between nodes in a network. In a cross-border banking credit network, the more relationships between economies, the more density and the stronger connection of the network. Let the number of nodes in the network be N, and the number of edges present be m. The network density is given by

$$D = \frac{m}{N(N-1)} \tag{5}$$

2. Average path length: The number of edges contained in the shortest path connecting two nodes in a network is defined as the distance between the two nodes. Let i and j be any two nodes in the network; d_{ij} represents the number of edges included in the shortest path connecting node i, j. The average path can be expressed as

$$L = \frac{2}{N(N-1)} \Sigma_{i \geq j} d_{ij} \tag{6}$$

3. Average clustering coefficient: Clustering coefficient is a network indicator that measures the degree of node clustering. The higher the clustering coefficient, the more clustered and connected the network is. For a node, the clustering coefficient is the ratio between the number of edges between all adjacent nodes of the node and the maximum number of possible edges. The average clustering coefficient of a network is equal to the average of the clustering coefficients of all nodes in the network. Let the average clustering coefficient of the network be C. $C \leqq 1$, $C=1$ when and only when the network is a fully connected regular network. The average clustering coefficient is given by

$$C = \frac{1}{N} \Sigma_{i=1}^{N} \frac{2n_i}{k_i(k_i - 1)} \tag{7}$$

where, k_i represents the number of edges directly connected to node i, and n_i represents the number of edges connected by k_i.

4.2.2. Network Importance Node Analysis Indicators

1. The purpose of analysing the important indicators of banking is to observe their position and role in the network. The so-called important nodes refer to some special nodes that can influence the structure and function of the network to a greater extent than other nodes in the network. Different important node ranking methods describe different node characteristics. Considering nodes' local environment and location, we choose the following four metrics for nodal analysis.
2. Degree centrality: In complex network analysis, the importance of a node is also known as 'centrality'. Degree centrality is the idea that the more neighbours a node has the more influence it has. In cross-border banking credit networks, reflect the degree of connectivity of an economy in the network, with greater connectivity indicating a strong regional relationship. In a directed network, the degree of a node can be divided into out-degrees and in-degrees depending on the direction of the edges. This is explained as follows.
3. In-degree represents the number of relationships sent out by a node; out-degree represents the number of relationships received by a node. The direction of the arrow in a cross-border banking network indicates the flow of funds from the lender to the borrower. Let be the degree of node , is the number of nodes directly connected to node . The formula for degree centrality is as follows:

$$DC_i = \frac{k_i}{N-1} \tag{8}$$

where, $k_i = \Sigma i a_{ij}$, a_{ij} is the element in row i and column j of the network matrix A, N is the number of all nodes in the network, and N–1 is the maximum possible degree of the node v_i.

4. Weighted degree centrality: In a weighted network, the degree of a node is also known as the node strength; degree centrality is also known as weighted degree centrality, which is expressed as the sum of the weights of the edges connected to the node. Similarly, the node strength can be divided into out-strength and in-strength. This is explained as follows.

Out-strength represents the strength of the node's outgoing relationship; in-strength indicates the strength of the node's incoming

relationship. Node strength is the simplest weighted network indicator, which reflects the strength of financial linkages between economies. In a weighted network, the node strength is calculated as

$$b_i = \Sigma_{j=1}^{N} w_{ij} \tag{9}$$

where $W = (w_{ij})$ is the weighted adjacency matrix of the network, and w_{ij} is the weight of edge between node v_i and v_j. If there is no edge between two nodes, then $w_{ij} = 0$. Similarly, we can obtain the out-strength of node v_i, let it be b_i^{out}; and the in-strength of node v_i, let it be b^i_{in}. The degree centrality of a node in weighted network is given by

$$WDC_{(i)} = \frac{b_i}{\Sigma_{j=1}^{n} b_j} \tag{10}$$

5. Closeness centrality: The smaller the average distances between a node and other nodes in the network, the greater the closeness centrality of that node. Closeness centrality uses the relative distance between all pairs of nodes to determine the importance of a node. For a connected network, the average shortest distance between node and other nodes in the network is given by

$$d_i = \frac{1}{N-1} \Sigma_{j \neq i} d_{ij} \tag{11}$$

The smaller is, the closer node is to other nodes in the network. Therefore, the reciprocal of is used to represent the closeness centrality of node , which is calculated as follows.

$$CC_{(i)} = \frac{1}{d_i} = \frac{N-1}{\Sigma_{j \neq i} d_{ij}} \tag{12}$$

6. Betweenness centrality: Generally, there are multiple shortest paths between a pair of nodes. Betweenness centrality considers that the more shortest paths through a node, the greater the importance of the node and its betweenness centrality. The greater the betweenness centrality of an economy's banking, the stronger will its mediating role in the network be. Nodes's betweenness centrality can be expressed as

$$BC_{(i)} = \frac{2}{(N-1)(N-2)} \Sigma \frac{g_{st}^{j}}{g_{st}} \tag{13}$$

where, g_{st} is the number of all the shortest paths from node v_s to v_t. g^j_{st} is the number of the shortest paths through node among all the shortest paths from v_s to v_t.

5. Eigenvector centrality: Eigenvector centrality considers that the importance of a node depends not only on the number of its neighbouring nodes (i.e. the degree of that node) but also on the importance of each neighbouring node. Therefore, this index focuses on portraying the node's surroundings, which means that a node can increase its importance by connecting to other important nodes. Greater eigenvector centrality of an economy means that it is connected either to a large number of ordinary economies or to a small number of important ones. Letbe the importance measure of node, is a proportional constant. The eigenvector centrality can be expressed as

$$EC_{(i)} = x_i = c\Sigma_{j=1}^{N} a_{ij} x_j \tag{14}$$

4.3. Data

The cross-border bank credit data were obtained from the BIS LBS database. In this database, all economies are divided into reporting and non-reporting economies. Reporting economies are required to provide the BIS with quarterly multilateral data on cross-border claims and liabilities of all international active banks located in their country (or region) to all counterparty economies in the world. International active banks in this context refer to foreign banks as well as domestic banks with significant international operations. In this paper, sample economies were selected according to the following two principles: (1) large scale cross-border claims and liabilities; (2) quarterly data availability. Finally, we considered the following 14 Asian economies as a sample: China,[5] Hong Kong, Macao, Taiwan, Japan, Korea, the Philippines, Malaysia, Indonesia, Turkey, India, Singapore, Bahrain, and Australia. The data covered the period from 2016 Q1 to 2021 Q4. The cross-border financial flows used to construct the cross-border banking credit network were estimated based on stock changes, adjusted for exchange rate fluctuations and inflation rates, which made those data comparable over time. Since most Asian economies only provide the data of multilateral cross-border claims and liabilities, we converted the claims and liabilities data into an intensity matrix during the sample period according to equations (1) - (4), and then threshold the intensity matrix to obtain a network matrix[6], and finally generated a network.

The abbreviations of the sample economies are shown in Table 1, and we will refer to the economies by abbreviations in the analysis section below.

Table 1: Sample Economies

CN: China	PH: the Philippines
HK: Hong Kong, China	SG: Singapore
MO: Macao, China	ID: Indonesia
TW: Taiwan, China	IN: India
JP: Japan	TR: Turkey
KR: Korea	BH: Bahrain
MY: Malaysia	AU: Australia

5. Network Structure Analysis

5.1. Dynamic Characteristics of Cross-Border Banking Credit Network in Asia

Firstly, we used network density, average path length, and average clustering coefficient to analyse the overall network structure from 2016-2021, as shown in Figure 4 to Figure 6.

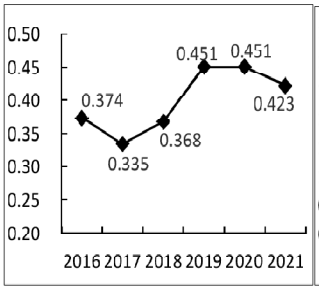

Figure 3: Network density

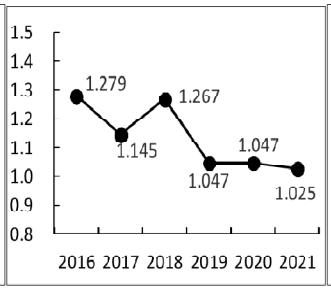

Figure 4: Network average path length

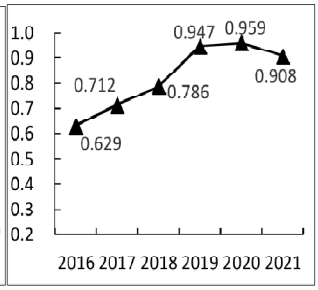

Figure 5: Network average clustering coefficient

On the whole, both the network density and the network average clustering coefficient showed an upward trend from 2016 to 2021, while the network average path length was on a downward trend, indicating that banking in Asian economies was increasingly closely connected. The cross-border banking credit networks in Asia between 2016 and 2021 are shown in Figure 6 and Figure 7. It can be seen that there were more connected edges in 2021 compared to 2016, and the network was tighter. Among them, the thickness of the connected edges represents the strength of cross-border linkages among economies. All connected edges showed

thickening in 2021, i.e., cross-border linkages among economies were generally stronger.

Specifically, the network density and average clustering coefficient rose most significantly in 2018-2019, and correspondingly, the average path length decreased significantly. The above indicators did not change in 2019-2020, but both the network density and average clustering coefficient showed a small decrease in 2021, indicating that the strain of global epidemic in 2020 had less impact on cross-border linkages between the banking of Asian economies and would gradually be reflected in the post-epidemic period. The network average clustering coefficient exhibited a year-on-year increase and reached 0.959 in 2020, close to the maximum value of 1. Although it fell to 0.908 in 2021, it remained high, which further demonstrate the convergence trend or strong degree of collectivisation of cross-border banking in Asia.

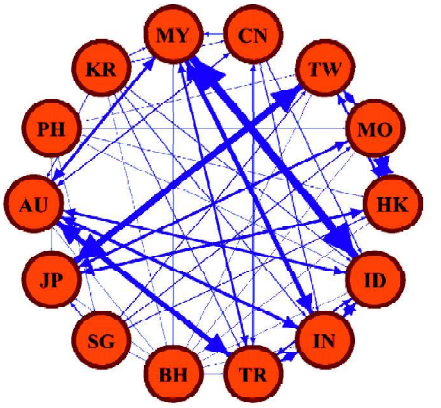

Figure 6: Cross-border banking credit network in Asia: 2021

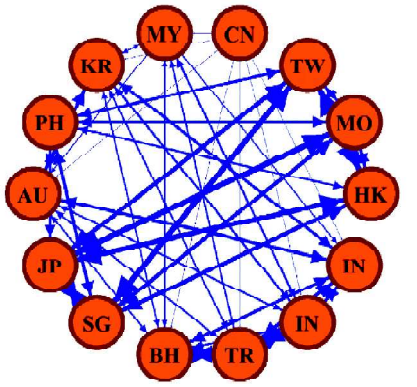

Figure 7: Cross-border banking credit network in Asia: 2016

Secondly, in order to analyse the changes that had occurred in the network structure, the following summarised statistics were based on the node level for the nodal degree in the networks in 2016, 2018 and 2020. The node degree was chosen here because it reflects the cross-border connections sent or received by nodes and their corresponding strengths, which is the most basic and intuitive indicator of the strength of inter-economy linkages in the network.

As seen from the node in-degree (node out-degree) in Table 2, economies borrowed (lent) funds from 4.9 economies on average in 2016; it was almost unchanged in 2018; by 2020 it rose to 5.9. It indicates that the cross-border linkages received or sent between economies had increased

Table 2: Descriptive statistics on node degree of cross-border banking credit networks in Asian economies

Periods	*Node degree*	*Mean*	*S.D*	*Min*	*Max*
2016	In-degree	4.9	2.7	0.0	8.0
	Out-degree	4.9	2.1	3.0	11.0
	In-strength	45.1	33.4	0.0	92.2
	Out-strength	45.1	25.7	6.0	84.0
2018	In-degree	4.8	1.9	1.0	7.0
	Out-degree	4.8	1.3	2.0	7.0
	In-strength	54.3	39.7	2.6	139.5
	Out-strength	54.3	30.1	12.5	123.2
2020	In-degree	5.9	1.3	3.0	7.0
	Out-degree	5.9	0.9	5.0	7.0
	In-strength	67.5	17.1	24.3	87.2
	Out-strength	67.5	12.2	44.9	84.4

compared to the previous ones. During this period, China, Japan, Korea, New Zealand, Australia and ASEAN officially signed the Regional Comprehensive Economic Partnership (RCEP), which further deepened regional economic and financial cooperation. By comparing the difference between the maximum and the minimum degree, it can be found that the gap decreases with time, that is, the cross-border linkage number of Asian economies tends to balance, which may be the result of the continuous promotion of the various government-led Asia-Pacific Economic and Cooperation organisations.

In terms of node strength, the mean of out-strength (in-strength) in 2020 was 67.5, an increase of almost 50% as compared to 45.1 in 2016. This specifically shows that the average capital flow of each node had increased by 50%, and intensity of the linkages across the banking of each economy had increased significantly. However, the standard deviation of node strength is high, i.e., the difference between the maximum and minimum node strength is remarkable. This reflects the uneven distribution of the strength of cross-border linkages in Asian banking, with a tendency to "cluster" or converge towards a few regional financial centers.

5.2. The Node Importance of Chinese Banking and Japanese Banking

5.2.1. From the node strength to analyse the changes in lender and borrower

We analysed the evolution of the lenders and borrowers of funds according to the changes in each node's out-strength (in-strength). As seen from Table 3, Chinese banking always sent out stronger cross-border connections than it received, played an important role as a lender, and was relatively able to

Table 3: Node strength of banking in Asian economies: 2016-2021

	2016		2017		2018		2019		2020		2021	
	Out-strength	*In-strength*	*Out-strength*	*In-strength*	*Out-strength*	*In-strength*	*Out-strength*	*In-strength*	*Out-strength*	*In-strength*	*Out-strength*	*In-strength*
CN	26.8	14.4	21.8	2.9	34.2	29.9	85.2	85.2	44.9	24.3	11.4	0
HK	44.1	49.7	264.7	302.5	107.7	129.6	112.5	120.1	75.9	75.9	107.7	107.7
MO	47.2	48.9	249.2	283.7	123.2	139.5	103.7	110.0	71.2	71.2	96.6	96.6
TW	53.3	59.3	69.0	32.4	61.6	44.3	90.1	90.1	52.2	52.2	112.6	112.6
JP	57.8	64.2	153.3	157.4	65.8	65.8	103.1	109.8	66.0	66.0	134.7	134.7
KR	19.1	2.9	6.7	0	12.5	2.6	79.4	79.4	50.6	50.5	68.8	70.4
PH	6.0	0	52.7	29.8	48.7	42.8	66.2	66.2	57.5	57.5	73.9	73.9
MY	84.0	92.0	99.0	106.3	49.5	59.6	107.7	116.0	84.4	84.4	45.1	34.8
IN	61.5	70.0	95.4	102.8	47.1	57.1	114.7	114.7	74.7	79.2	83.9	85.6
SG	16.9	6.0	22.5	5.6	32.2	17.2	47.0	26.4	57.5	57.5	129.4	129.4
ID	73.5	82.4	108.2	115.4	61.4	67.6	131.8	131.8	81.8	86.6	86.0	94.4
TR	62.0	66.1	119.7	126.8	33.6	29.5	73.3	73.3	68.2	73.0	91.0	92.5
BH	7.7	0	13.4	2.8	27.4	13.7	67.0	58.7	80.9	87.2	75.9	77.5
AU	71.8	75.7	98.5	105.6	55.3	61.0	107.7	116.0	67.5	67.5	64.3	71.2

influence other economies in the network. The fluctuation range of the external and internal strength of Japanese banking was extensive, but there was little difference between the two in value, that is, the intensity of cross-border correlation sent out is equal to that received.

First, we analysed the relative changes in the lender or borrower role of Chinese banking from the changes in the node strength each year. Chinese banking's in-strength and out-strength from 2016 to 2019 showed an overall upward trend, and both reached a historical peak in 2019, higher than Korea, Philippines, Singapore, Turkey, and Bahrain, and lower than Japan, which was in the middle level. Compared with 2016, its in-strength and out-strength increased by 491.7% and 217.9% in 2019, respectively, and Chinese banking steadily strengthened its lender role during this period, but its borrower role played an unstable role. From 2020 to 2021, when the epidemic gradually spread globally, the banking sector in each economy contracted its cross-border credit business, making its cross-border linkage intensity significantly lower, and Chinese banking was no exception. In 2021, the in-strength of Chinese banking dropped directly to zero, i.e., it hardly played the role of a borrower. The in-strength and out-strength all ranked low in the Asian region, possibly to guard against cross-border financial risks from other economies during the epidemic. During the same period, Japan, Singapore, and Hong Kong had smaller decreases in cross-border linkage intensity, and the banking sector had larger cross-border capital flows, playing a significant role in lending and borrowing funds, highlighting the importance of regional financial centres.

As seen in the above table, Japanese banking's in-strength and out-strength are in the middle to upper range each year, and the strengths of outgoing and incoming cross-border linkages are comparable. In 2019, Japanese banking's in-strength (out-strength) was lower than that of Hong Kong, Macao, India, Malaysia, Indonesia, and Australia, and higher than that of most Asian economies, and was an important cross-border creditor in the region. During the epidemic period of 2020~2021, its outgoing and incoming cross-border links did not show a significant trend of contraction, demonstrating a strong ability to withstand external shocks. It is worth mentioning that India had been ranking high with considerable growth in both in-strength and out-strength from 2016 to 2021 and has been gaining importance in the Asian regional network. Malaysia, Australia, and the Philippines are gradually strengthening as borrowers of funds; Turkey and Australia play an important role as lenders.

After comparing the total node strength[7] of Chinese banking and Japanese banking, it can be seen that the total node strength of Chinese banking was lower than that of Japanese banking during the period from

2016 to 2021, but the difference in node strength between Chinese banking and Japanese banking gradually shrank as Chinese banking continued to expand outward. The node strength of Japanese banking in 2019 was 212.9, an increase compared to 2016, which is about 73.1%, while the node strength of Chinese banking in the same period increased by approximately 324.6%, which is much higher than that of Japanese banking. That is, while Chinese banking expanded its cross-border banking credit business and strengthened its cross-border banking ties, Japanese banking's cross-border linkage strength within the Asian region remained essentially unchanged. Thus, Chinese banking significantly increased its importance in the Asian regional banking network. Its role as a lender of funds was enhanced, placing it at the network's core at the same time as Japanese banking. However, Japanese banking was more resilient to external shocks during the global epidemic and was much less negatively affected by the epidemic than Chinese banking.

5.2.2. From node centrality to analyze the changes in core position

In order to gain a multi-dimensional understanding of the role and relative position of banking in each economy, based on the quarterly data of cross-border claims and liabilities of economies from 2016 to 2021, an overall credit network for the full sample period was constructed. Table 4 is the summary of indicators after centrality analysis of this network.

Table 4: Centrality analysis of cross-border banking credit network in Asian economies: 2016-2021[8]

Economic	*Weight degree centrality*	*Rank*	*Closeness centrality*	*Rank*	*Betweenness centrlity*	*Rank*	*Eigenvector centrality*	*Rank*
HK	81.597	**1**	0.351	**7**	0.000	**10**	0.291	**7**
JP	77.514	**2**	0.481	**6**	3.333	**4**	0.291	**7**
MO	74.910	**3**	0.481	**6**	3.333	**4**	0.291	**7**
IN	70.088	**4**	0.542	**3**	2.367	**5**	0.941	**2**
ID	63.735	**5**	0.500	**5**	0.500	**8**	0.941	**2**
TW	56.900	**6**	0.481	**6**	3.333	**4**	0.291	**7**
MY	53.059	**7**	0.520	**4**	0.700	**7**	0.941	**2**
AU	48.104	**8**	0.722	**1**	62.367	**2**	1.000	**1**
CN	33.953	**9**	0.500	**5**	0.200	**9**	0.941	**2**
TR	30.961	**10**	0.500	**5**	0.000	**10**	0.810	**3**
SG	28.583	**11**	0.684	**2**	80.000	**1**	0.383	**6**
PH	22.606	**12**	0.481	**6**	0.000	**10**	0.243	**8**
KR	22.176	**13**	0.542	**3**	0.867	**6**	0.698	**4**
BH	16.500	**14**	0.542	**3**	18.000	**3**	0.496	**5**

In the first place, looking at weighted degree centrality describing the strength of nodes' linkages, Hong Kong, Japan, and Macao rank high. They are all developed economies in Asia and are linked closely to other economies. The fourth-ranked economy is India, which ranks first among emerging Asian economies. To strengthen ties with East Asia, India has actively pursued the "eastward policy," strengthening economic and trade cooperation and credit flows with ASEAN, China, Japan, Korea, and Australia. The trade war between China and the United States in 2018 seriously affected the mutual trust among economies. Coupled with the impact of the global epidemic in 2020, the cross-border business of Chinese banking shrank to some extent, and the cross-border correlation intensity was much lower than that of Japanese banking, ranking lower in weighted degree centrality.

In terms of closeness centrality, which measures the distance between nodes, Australia, Singapore, India, Korea, and Bahrain are in the top tier, geographically located in Oceania, Southeast Asia, South Asia, East Asia, and West Asia, respectively, which makes cross-border credit flows within the Asia-Pacific banking easier. Combined with betweenness centrality, we find that Singapore, Australia, and Bahrain are far higher than other economies and play a significant "bridging" role in strengthening cross-border financial links between Oceania and Asia. Chinese banking's betweenness centrality is at the middle level; it's in the transition position from the edge to the core in the network and hardly plays an intermediary role. Closeness centrality of Japanese banking is slightly lower than that of Chinese banking, and the betweenness centrality is higher than that of China, after Singapore, Australia, and Bahrain, indicating that it is only closely associated with a few economies in the region and relatively distant from most of them.

Thirdly, in terms of eigenvector centrality, which portrays the adjacent nodes' importance around the goal node, Chinese banking's eigenvector centrality is 0.94, ranking second, below Australia, and at the same level as India, Malaysia, and Indonesia. These economies enhance their core position by being connected to other important nodes. However, when a financial crisis occurs, the banking sector of such economies can be a crucial pathway for cross-border financial risk transmission and is also an important target for financial regulators to prevent.

It is worth mentioning that the node clustering coefficients of Chinese banking from 2016 to 2021 are 0.83, 0.74, 0.76, 0.98, 1, and 0.95, respectively, reaching a maximum of 1 in 2020 and remaining at a high level of 0.95 in 2021 despite a slight decrease. The clustering coefficient of Japanese banking continued to grow during these six years, reaching a peak of 1 in

2020, indicating that the banking sector of significant economies is converging to the core nodes such as China and Japan. The development of the banking sector in the Asian region shows an important "collectivise" characteristic, which also verifies the previous conclusion that the dynamic network structure shows an aggregation trend. This confirms the previous finding that the dynamic network structure has an aggregation tendency.

5.2.3. Cross-border linkages of Chinese banking and Japanese banking

According to the cross-border links sent by Chinese banking and Japanese banking to other economies, the top five economies with the strongest links to China or Japan were selected here for analysis.

Table 5: The strength of cross-border linkages of Chinese and Japanese banking to other Asian economies[9]

Periods	*CN*					*JP*				
	AU	*TR*	*IN*	*MY*	*ID*	*HK*	*MO*	*TW*	*PH*	*SG*
2016	5.8	6.3	4.1	4.2	4.2	13.0	12.5	32.3		
2017	3.9	3.9	3.9	4.1	4.1	70.1	54.6	15.0	13.7	
2018	5.9	14.8	5.3	4.1	4.1	11.9	13.0	24.0	9.6	7.2
2019	12.8	11.1	13.8	9.8	10.5	34.3	40.4	18.5	9.9	
2020	12.4	4.8	4.8	7.9	4.5	21.4	22.1	7.4	6.6	8.5
2021	1.5	1.6	1.6	1.8	1.7	27.2	30.5	23.1	14.4	39.6
Total strength	42.3	42.5	33.5	31.7	29.1	177.9	173.1	120.2	54.1	55.4

The left side of Table 5 shows the strength of cross-border linkages that Chinese banking sends to other economies. As can be seen the economies closely linked to Chinese banking are all emerging economies except Australia. It is clear that Chinese banking had sent the strongest cross-border linkages to Turkey and Australia from 2016-2021, at about 42.5 and 42.3. In contrast, the linkages with Korean and Bahrain banking are relatively weak, while the linkages with Malaysia, Indonesia, and India are in a steady growth trend. It is worth noting that Chinese mainland banking is not as closely linked to banking in Hong Kong, Macao and Taiwan as expected. By this period, the strength of linkages issued outward by Chinese banking had increased significantly in 2019, but then contracted notably due to the negative impact of the global epidemic in 2020-2021.

The right-hand side of Table 5 shows the cross-border linkages issued by Japanese banking to other Asian economies. From 2016 to 2021, Japanese banking had the strongest cross-border correlation with Hong Kong and Macao, with 177.9 and 173.1 respectively. Its linkages issued to Singapore are gradually increasing, with an approximate five-fold increase in 2021

compared to the strength first issued in 2018. Cross-border contact with the Philippines began in 2017, and the strength showed a downward trend in the past five years. Then it can be clearly seen from the table that the cross-border links sent out by Japanese banking fluctuated greatly. Compared with Chinese banking, Japanese banking had issued fewer linkages and had not shown a trend of outward expansion or strengthening cross-border connections in banking.

6. Conclusion

In this paper we took the quarterly data of multilateral cross-border claims and liabilities of 14 Asian economies from 2016 to 2021. Then we used the Euclidean distance to measure the correlation between the two economies' banking, thus constructing the cross-border banking credit network in Asian economies. The main study examines how the network structure and important nodes have changed and provides a comparative analysis of the cross-border linkages and importance of Chinese and Japanese banking in the network. The conclusion of this paper is as follows:

Firstly, cross-border linkages between the banking of economies in Asia were becoming stronger in 2016-2021. This was evidenced by increased network density from 0.374 to 0.423 and increased clustering coefficient from 0.629 to 0.908. The network showed dynamic features of peripheral economies converging on core economies such as China, Japan, Hong Kong, and Singapore. However, the significant contraction of cross-border credit links in the banking sector from 2021 may be related to the impact of the global pandemic.

Secondly, Chinese banking is increasingly important as a lender of funds in Asian regional banking, and its role as a borrower is gradually weakening. Japanese banking and Hong Kong banking are important lenders of funds and have consistently high credit flows. As Chinese banking continues to open up, the gap between the out-strength of Chinese banking and Japanese banking is gradually narrowing. Malaysia, Indonesia, and India are the significant borrowers and are at the network's periphery. Singapore, Australia, and Bahrain are important intermediaries between Asian and Oceanian banking for cross-border credit.

Thirdly, Chinese banking is more closely linked to Australia, Turkey, and India, while Hong Kong, Macao, and Taiwan have relatively weak credit links with Chinese mainland banking. Japanese banking has strong ties with Hong Kong, Macao, and Singapore, and weaker ties with the banking sectors of most Southeast Asian economies. While Chinese banking is expanding abroad and strengthening its cross-border linkages, Japanese banking's cross-border linkage has mainly remained stable,

making it relatively less important in the network, while Chinese banking is steadily increasing in importance.

The relevant policy implications are as follows. First, the cross-border business of international commercial banks in the Guangdong-Hong Kong-Macao Greater Bay Area should be used as a breakthrough to promote the openness of Chinese banking. The government should support the branch banks of Hong Kong and Macao on the Chinese mainland to provide loan services for the Guangdong-Hong Kong-Macao Greater Bay Area. This measure will help strengthen credit ties between the Chinese mainland, Hong Kong, Macao, and Taiwan. Among them, Hong Kong is an international financial centre linked to the Southeast Asian economic system, which should play a leading role and consolidate the development of its status as an international financial centre.

Secondly, under increased uncertainty in the international situation and the headwinds of economic globalisation, the banking sector in many economies may contract their cross-border credit business. It may result in a large number of credit funds flowing back to developed economies, which could create an imbalance in the financial structure within emerging market economies. Therefore, while expanding cross-border credit business, the relevant financial regulators in China must also improve their ability to monitor cross-border financial risks, focusing on the banking of important economies such as Japan, Singapore, Hong Kong, and India.

Finally, under the impact of the global epidemic, Asian economies have taken the lead in achieving recovery and are an important engine of global economic recovery. When faced with uncertainties from many sides, economies within Asia should strengthen cooperation, make full use of regional cooperation mechanisms such as RCEP, and play the role of cross-border credit fund intermediaries in the banking sector of Singapore, Australia, and Bahrain to im;prove the efficiency of cross-border banking activities and promote the realisation of Asian regional financial integration and enhance the status of Asian banking in the international banking system.

Notes

1. Data from the BIS LBS database.
2. Chinese banking here includes Chinese mainland banking and Hong Kong banking.
3. Australia and New Zealand were grouped into the Asian Region according to the scope of the Asian Development Bank (ADB) report. New Zealand is a non-reporting economy, so it was not selected as a sample economy.
4. The following empirical part of China refers to the Chinese mainland.
5. The threshold is specified by the probability density distribution of the intensity matrix S, and the threshold of the cross-border credit network in Asia from 2016 to 2021 is 4.0, 3.5, 4.0, 9.5, 4.5 and 1.5, respectively.

6. Total node strength = in-strength plus out-strength.
7. Economies are listed in order of weighted centrality from highest to lowest.
8. The blank space in the table indicates that Japanese banking has no linkage with the corresponding economy in the network for the corresponding year.

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