The trade network structure among China, Japan, and South Korea

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1. Introduction

Up to the present, China, Japan, and South Korea (CJK) have deepened their economic ties with each other. Despite having different political and economic systems and historical challenges, these countries have engaged in private and intergovernmental exchanges that have strengthened their ties. In addition, it is also due to the economic importance and geographical location of these countries. Economic conditions, geographical situations (distance or contiguity), and cultural factors (commonness of official language or main religions) can affect international exchanges, such as trade of goods or human mobility. Using imports of goods and inbound tourist data for the past 20 years, this study clarifies the current state of the trade network of CJK and the volatility of the network construction due to downward demand shocks, such as global recession.

The network is assumed to be of a wider scale, not the size between CJK and trade partners. This study not only clarifies the general situation of trade among the three countries, but also reveals the structure of the trade network centered on these three countries. Furthermore, it compares the goods trade network and human mobility network to shed light on how the network is formed. To compare the construction of the networks, the correlation coefficients for the two networks' weight matrices were calculated.

Some studies analyze the network of CJK countries. Kuroiwa (2011) evaluates the general situation of innovation networks in CJK countries using the patent data of Japan. They revealed that China achieved a high-speed improvement in technology, and the importance of intellectual property protection and the necessity of institutional cooperation, such as making common rules. Wen et al. (2014) examine the foreign direct investment (FDI) network of CJK countries. They estimated the gravity model of the FDI and goods trade variables, and suggested that investment from Japan and Korea to China can affect China's trade behavior. They concluded that the CJK Free Trade Agreement (FTA) will increase China's foreign investment, eventually leading to a balance of trade equilibrium between Japan and Korea. Guo et al. (2017) applied network analysis on the shipping network of CJK countries and clarified the characteristics of the main ports.

In contrast, while these studies only analyzed the network formed by three countries, Kuroiwa and Ozeki (2010) evaluated the characteristics of wider networks, including CJK countries. They suggest that CJK economies have a weakness due to heavy dependence on the United States and European markets. To alleviate the situation, CJK countries should promote

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the FTA and cross-border infrastructure.

Although Kuroiwa and Ozeki (2010) examine the change in the goods trade network before and after the Lehman shock, this study recognizes that trade networks are formed by the framework of the mechanism described by the gravity model, and evaluates the larger scale network as well as CJK and its trading partners. Based on the same concept, Bhattacharya et al. (2007) also examined the relationship between the framework of the gravity model and network formation. There are two steps to identify network member countries in this study. First, for each country of CJK, the countries that make up 80% of the trade volume are regarded as major trading partners and are extracted. Second, for the partner countries, their partner countries are extracted, which constitute 80% of the trade volume. The obtained countries and trade relationships refer to the nodes and branches of the trade network, which centered on China, Japan, and South Korea. To ensure the characteristics of the trade network, this study uses data on imports of goods for the past 20 years to identify the network configuration.

Moreover, similar to goods trade, the configuration of the human mobility network is also examined using inbound tourist data. The amount of human mobility is also decided by the framework of the gravity model, and the main factor of the model is thought to be the same as that of the gravity model of trade. This study reveals the mechanism of network formation in the past 20 years by comparing goods trade and human mobility networks, and evaluates the correlation index of the two networks. In addition, from the characteristics of network formation over the past 20 years, we consider the network response to shocks and examine whether the gravity factor or the factors specific to each network dominate during the recession period, such as the Asian currency and global financial crises.

The rest of this paper is organized as follows. The data and the empirical method used in this study are explained in section 2. The empirical results are presented in section 3, while concluding remarks are provided in section 4.

2. Data and Method

To understand the characteristics of trade and human mobility networks, this study uses the import data of UN Comtrade and inbound tourist data from the UN World Tourism Organization (UNWTO). Assuming that both networks are formed by the gravity model framework, the data for identifying networks have the same formation as the gravity model estimation. The period covered by the verification was from 1995 to 2015 for both networks. To calculate the similarity index between goods trade transaction and human mobility network, the target of verification is up to 2015, according to sample size of tourist data with data constraints.

Goods trade and human mobility volume of each country are assumed to be determined by the following equation.

$$y_{ijt} = X_{ijt}^{'}\beta + Z^{'}{}_{ijt}\gamma + D_i + D_j + D_t + \varepsilon_{ijt}$$

y_{ijt} denotes the exchange volumes from country i to country j in year t, and X_{ijt} denotes economic variables formed from country i and country j in year t. Z_{ijt} denotes the geographic condition or cultural commonness between country i and country j. D_i, D_j, and D_t are dummy variables that represent the characteristics of the country or year, and ε_{ijt} is the error term. Both the volume of goods trade or human mobility are determined by these common factors, and only the error term causes the difference between these two networks. The error term can reflect whether a bilateral FTA is signed, whether visa requirements are relaxed, or whether a direct air line route exists. These factors can affect either network only.

To examine the similarity of two networks, the correlation coefficient is calculated for their weight matrix components. The weight matrix has countries that make up the network in rows and columns, and takes 1 if the countries in the rows and columns form a network, and 0 otherwise. It is possible to verify the similarity between two networks by aligning to the composition of the weight matrix in the network of goods transaction and human mobility and calculating the correlation coefficient of elements other than the diagonal elements.

3. Empirical Results

Fig. 1 indicates how the similarities between goods trade and human mobility networks evolved over the period. According to the transition of the values, the target period can be classified into three categories. The first period is from 1997 to 2000, and the network similarity rapidly decreases. The second period is from 2001 to 2007, and the values decrease. The last period is from 2008 to 2014, and the value rises once and then starts to fall again.

The Asian currency crisis occurred in the first period and the currency values of Asian countries fell. As shown in Fig. 2, import data for CJK, except for China, reveal a decline due to the Asian currency crisis. In the second period, the September 11th attacks occurred in the United States, the Iraq War began, and the global financial crisis subsequently occurred. It can be seen that even during the period of terrorist attacks, only China's import volume did not experience downward pressure, and the trade volume between Japan and South Korea decreased. In third period, China carried out a fiscal policy of 4 trillion RMB after the global financial crisis, and the import volume of all CJK countries is shown to be under downward pressure.

Fig. 3 shows the constituent countries of the goods trade network centered on CJK. A country is connected by a line if it constitutes 80% of the value of imports; the green line represents imports from China, the red line represents those from Japan, the blue line shows imports from South Korea, and the gray line those from partner countries, which constitutes 80% of the value

of imports. The number of network branches was 52 in 1997, 53 in 2001, 62 in 2008, and 62 in 2014. Over the period, the smallest number of branches (50) occurred in 1998, and the largest in 2012 (67 branches). The fact that many countries constitute the network does not necessarily mean that trade is active. When a large volume of trade is carried out in a small number of countries, the amount of trade can increase, but the number of countries that constitute the network may decrease. However, as far as can be seen from the data, the number of network-forming countries is increasing when global trade is considered to be active.

Fig. 4 shows the constituent countries of the human mobility network centered on CJK countries. Similar to the trade network, this network connects the countries whose inbound arrivals make up 80% of all tourists. The green line represents China, red represents Japan, blue represents South Korea, and gray represents the exchange with countries other than CJK. The number of network branches was 45 in 1997, 45 in 2001, 50 in 2008, and 52 in 2014. Over the period, the smallest number of branches (41) occurred in 2002, and the largest in 2013 (53 branches).

3.1 Goods Trade Network of CJK Countries

From 1995 to 2015, the countries that made up the goods trade network of China were Australia, Germany, Japan, South Korea, Russia, Singapore, and the United States (Table 1). During the period from 1997 to 2000, Malaysia, France, and Indonesia were added, and the Philippines, Malaysia, and Thailand were added from 2001 to 2007. Brazil, Canada, Chile, France, India, Malaysia, Saudi Arabia, South Africa, Switzerland, and Thailand were added from 2008 to 2014, and the number of network members increased rapidly during the last period.

The countries that have been selected as network-forming countries for the entire period covered by Japan's goods trading network are Australia, China, Germany, Indonesia, Malaysia, South Korea, Thailand, the United Arab Emirates, and the United States (Table 1). During the period from 1997 to 2000, developed countries such as Canada, France, and Italy, the Philippines, and Saudi Arabia were added to it. Canada, France, the United Kingdom, and countries in the Middle East were added from 2001 to 2007, and Kuwait, Russia, Vietnam, and other countries were added from 2008 to 2014.

Regarding the South Korea network, Australia, China, Germany, Indonesia, Japan, Malaysia, Saudi Arabia, and Singapore, and the United States made up the network during all periods from 1995 to 2015. In the period from 1997 to 2000, developed countries such as Canada, France, and Switzerland, as well as Middle Eastern countries joined. From 2001 to 2007 and from 2008 to 2014, resource-rich countries such as those in the Middle East and Russia joined.

The goods transaction network shows that the three countries of Japan, China, and South

Korea have formed a network since 1995. In China, the number of network constituent countries has increased in recent years, while in Japan and South Korea, the number has been stable. China had an average of 10.3 networked countries from 1997 to 2000, but the number increased to 12.9 from 2001 to 2007 and 18.3 from 2008 to 2014. On the other hand, the network for Japan consists of 15 countries in all periods. For South Korea, the network included 14.5 countries since 1997, 13.9 countries since 2001, and 15.1 countries since 2008. This reveals that China has diversified its trade target countries since 2008, after the global financial crisis.

It can be seen that not only the three countries of Japan, China, and South Korea, but also the United States, form a network in the goods trading network, and Australia, Germany, and Malaysia also formed a network during the period 1997–2000.

3.2 Human Mobility Network of CJK Countries

Regarding China's human mobility network, the countries that make up the network during all periods from 1995 to 2015 are Japan, South Korea, Malaysia, Mongolia, Philippines, Russia, Singapore, Taiwan, and the United States (Table 2). Germany and the United Kingdom joined during the period 1997–2000, and Thailand and the United Kingdom joined in the period 2001–2007. Australia, Canada, Thailand, and Vietnam were added during the period 2008–2014. As reflected in the entire network, the number of countries with direct branches to China is smaller than in the case of goods transactions.

As shown in Table 2, for Japan, the countries that make up the network during all periods from 1995 to 2015 are China, South Korea, Taiwan, and the United States. Australia, Canada, and the United Kingdom were added during the period from 1997 to 2000, and Australia and the United Kingdom were added during the period from 2001 to 2007. Australia and Thailand were added during the period from 2008 to 2014. Compared to the case of goods transactions, Japan's network is characterized by a smaller number of constituent countries, and, like China, by a stable constituent country of the human mobility network.

The countries that comprise the human mobility network in South Korea during the entire period from 1995 to 2015 are China, Japan, the Philippines, Taiwan, and the United States. From 1997 to 2000, Russia, Singapore, Thailand, and the United Kingdom were added, and from 2001 to 2007, Malaysia, Russia, Singapore, and Thailand were added. Thailand will be added from 2008 to 2014.

It can be seen that Japan, China, and South Korea have formed the human mobility network since 1995. In addition, the number of member countries in the network has been increasing in China in recent years, while it has been decreasing in Japan and South Korea. China averaged 10.8 countries from 1997 to 2000, 11.1 countries from 2001 to 2007, and increased to 13.4

countries from 2008 to 2014. Japan has averaged 7.0 countries since 1997 and 6.7 since 2001, while it has decreased to 6.0 since 2008. South Korea has had 8.5 countries since 1997 and 8.6 since 2001 but has decreased to 7.4 since 2008. As the network of human mobility shows, external ties strengthened after the global financial crisis.

3.3 Correlation Coefficient of Similarity Between Two Networks of CJK Countries

The network similarity indicates the degree to which the factors formulated in the gravity model are reflected in the data, and the decrease in the similarity index is due to the network formation factors unique to goods transactions and human migration. This means that it is reflected more. Fig. 5 shows only the network of each of the three countries and calculates the index of similarity between goods transactions and human migration. From the values of the indicators, the transition of the indicators of similarity more strongly reflects the behavior of China. This is because the number of countries that make up the network in Japan and South Korea is stable in both goods transactions and human migration.

The value of the Chinese index shows that the similarity index increased after 2001, decreased from 2006, increased from 2009 to 2012, and then decreased until 2014. In addition, the current state of the network shows that economic factors strongly influenced the increase and decrease in external transactions, such as participation in the World Trade Organization since 2001 and the foreign expansion policy, and the effects of SARS. After that, the similarity decreased until after the global financial crisis, and the similarity index increased again during the expansion of the import value, and the factor of trade expansion due to economic reasons.

4. Concluding Remarks

The three countries of CJK have promoted trade and human exchanges with each other and have built a strong network. The current state of the network from 1995 to 2015 shows that China’s network formation as a rapidly growing emerging country is active and that the number of its constituent countries is expanding. The expansion of trade target countries along with economic growth gives consumers in China a variety of options, and the fact that there are many countries in which goods and human exchanges are normally active means that it contributes from an economic viewpoint. On the other hand, for countries with stable economies such as Japan and South Korea, a stable network of trade should be formed according to roles such as resources and consumer goods rather than the formation of a flexible network. It was also found that there is no significant change in the number of member countries with regard to human mobility.

In addition, we divided the target period from 1995 to 2015 into three periods based on the index of similarity between goods transactions and human exchange networks, and verified the

network constituent countries of each country and the background of the period. The verification results are as follows. First, in the period after 2008, including institutions after the global financial crisis, the number of member countries of both goods transactions and human exchanges increased in China, while the number of constituent countries in Japan and South Korea was stable or decreased in any network.

Although it was not explicitly stated by Japan and Korea, looking at the total number of constituent countries shows that the number will increase during the period following the Asian currency crisis and the global financial crisis. There is a phenomenon in which the network expands instantaneously. This means that in the case of goods transactions and human mobility, transactions with countries that had occupied a large proportion due to inertia up to that point will shrink, and the number of countries entering new networks will increase. Furthermore, while the number of member countries increases in both goods transactions and human exchanges, the indicator of similarity declines, which means that the attributes of new entrants differ between goods transactions and human exchanges.

We validate actual data for the period of recession shock. From the comparison of member countries in 1998 and 1999 and in 2009 and 2013, the increase in trade in goods was not previously included in the network in South America, Africa, the Middle East, and Eastern Europe. While other countries have entered, the network of human mobility has the characteristic that it is limited to those from countries in the Middle East and Eastern Europe.

With the spread of the new coronavirus, exchanges have stagnated in both aspects of goods transactions and human movement. In the future, when full resolution of the infectious disease is achieved, it is likely that recovery will occur in both goods transactions and human mobility. Under such circumstances, in countries such as China that form flexible and diverse networks, there are more options for players to make decisions than in countries that form stable networks such as Japan and South Korea. As a result, in many cases, the amount of trade and movement of people will be able to move toward recovery more flexibly.

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Tables and Figures

Table 1. Main Constituent Countries of the Goods Transaction Network for CJK

	CHN	JPN	KOR
1997-2000	Malaysia, France, Indonesia	Canada, France, Italy, Philippines, Saudi Arabia, Singapore, UK	Canada, France, Iran, Switzerland, United Arab Emirates, UK
2001-2007	Philippines, Malaysia, Thailand	Canada, France, Iran, Philippines, Qatar, Saudi Arabia, UK	Kuwait, Qatar, Russia, United Arab Emirates, UK
2008-2014	Brazil, Canada, Chile, France, India, Malaysia, Saudi Arabia, South Africa, Switzerland, Thailand	Canada, France Iran, Kuwait, Qatar, Russia, Saudi Arabia, Vietnam	Iran, Iraq, Kuwait, Qatar, Russia, United Arab Emirates
Total period	Australia, Germany, Japan, South Korea, Russia, Singapore, USA	Australia, China, Germany, Indonesia, Malaysia, South Korea, Thailand, United Arab Emirates, USA	Australia, China, Germany, Indonesia, Japan, Malaysia, Saudi Arabia, Singapore, USA

Table. 2 Main Constituent Countries of Human Mobility Networks for CJK

	CHN	JPN	KOR
1997-2000	Germany, UK	Australia, Canada, UK	Russia, Singapore, Thailand, UK
2001-2007	Thailand, UK	Australia, UK	Malaysia, Russia, Singapore, Thailand
2008-2014	Australia, Canada, Thailand, Vietnam	Australia, Thailand	Thailand
Total period	Japan, South Korea, Malaysia, Mongolia, Philippines, Russia, Singapore, Taiwan, USA	China, South Korea, Taiwan, USA	China, Japan, Philippines, Taiwan, USA

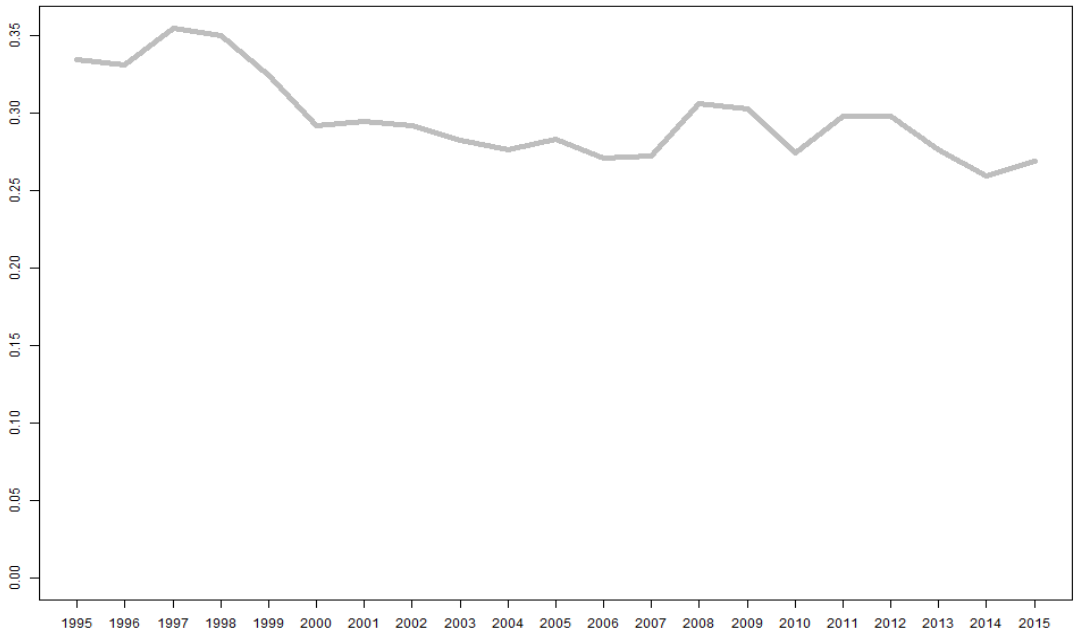

Fig. 1 Correlation Index of Network Similarity

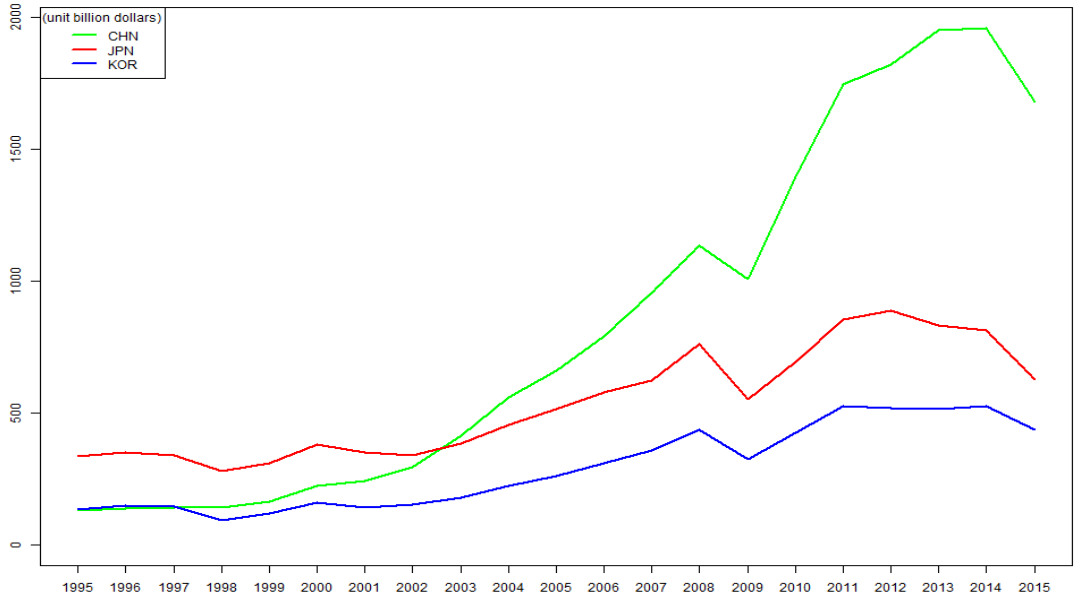

Fig. 2 Imports (Unit: Billion Dollars)

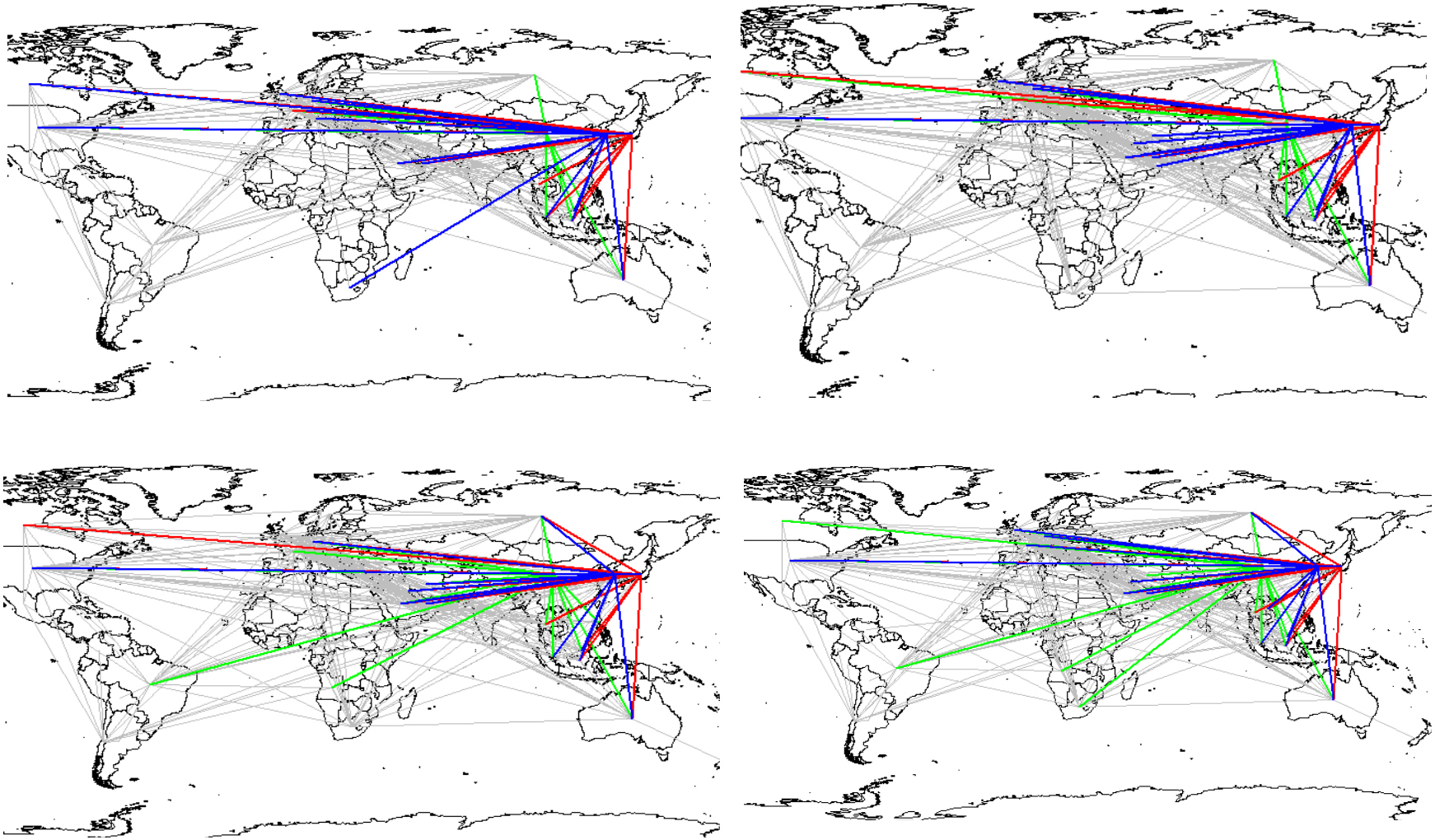

Fig. 3 Trade Networks for Imports
(Top left: 1997; Top right: 2001; Bottom left: 2008; Bottom right: 2014)

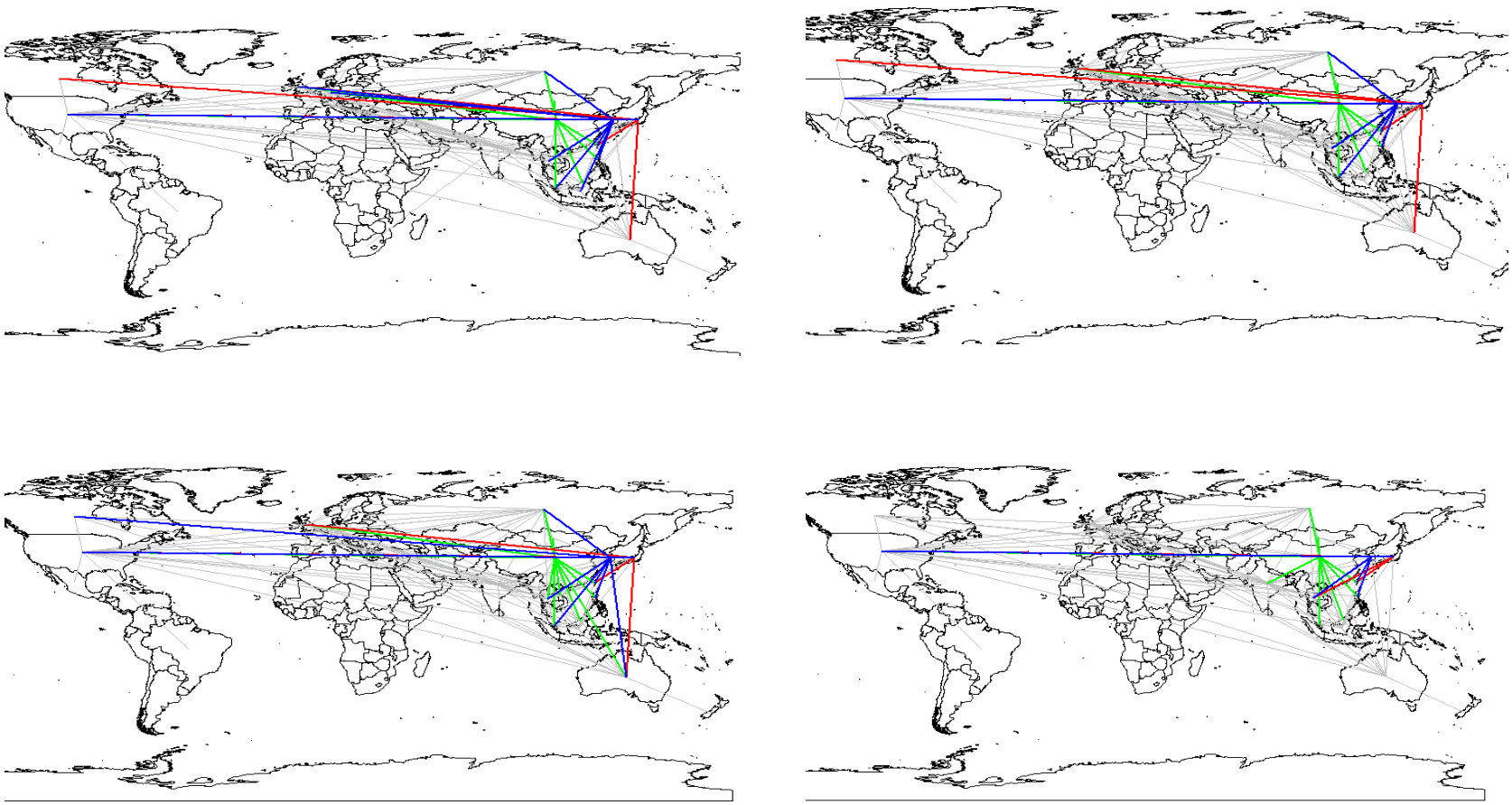

Fig. 4 Human Mobility Networks for Inbound Tourists
(Top left: 1997; Top right: 2001; Bottom left: 2008; Bottom right: 2014)

Fig. 5 Correlation Index of Network Similarity for CJK