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**Descriptive Analysis of the
Knowledge Network Formation in
East Asia**

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Abstract

This paper shows descriptively how the knowledge network in East Asia has been formed. In addition, the correlation between the knowledge network and economic growth is also examined. Evidence is provided to show that plugging into the knowledge network of developed countries could be a key for increasing innovativeness in a country.

Keywords: East Asia, Knowledge network, Patent data

JEL classification: O11, O40, O53

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I. Introduction

East Asian countries, particularly advanced Southeast Asian countries, are currently confronted with the challenge of the middle income trap.¹ East Asian countries have posted rather impressive growth rates since they initiated their development drive, as described by the World Bank (1993). However, the financial crisis that afflicted the region in 1997 seemingly changed the euphoria about their future growth performance. Even though these economies recovered rapidly from the aftermath of the financial crisis, they have started to have worries about their future growth performance. While these countries are growing at favorable rates, their growth rates have remained lower than in the pre-1997 period.

The middle income trap is typically defined as the difficulties associated with transforming the development path from input-driven to innovation-driven growth strategies. As early as 1994, Paul Krugman cautioned that much of the growth in East Asia was driven by increases in capital investment rather than from productivity growth. Unless these economies shift to a growth pattern that is based more on productivity growth, their growth will be slower in future (Krugman 1994). Countries such as Malaysia and Thailand are currently at the forefront of this challenge. Often the prescribed solution to their concerns is “to nurture innovation capabilities” through increases in R&D spending; more attention given to higher education, especially on research capabilities; greater availability of risk capital and so forth. While recognizing that these are valid policy recommendations based on the experiences of advanced countries, in this paper we investigate whether the development of innovation capabilities in these countries is related to the development of a “knowledge network” among themselves.

We are interested in the formation of a “knowledge network” as a possible conduit for the development of innovation capabilities in Southeast Asian countries, because these countries have relied on the formation of a “production network” as a way

¹ There is a growing interest in the analysis of the issues surrounding middle income traps. See for instance, Ohno (2009); Yusuf and Nabeshima (2009a; 2009b); Kharas and Kohli (2011); Felipe et al. (2012); Paus (2012); Im and Rosenblatt (2013); Kang et al. (2015).

to industrialize and to develop export-oriented industries. These countries grew as globalization was proceeding, international trade was expanding, and investments by multinational corporations (MNCs) were increasingly rapidly. Lowering of the trade costs (transportation and other costs associated with international trade) due to the advancement in transportation technologies and information and telecommunication technologies (ICT) led to the fragmentation of production across many countries. Industrial development in Southeast Asian countries was unique because these countries were active participants in the global production network.

East Asian countries, especially Southeast Asian countries, have taken advantage of growing international trade by switching from import substitution policies to export-oriented policies. With falling trade costs, these developing countries saw opportunities to participate in global supply chains by (gradually) liberalizing trade and investment. Through trade and investment liberalization, these countries were able to attract foreign direct investment (FDI) into their countries. This attraction of FDI was instrumental in making Southeast Asian countries part of a global production network.² By doing so, the industrialization of these countries was accelerated.

Baldwin (2012) explains that it is not a prerequisite for industrialization to establish supporting industries domestically in a way that the current developed countries experienced in the course of their development. With lowered transportation costs as well as timely communication enabled by ICT, a firm in a developing country can easily participate in parts of supply chains that fit into its own comparative advantage. Developing countries do not need to have the whole set of supporting industries to participate in manufacturing for export. If they can join production networks, it is much easier for developing countries to participate in manufacturing products and exporting than previously. Along supply chains, parent companies in developed countries or other participants in supply chains can offer advanced technologies, parts that cannot be procured domestically, markets and product quality management. Thus, these trade linkages are closely related to the flow of knowledge.

What we hypothesize in this paper is that because industrial development was greatly facilitated by the development of production networks in the region, a parallel

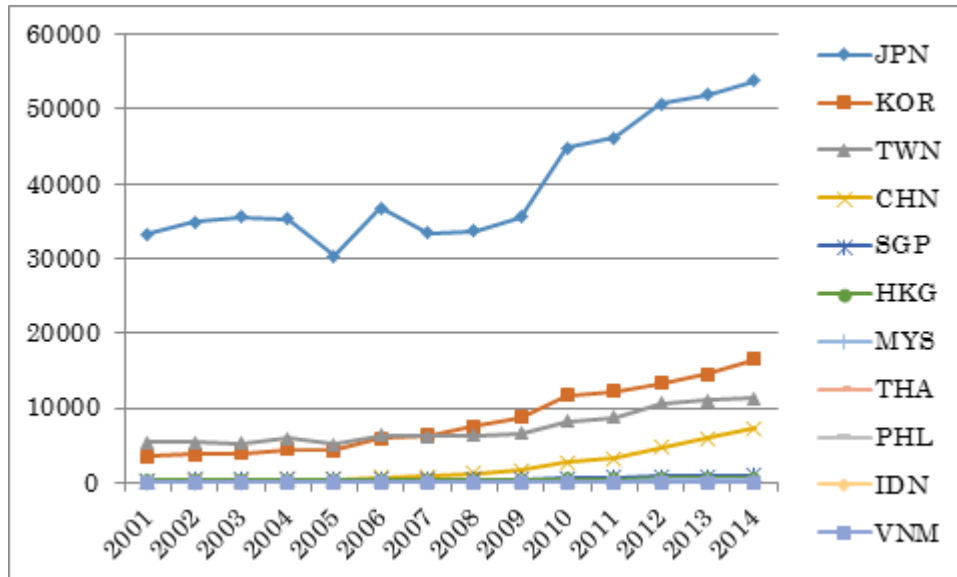
² See for instance, Kimura (2008).

development can be seen in the development of innovation. The growth patterns that Southeast Asian countries have taken are quite unique compared to other countries. They have taken export-oriented policies as a major pillar of their development strategies, complemented by the liberalization of trade and investment. This latter part of liberalization on investment, especially the attraction of foreign direct investment, is what distinguishes Southeast Asian countries from other countries in terms of their development strategy. For this reason, the development of innovation capabilities in these countries may take different paths from the experience of other countries, especially advanced countries.

East Asia consists of diverse groups of countries. In the context of the current paper, Japan is the leader in innovation among the countries in the region. Japan is followed by the second group of countries that consists of Korea, Taiwan, Singapore, and China. The third group of countries is the advanced ASEAN countries: Malaysia, Thailand, the Philippines, and Indonesia. The last group of countries is the CMLV countries: Cambodia, Myanmar, Laos, and Vietnam. To some extent, these groups of countries reflect the timing of the development, with China being the exception. China's rapid growth began only recently.

The difference in their innovation capabilities is quite apparent (see Figure 1). Figure 1 shows the number of patents granted by the US Patent and Trademark Office from 2001 to 2014. Clearly, Japan received the largest number of patents among East Asian countries, followed by Korea, Taiwan, and China (in order of the number of patents received).

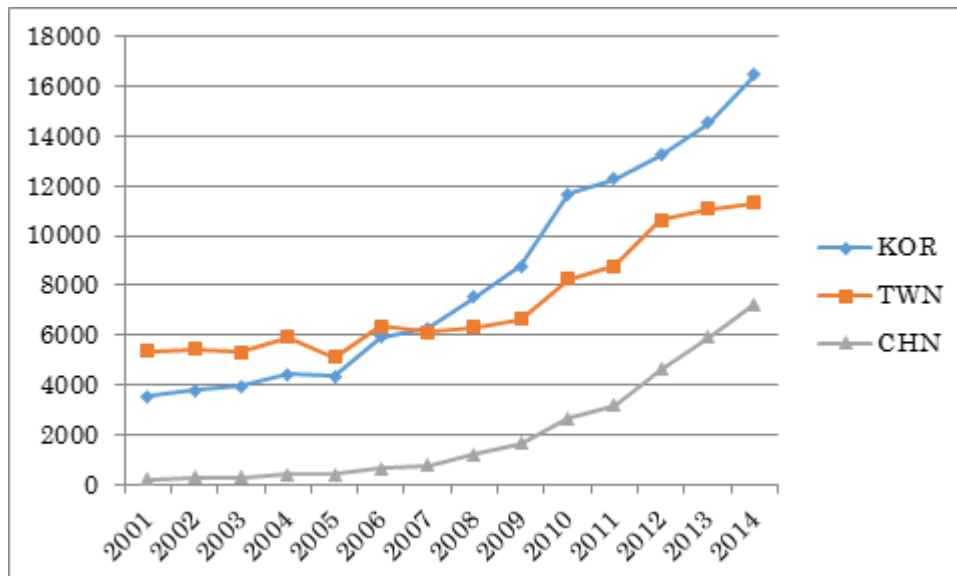
Figure 1. Patents granted to East Asian Countries, 2001-2014



Source: US Patent and Trademark Office

Figure 2 shows the patents granted to Korea, Taiwan, and China. From 2001 to 2006, Taiwan received more patents than Korea but their positions have reversed since then. China also saw a rapid increase in the number of patents granted during the post-2006 period.

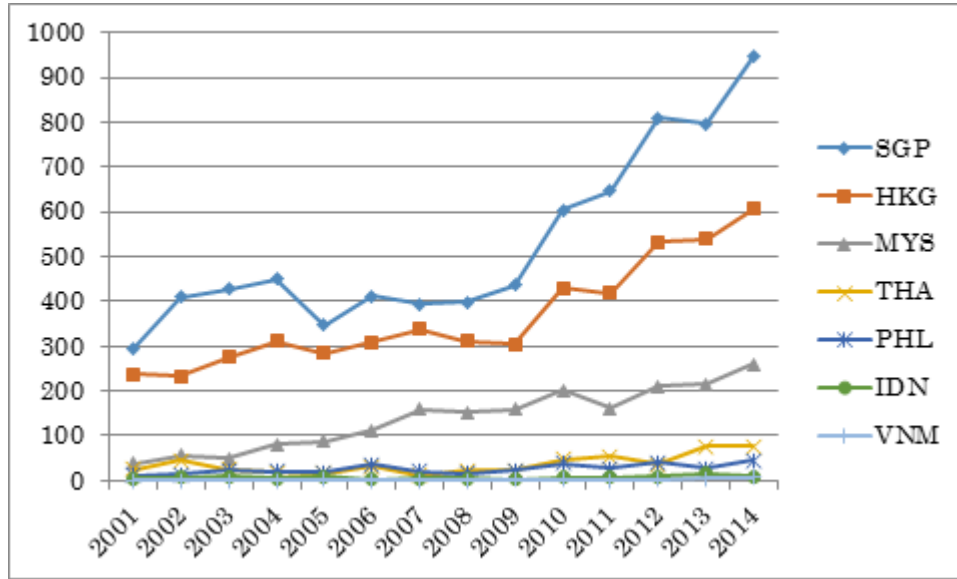
Figure 2. Patents granted to Korea, Taiwan, and China, 2001-2014



Source: US Patent and Trademark Office

Turning our attention to the remaining Asian countries, Singapore received the most patents among these countries (mostly Southeast Asian countries, except for Hong Kong), followed by Hong Kong (see Figure 3). Following these two city-states are Malaysia, Thailand, the Philippines, Indonesia, and Vietnam. There were no patents granted to Cambodia, Laos, or Myanmar³ during this period.

Figure 3. Patents granted to Southeast Asian countries, 2001-2014



Source: US Patent and Trademark Office

Clearly these three groups of countries differ in their innovation capabilities as measured by US patents. Our interest in this paper is to see whether these countries have also had different paths for knowledge network formation. We will examine the formation of the knowledge network through the citations that are made to these patents.

II. How the data was constructed

We retrieved patent data registered to the United States Patent and Trademark Office (USPTO)⁴ since 1976 from PATSTAT. In order to track international knowledge

³ There are four patents that were assigned to Myanmar before 2001.

⁴ There are two reasons for using US patents. First, we assume that because of the US

flows, we processed the patent data in three steps. The first step was to identify to which country a patent belonged. We used the country of origin of the applicant to determine the nationality of each patent. If a patent was filed by several applicants, we used the nationality of the first applicant.⁵ The second step was to measure the directions and amount of knowledge flow. We used patent citations as a proxy for knowledge flow. Patent citations have been widely used as a proxy for knowledge flow (Jaffe et al., 1993; MacGarvie, 2005; Hu, 2009; Kang, 2016). A patent document provides a list of citations on which new inventions in the patent document are based. If an applicant, say A, for a patent cites patents by an applicant, say B, we interpret this as a knowledge flow occurring from applicant B to applicant A. Since we use the country of origin of applicants, we can track international knowledge flow. The last step was to track change over time. Because of continuing patent applications under United States patent law, an identical patent may have different application dates. In order to avoid duplication, we arranged patent data to patent family data. By using the earliest priority year of each patent family, we were able to track changes in international knowledge flows over time.

Since it would require many pages to show all the results in this paper, we limit our descriptive analysis in two ways. Firstly, we limit our analysis to East Asia. The East Asian countries in which we have an interest here are the Northeast Asian countries (China, Hong Kong, Japan, Korea, and Taiwan) and Southeast Asian countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam). For comparison, U.S. and Europe are added as the two major economies. The 28 member countries of the European Union are defined as Europe. The remainder of the countries are categorized as ‘the Rest.’ Countries such as Australia, Brazil, Canada, Israel, and Russia are included. Secondly, we limit our analysis to several

market’s global significance, companies, even in developing countries, doing business in global markets apply for and register patents in the US. Second, patent data registered in USPTO result in more patent citations than patent data registered in other patent authorities because of the duty of candor.

⁵ The first applicant means the applicant whose applicant sequence number in PATSTAT is 1.

selected years. We show the results of 5-year summed international knowledge flows; 1981-1985, 1991-1995, 2001-2005, and 2006-2010.

III. Trends in overall knowledge network formation in East Asia

In this section we describe the patterns of knowledge network formation in East Asia during the period 1981-2010 based on the analysis of our patent dataset. The results are shown in the Appendix. The total flow of knowledge from country A to country B in a particular year is the sum of citations found in all country B patents of patents from country A in all industries. For convenience of presentation, we summarize citations for every five consecutive years to track changes in overall citations patterns over time. The 5-year intervals are chosen to show the dynamic in the formation of the knowledge network over time.

Based on the data analysis, the following major patterns of knowledge network formation emerge in East Asia during 1981-2010:

- (i) More advanced countries tend to cite patents from more countries;
- (ii) More advanced countries tend to cite other countries' patents earlier;
- (iii) All the countries tend to cite from more countries over time;
- (iv) The order of partner acquisition is similar for all countries;
- (v) The US, EU, Japan and the Rest emerge as the four knowledge hubs, whose patents East Asian countries start citing first. Over time, the flow of citations of the patents from these hubs increases and extends to citations of patents from other East Asian countries.

The remainder of this chapter explains the above patterns in detail, accompanying the description with the graphs for a few selected countries.⁶

⁶ We do not show the graphs for all the countries in our dataset due to limited space for presentation. The additional graphs are available upon request.

Brunei, Cambodia, Laos and Myanmar are four countries from the original group of East Asian countries which hardly had any patents registered in the US during the period 1981-2010. The only exception observable in our database of patent citations is a patent from Canada in 2007 (for convenience of presentation combined with Australia, Brazil, Canada, Israel, and Russia in “the Rest”) citing a US patent originating from Myanmar in 1991. Brunei, Cambodia, Laos and Myanmar are therefore excluded from further analysis of the trends in the East Asian knowledge network formation.

Based on the analysis of patent citations, the US, EU, Japan and the group of countries combined as the Rest emerge as the primary knowledge hubs for the East Asian countries in our group. Almost all East Asian countries started citing patents from these four knowledge hubs as early as 1981-85. The only two exceptions are Indonesia, which began to cite from them one decade later, in 1991-95, and Vietnam, which had its first citations of patents from these four centers as late as 2001-05. Malaysia and Thailand also started citing from the group of countries comprising the Rest one decade later, in 1991-95, compared to their other East Asian neighbors.

The US, EU, Japan and the Rest have cited each other’s patents from the early 1980s, the beginning of our data period. During the same period, all of them were also citing patents from many East Asian countries. In particular, during 1981-85 US patents cited from the largest number of East Asian countries, in fact from all the East Asian countries in our group. Europe cited patents from all the countries in the group except for Singapore and Vietnam. Japan further did not include citations of patents originating from Thailand during this period. The group of countries combined in the Rest cited from the lowest number of East Asian countries during 1981-85, also including no US patents originating in Singapore.

By 1991-95 all four knowledge centers were already connected to all East Asian countries in our dataset, except for Vietnam in the cases of the US, Japan and the Rest. They all connected to Vietnam in the following decades, all forming the most extensive citation network observed within our group, citing patents from all 14 countries by 2006-10.

While these more advanced countries were already connected to each other and all except one East Asian country in our dataset by 1991-95 (US patents originating in

Vietnam were not cited before 1991-95), the countries in East Asia all had fewer partner countries during the same period.

In particular, more advanced countries within East Asia, such as Hong Kong, Korea, Taiwan, and Singapore were connected to 7-9 countries during 1991-95. Less advanced East Asian countries had fewer citation partners in the same period: China and Malaysia had six partner countries, Thailand and Indonesia cited from four countries, the Philippines cited only from three countries, while Vietnam cited no patents at all until a decade later, in 2001-05, when it first connected to the four knowledge hubs.

Compared to Vietnam, Thailand, Indonesia and the Philippines were citing patents from seven relatively more advanced countries by 2001-05. They still all had fewer connections during the same period compared to their more advanced East Asian neighbors. In particular, Hong Kong, Korea, Taiwan, Singapore, Malaysia, and China already cited patents from 10 to 12 countries, commonly excluding Vietnam, Indonesia or the Philippines.

By 2005-10, Korea and Taiwan connected to all the countries in our group, China and Singapore connected to all the countries except for Vietnam, while the rest of the East Asian countries still had 2-3 links missing, and the Philippines and Vietnam still lacked four links.

IV. Trends in knowledge network formation in East Asia by Industries

In this section we describe the knowledge flows in two specific industries, the computer industry and the transport equipment industry.

The Computer industry is chosen for analysis as it was by far the most dynamic industry during the period analyzed. Most of the world's innovation was happening within the Computer industry since the 1980s, and as a result the industry accumulated the largest number of patents.

The Transport Equipment industry is chosen for analysis because it was and continues to be particularly important for the development of East Asia, both from the supply side and demand side perspectives. Many countries in the region are part of the worldwide transport equipment supply chain, supplying parts for motor/auto vehicles and railroad equipment. Moreover, given the poor public infrastructure in many

countries of the region, the motorcycle is the transportation mode in greatest demand in the least developed countries of the region such as Vietnam, Cambodia and Thailand.

Computer Industry

In this section we describe the observed trends in East Asian knowledge flows during the 1981-2010 period within the Computer industry. We retrieved patents in IPCs belonging to Division 26 (Manufacture of Computer, Electronic and Optical Products) of NACE Rev. 2 (Van Looy et al., 2014).

The US, EU, Japan and the Rest started citing each other's patents in the Computer industry from the early 1980s. Japan, in addition to citing from the other three knowledge hubs, also cited patents from Korea and Hong Kong in the same period. Korea and Hong Kong are the only two other countries which cited patents from other countries in our group in 1981-85 (Korea-originating patents cited US and EU patents, and patents from Hong Kong cited Japanese patents). The other countries in East Asia had no patent citations during 1981-85.

During 1991-95 Japan was already citing patents from all but four East Asian countries (i.e. Vietnam, Thailand, the Philippines and Indonesia), while drawing most of its knowledge in the Computer industry from the US. The other three knowledge centers had fewer partner countries in East Asia compared to Japan. In particular, the US cited patents from China, Hong Kong, Korea, Taiwan and Singapore in addition to the other three knowledge hubs. Europe cited from all the same countries as the US, except for Hong Kong. The group of countries combined in the Rest cited only from the other three knowledge hubs up until 1991-95, seemingly yielding its potential position as another knowledge hub for the Computer industry.

Korea, China, Hong Kong, Singapore and Taiwan are the only other countries which had any citations of US patents from any of the countries in our group in the period 1991-95. Korea had the largest number of partners among East Asian countries, citing patents from all four knowledge hubs plus Hong Kong and Taiwan. Singapore and Hong Kong were only connected to the four major knowledge centers at that time, while Taiwan and China only cited patents from two (i.e., Japan and the US) and one (i.e., Japan) partner countries, respectively.

By 2001-2005 all the countries in our group except for Indonesia, the Philippines and Vietnam had joined the network of knowledge flows in the Computer industry. The US, EU, Japan and Korea were the most active countries in this period, with most of the knowledge flowing between the US and Japan, and the EU and Korea drawing most of their knowledge in the Computer industry from the US and Japan. All these knowledge centers were connected to at least nine other countries within this period. Taiwan is the only other country which had ten partners at this time, seemingly emerging as another knowledge hub for the Computer industry, with most of its knowledge traveling from the US. Singapore, Hong Kong and China each had eight partners, Malaysia had seven partners, and Thailand had five partner countries in 2001-05.

In the 2006-10 period, the US, EU, Japan and Korea significantly intensified knowledge flows between each other, with most of the cross-citations occurring between the US and Japan. Patents originating from Taiwan also included significantly more citations from these two countries, while China significantly increased its citations from the US. Singapore, Hong Kong, Malaysia and Thailand all increased the number of its citation partners to at least ten countries. Indonesia, the Philippines and Vietnam all joined the knowledge network in the Computer industry by this time, citing from at least six other partner countries, while still excluding each other's patents.

Transport Equipment Industry

In this section we describe the trends in knowledge flows within East Asia for the Transport Equipment industry during the period 1981-2010. We retrieved patents in IPCs belonging to Division 30 (Manufacture of Other Transport Equipment) of NACE Rev. 2 (Van Looy et al., 2014).

The four knowledge centers, The US, EU, Japan and the Rest were all citing each other's patents from within the Transport Equipment industry starting from 1981-85. No other country in the group had any citations of US patents within that period. By 1991-1995 Korea started to cite US patents originating in Japan and the US, while the four knowledge hubs continued to cite only each other's patents.

By 2001-05, China, Taiwan, Hong Kong and Singapore joined the knowledge network in the Transport Equipment industry. Among these four countries, China was

drawing knowledge from the largest number of countries, the four knowledge hubs plus Taiwan, and on par with Japan, which also had five partner countries during that period. The EU and US had seven partners each while the Rest had six. Taiwan had four partners, while Singapore and Hong Kong had only two partners each.

During the 2006-10 period, the four knowledge hubs continued to cite from the largest number of partners (the EU from ten countries, the US from nine countries, Japan from eight countries, and the Rest from seven countries). China, Taiwan and Korea had six citation partners each. Hong Kong and Singapore were only citing from the four knowledge hubs up to this period. Malaysia and Thailand are the only two other countries that joined the knowledge network in the Transport Equipment industry up to and including the period 2006-10, when Malaysia started citing from the US and Thailand began to cite from Japan and the EU.

Vietnam, the Philippines and Indonesia had no patent citations from the other countries in the group during the whole period 1981-2010.

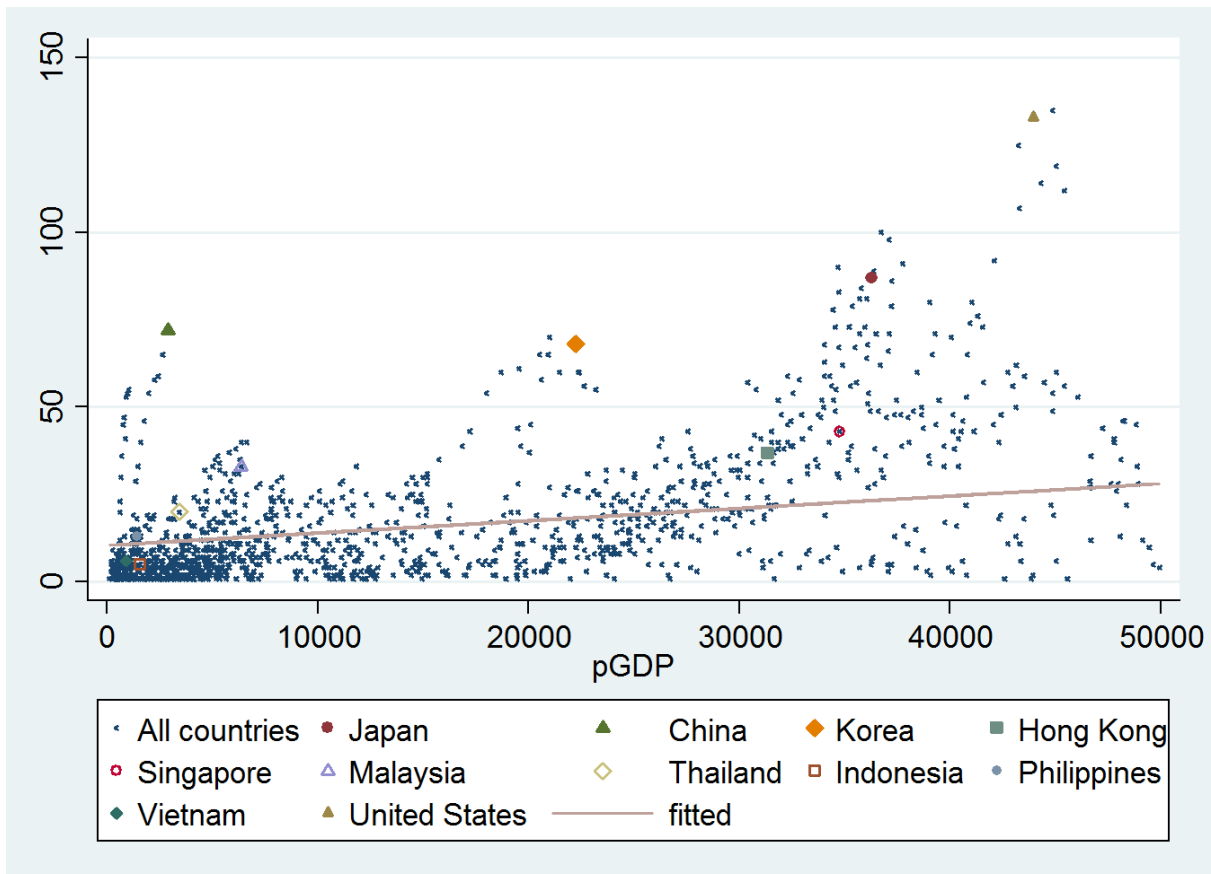
V. Future of Knowledge Network

In the previous section, we noted that East Asian countries tend to cite from more countries as they develop their innovation capabilities. Typically, they cite from the most advanced countries first, then from other countries. Similarly they are cited by more countries. What are the characteristics of these East Asian countries compared to other countries? Figure 4 is a graphic representation of the relationship between the number of countries that a country cites and per capita income (Figure 5 for cited case). The trend line was drawn using a simple regression with the number of countries as the dependent variable, and per capita GDP as the independent variable. As one would expect, the slope of the trend line is positive. Higher income countries tend to cite patents from more countries, which is consistent with the figures presented in the previous section. What this graph points out is that the US (included as a reference point), Japan, Korea, and China seem to belong to the same group. Perhaps we can call them “Highly Innovative Countries.” If we connect the points for these countries in 2010, the line is well above the trend line. Since these countries tend to cite from more

countries, given their income level, there might be something special about them. What is notable is China, which stands out strongly.

The next group is Hong Kong, Singapore, Thailand, and Malaysia. They are slightly above the trend line, suggesting that they are marginally better than other countries. These are followed by Indonesia, the Philippines, and Vietnam. They are clustered around the trend line. In Figure 4, the Philippines is slightly above the trend line, whereas Indonesia and Vietnam are below the trend line.

Figure 4. The relationship between the number of citing countries and per capita GDP, restricting the income to less than \$50,000 and only 2010 data for East Asian countries (1981-2010, 5-year intervals)



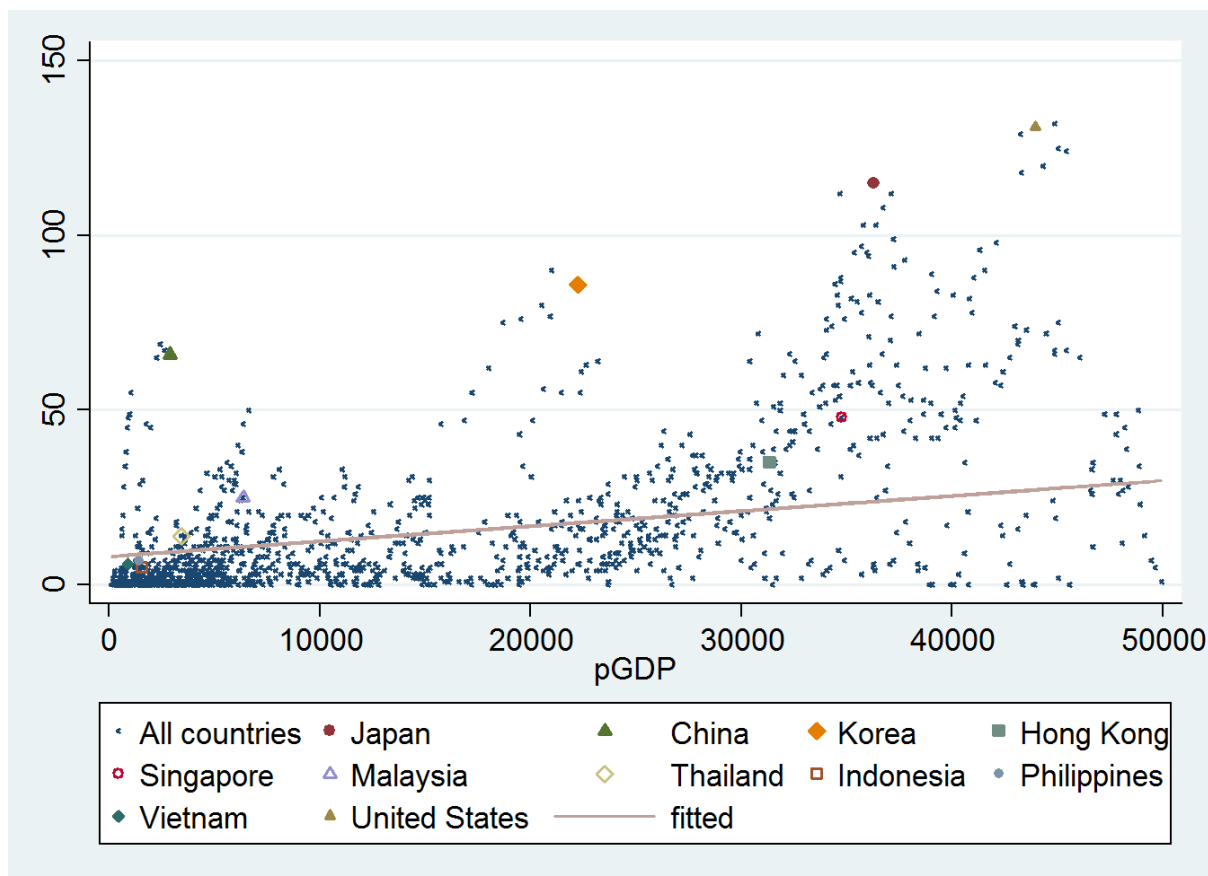
Source: created by the author using PATSTAT data

Note: The trend line was drawn with based on a simple regression with the number of citing (cited) countries on per capita GDP. Per capita GDP is measured in constant 2005 US\$. The data on per capita GDP was obtained from the World Bank's

World Development Indicators. The citing and cited figures are from PATSTAT. There is no data for Laos and Cambodia. As there were only a few data for Myanmar, it was excluded from the graph.

Figure 5 shows the relationship between the number of countries by which a country is cited and per capita income. The groupings of East Asian countries are the same for the citing case. Japan, Korea, and China (and the US, indicated here as a reference point) stand out. Their patents are cited by proportionally more countries, given their income level. This suggests that the quality of their patents may be higher than for patents from other countries. The second group of countries is Hong Kong, Singapore, Malaysia, and Thailand. They are slightly above the trend line. Finally, Indonesia, the Philippines, and Vietnam lie below the trend line.

Figure 5. The relationship between the number of cited countries and per capital GDP (1981-2005, 5-year intervals)



Source: created by the author using PATSTAT data

Note: The trend line was drawn based on a simple regression with the number of citing (cited) countries on per capita GDP. Per capita GDP is measured in constant 2005 US\$. The data on per capita GDP was obtained from the World Bank's World Development Indicators. The citing and cited figures are from PATSTAT. There is no data for Laos and Cambodia. As there were only a few data for Myanmar, it was excluded from the graph.

Figure 4 and Figure 5 point to a consistent pattern. China, Korea, and Japan seem to be similar to the United States, arguably the most innovative country. Their innovation efforts are based not only on their domestic resources, but integrate new ideas from a variety of countries. Furthermore, their patents tend to be cited by more countries compared to other countries at the same income level. This suggests that the

quality of their patents may be high. Following these high-performing countries are Hong Kong, Singapore, Malaysia, and Thailand. Two of them, Hong Kong and Singapore (both city-states) were successful in achieving high-income status, whereas Malaysia and Thailand are trapped in the middle income trap. They appear to have the capability to integrate new ideas from other countries, but are not doing so as much as the forerunner countries, China, Korea, and Japan. It will be interesting to see whether these countries can emerge as innovative countries and escape from the middle income trap. The third group of countries - Indonesia, the Philippines, and Vietnam - is still quite immature in terms of innovation capabilities and they are not well connected with innovation efforts in other countries. This is understandable if one assumes that gathering information about what is happening in foreign countries requires additional capabilities.

In this paper we have examined the trend in knowledge network formation and the correlation between citation behaviors and per capita income. As globalization proceeds, so do innovation activities. In the past growth strategy, being plugged into production networks was considered to be instrumental in supporting high growth rates in these East Asian countries. Looking into future, it may also be the case that being a part of a knowledge network could influence whether these countries can emerge as innovative economies or not. Continuing research in this area is critical to assess their growth prospects, and for some of the countries, whether or not they can escape from the middle income trap. In addition, while we have simply analyzed the correlation between knowledge network formation and per capita income in this paper, further research in this area is needed to clearly establish the causal linkages between the two.

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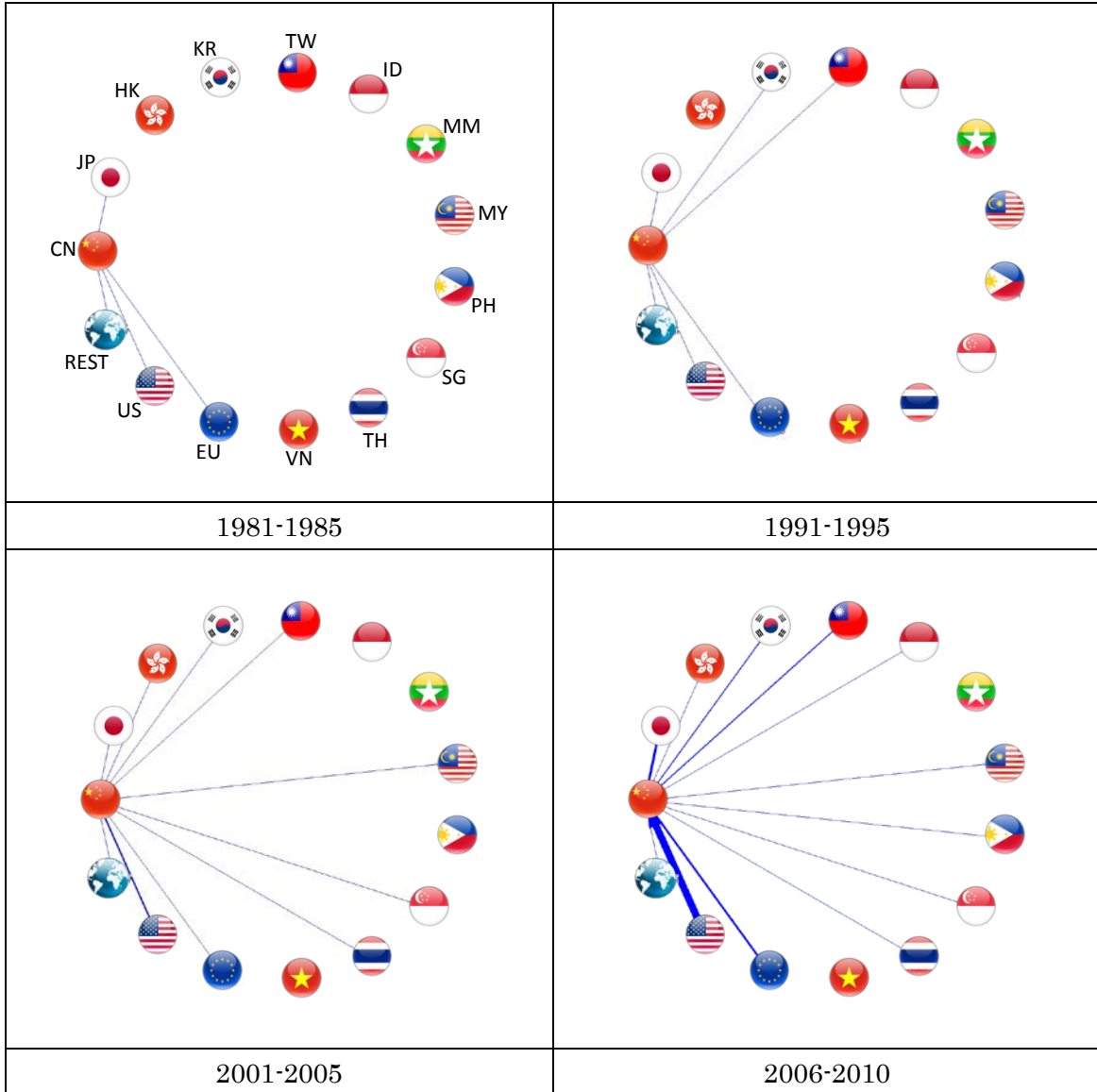
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Appendix:

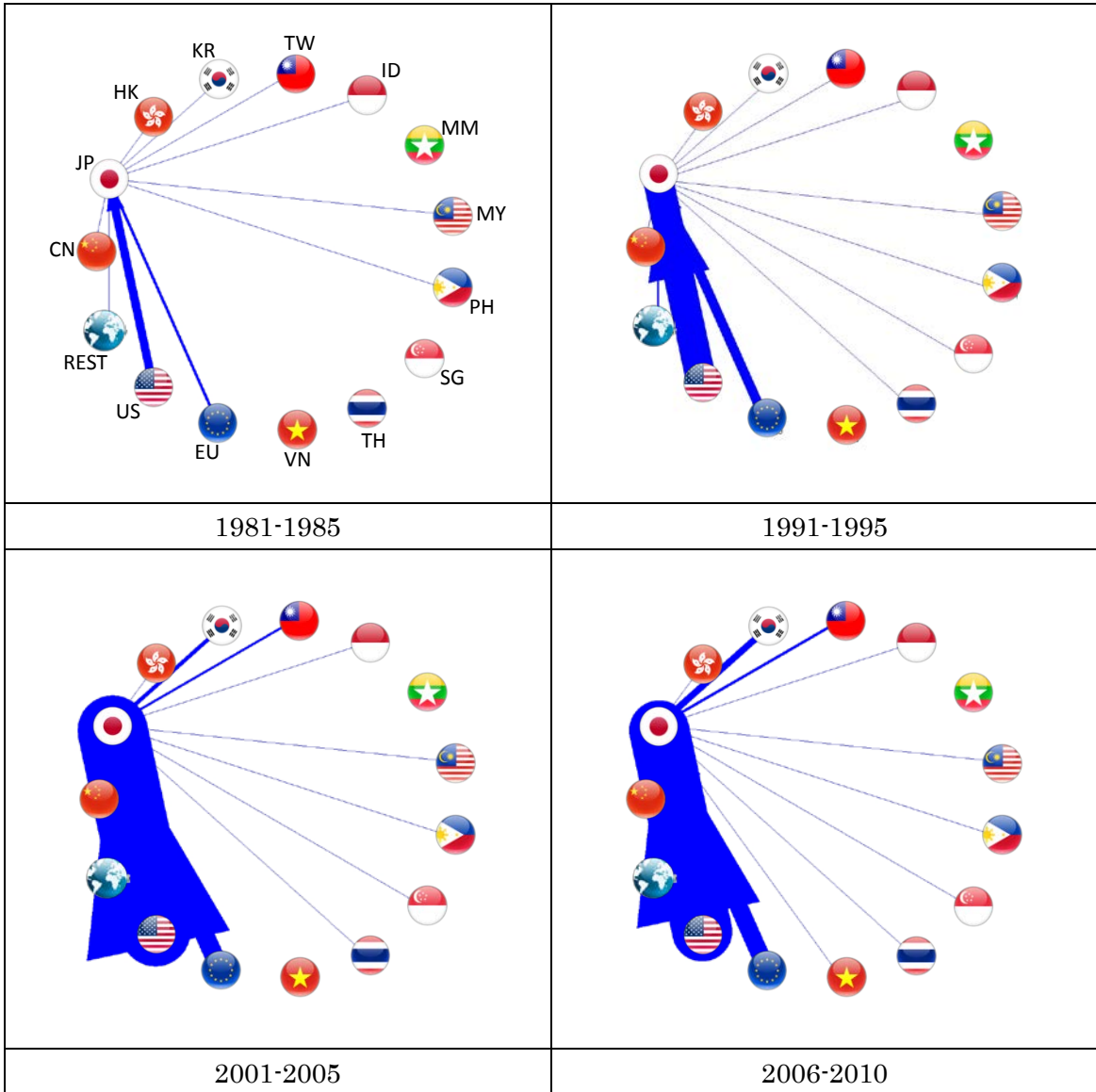
A1. All industries

North East Asia

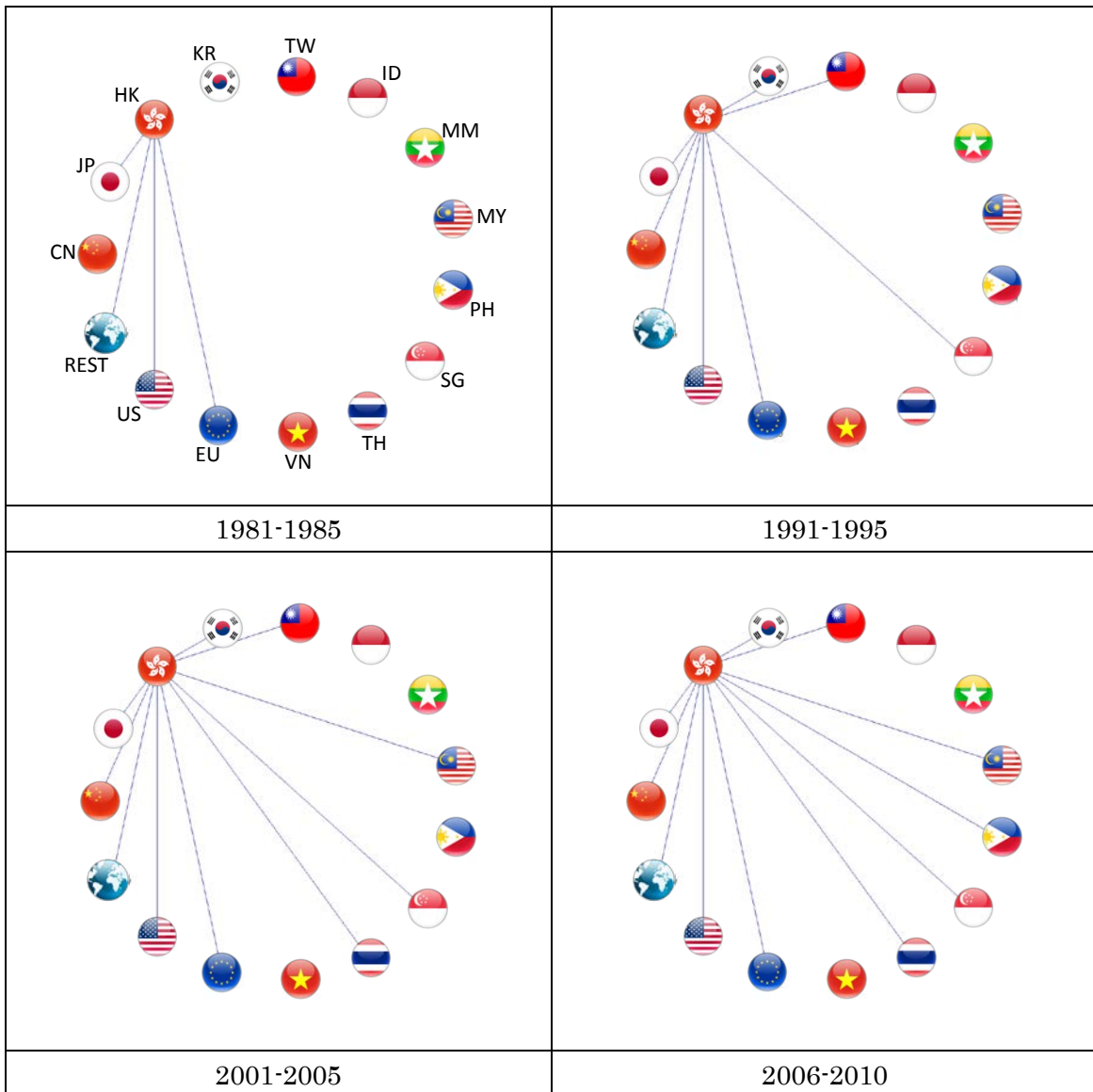
China



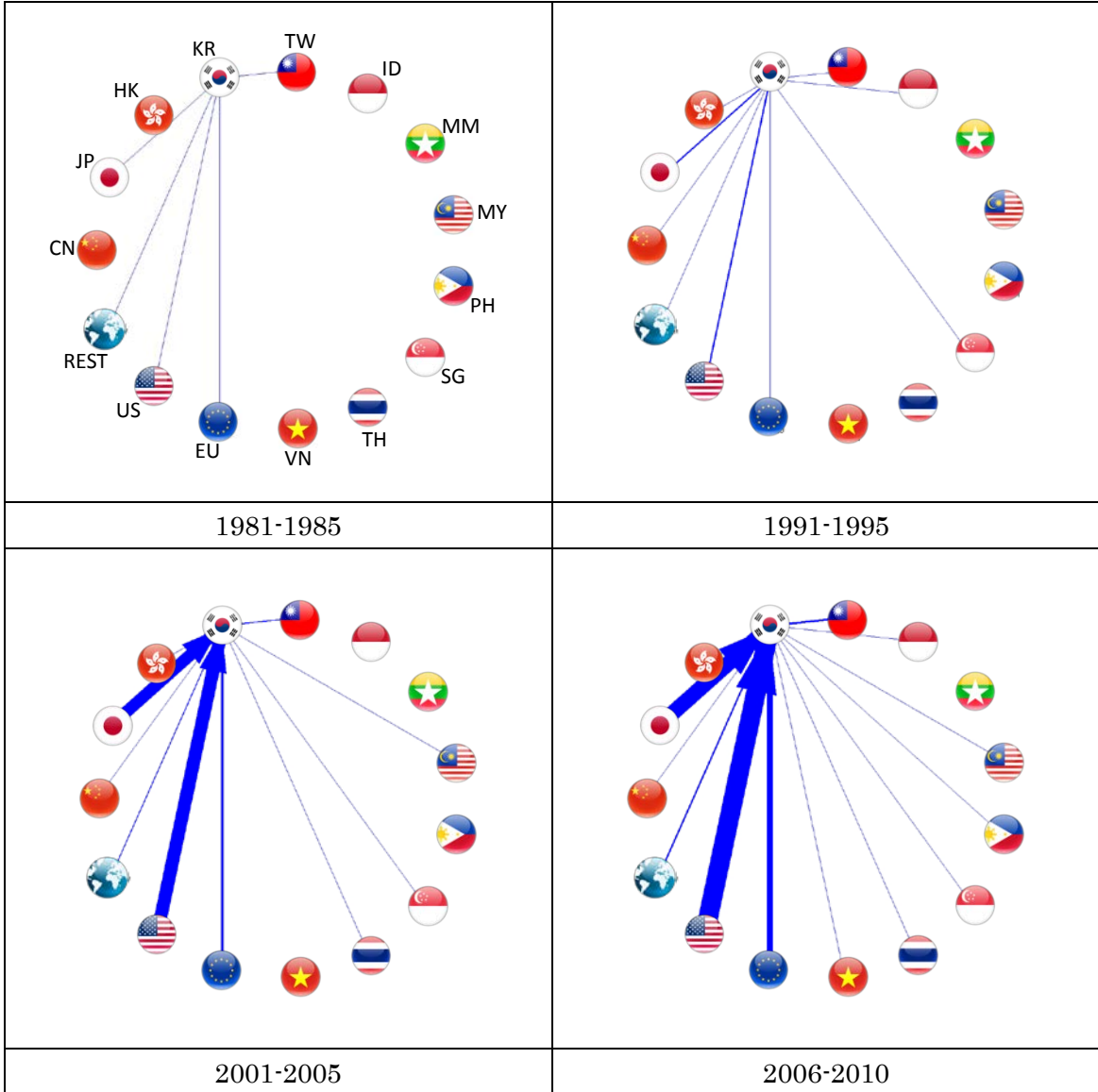
Japan



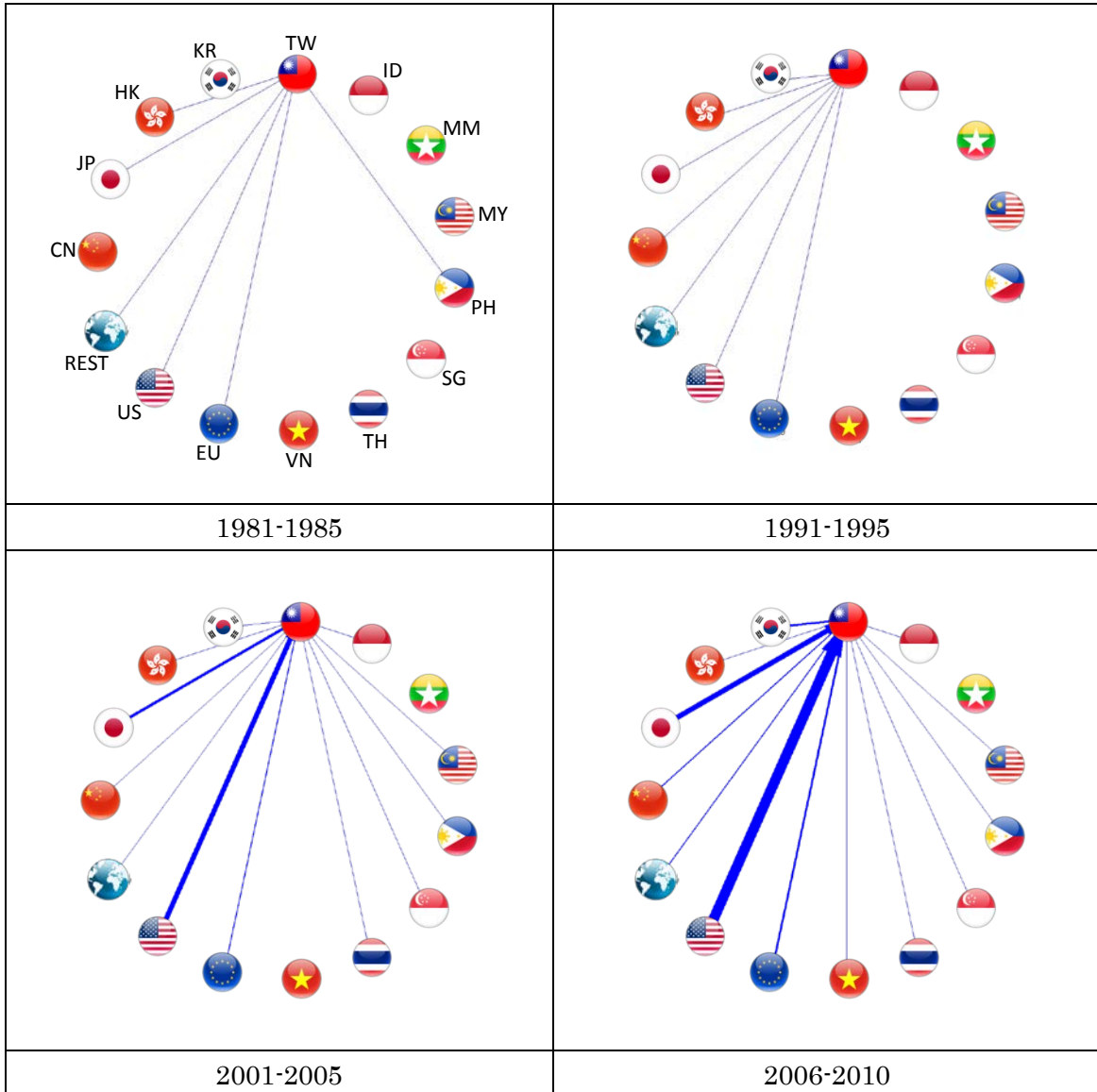
Hong Kong



Korea (Republic of)

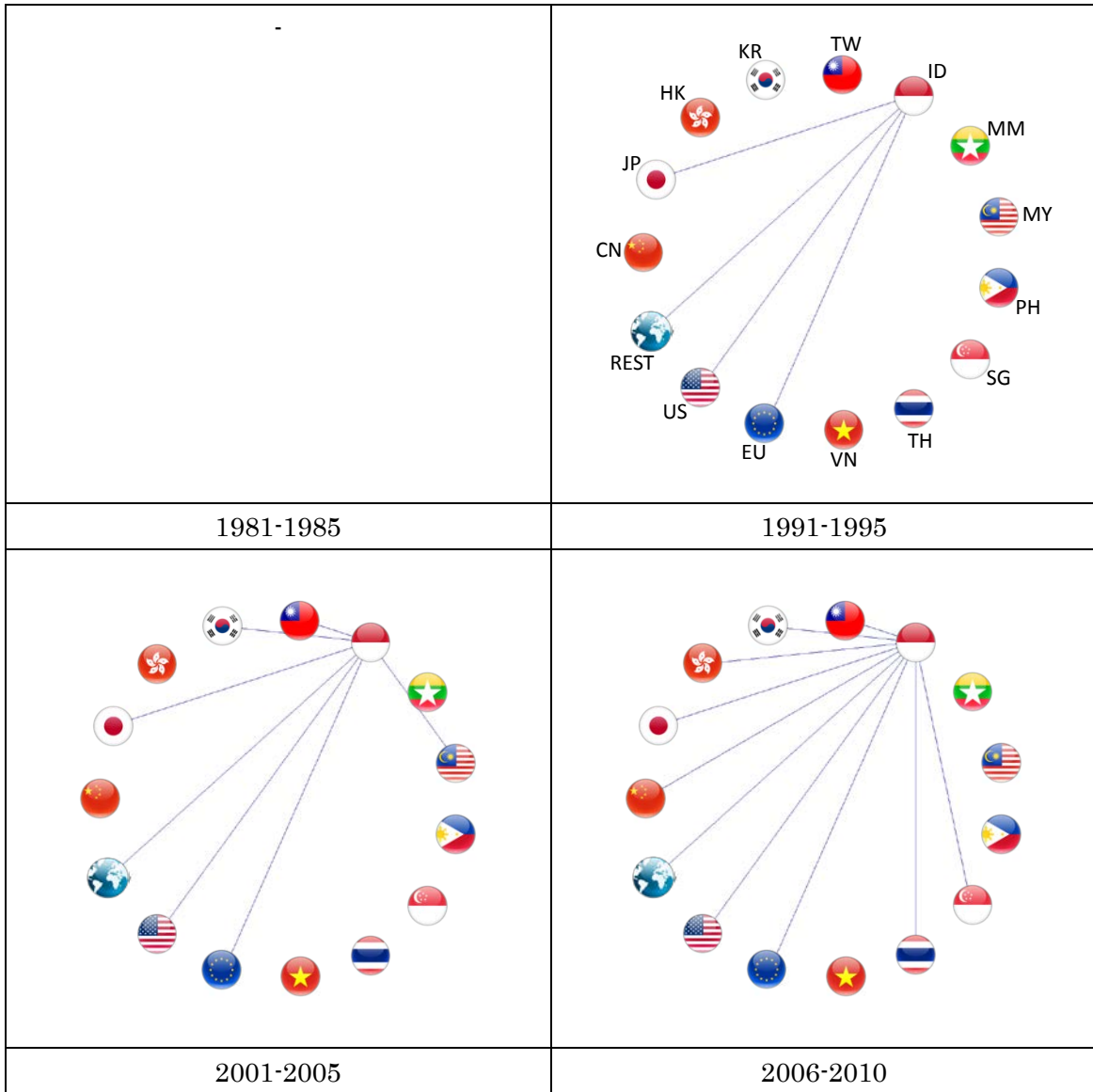


Taiwan

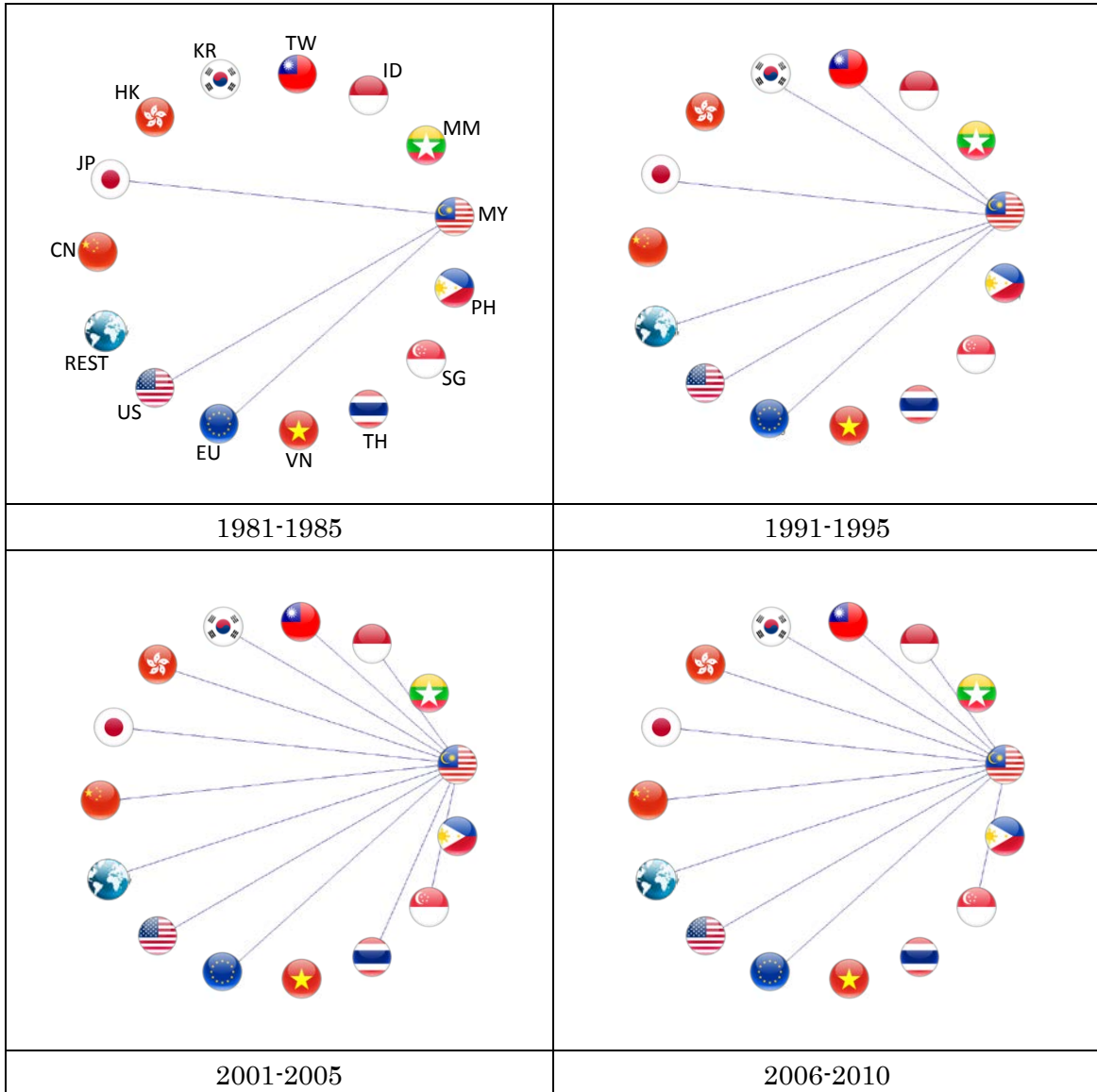


South East Asia

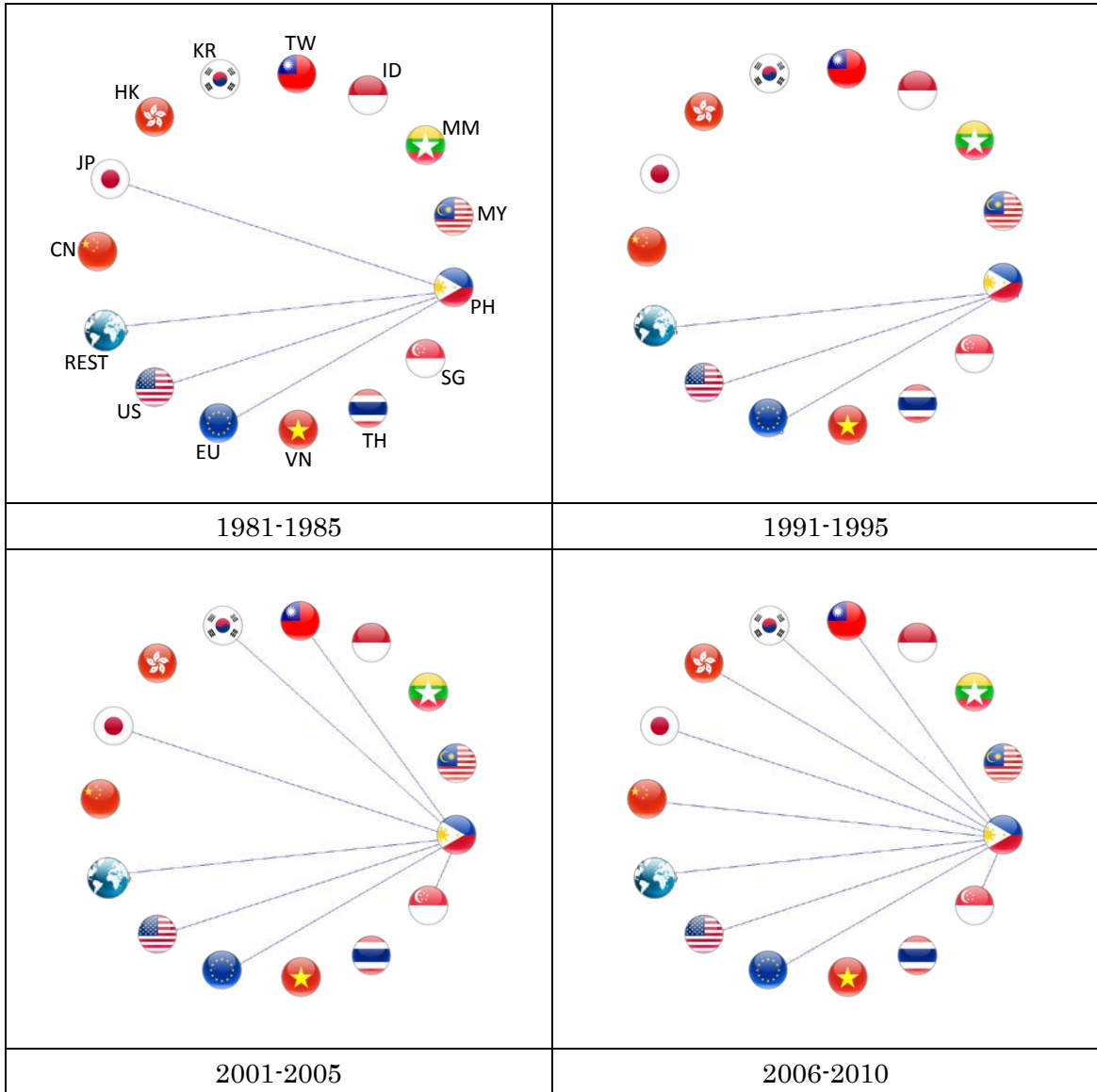
Indonesia



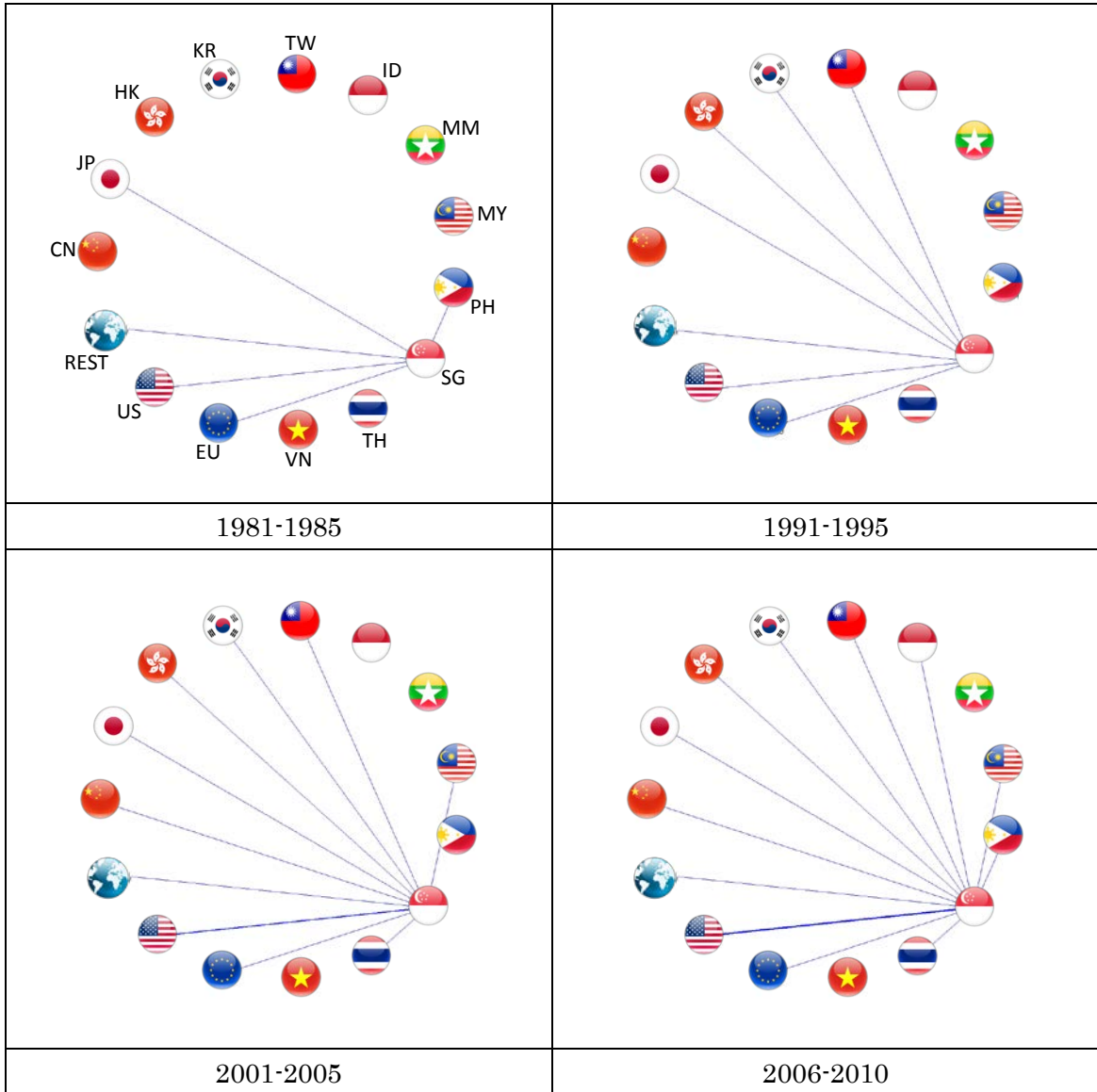
Malaysia



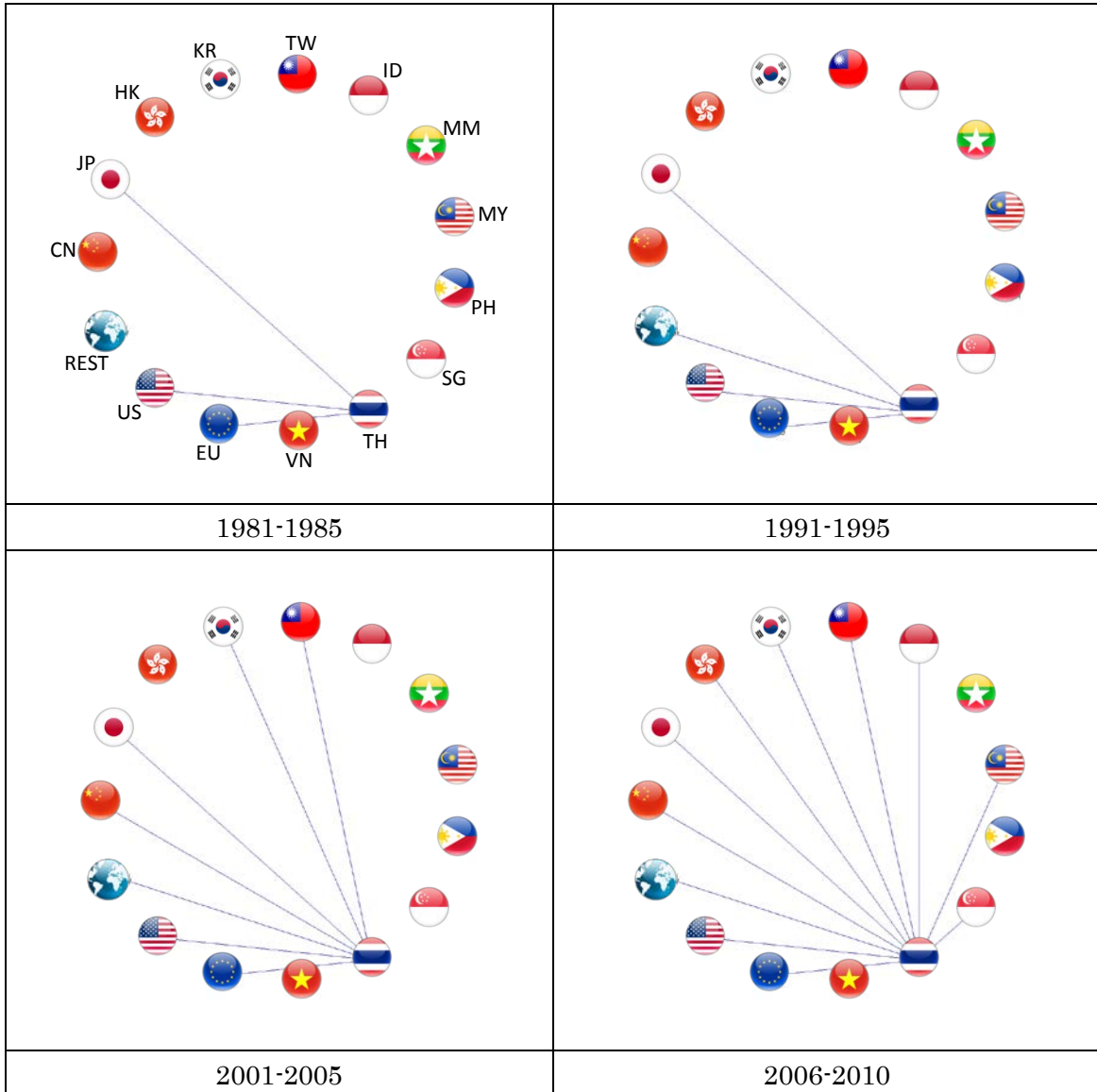
Philippines



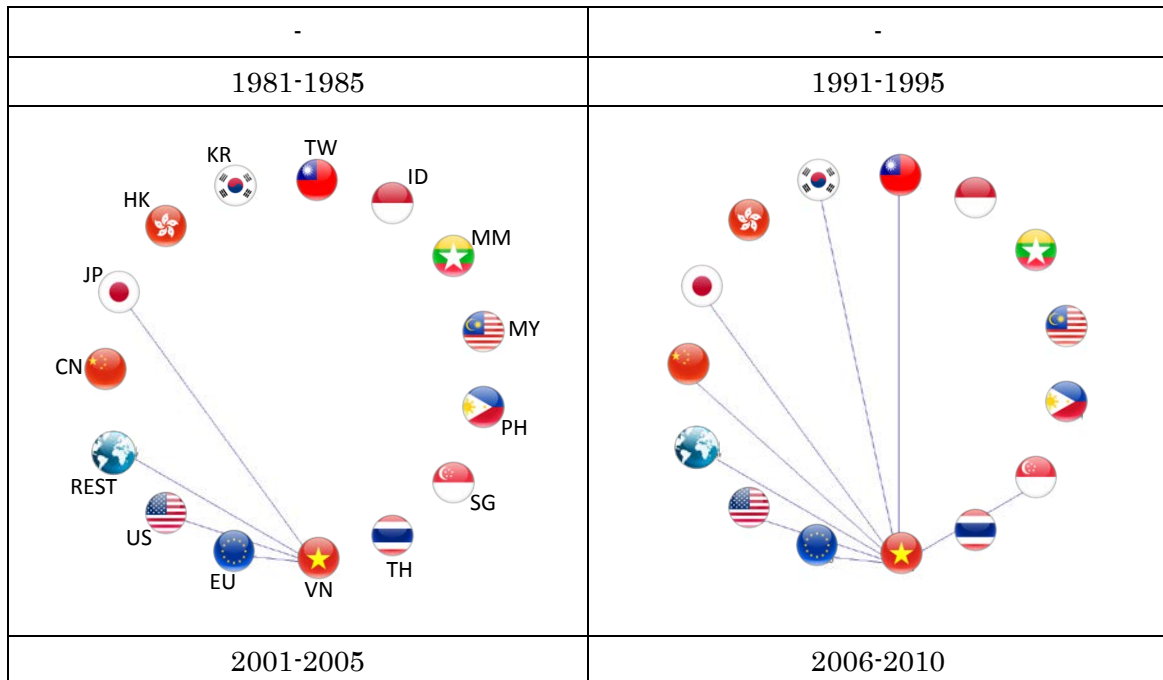
Singapore



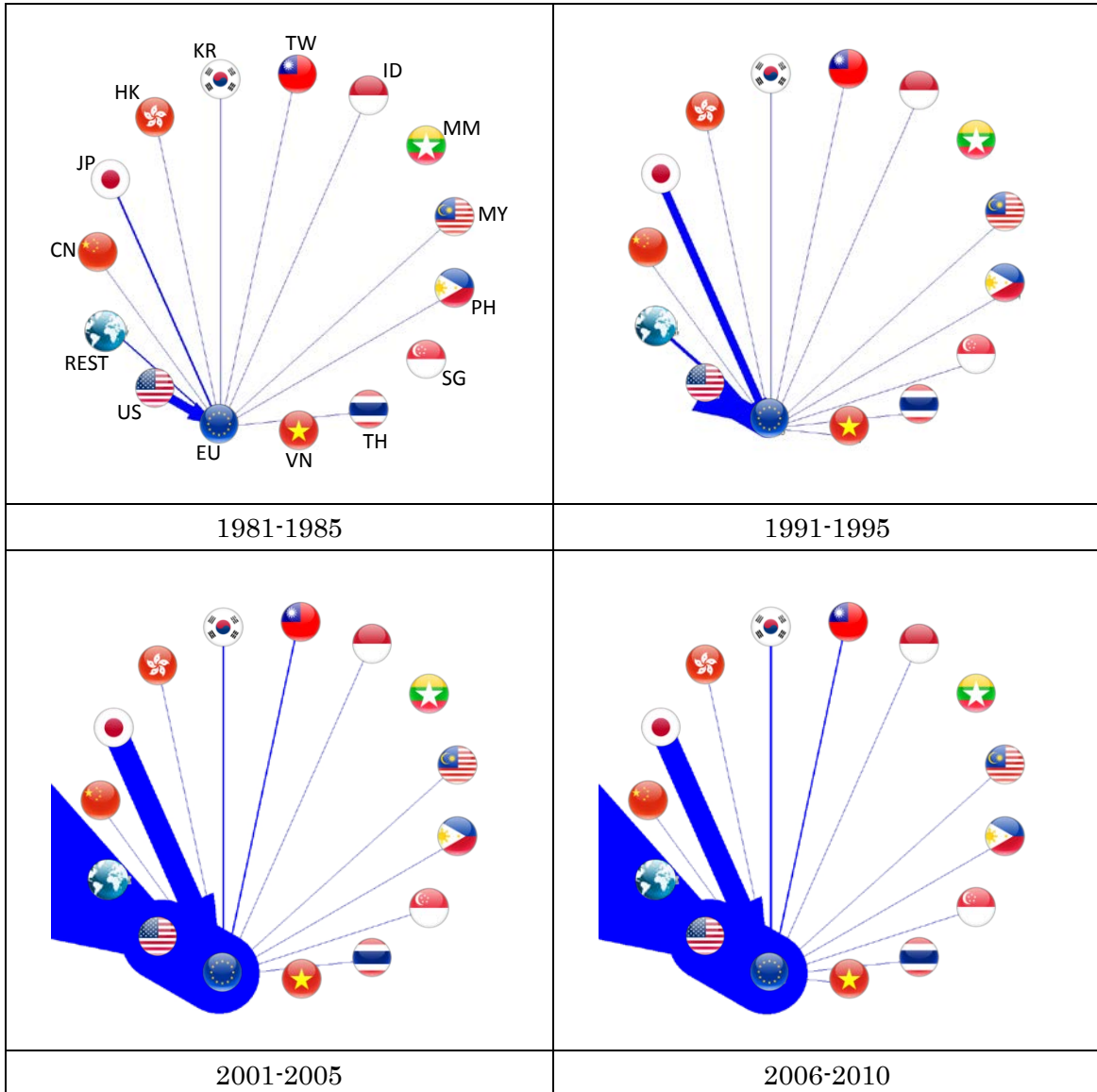
Thailand



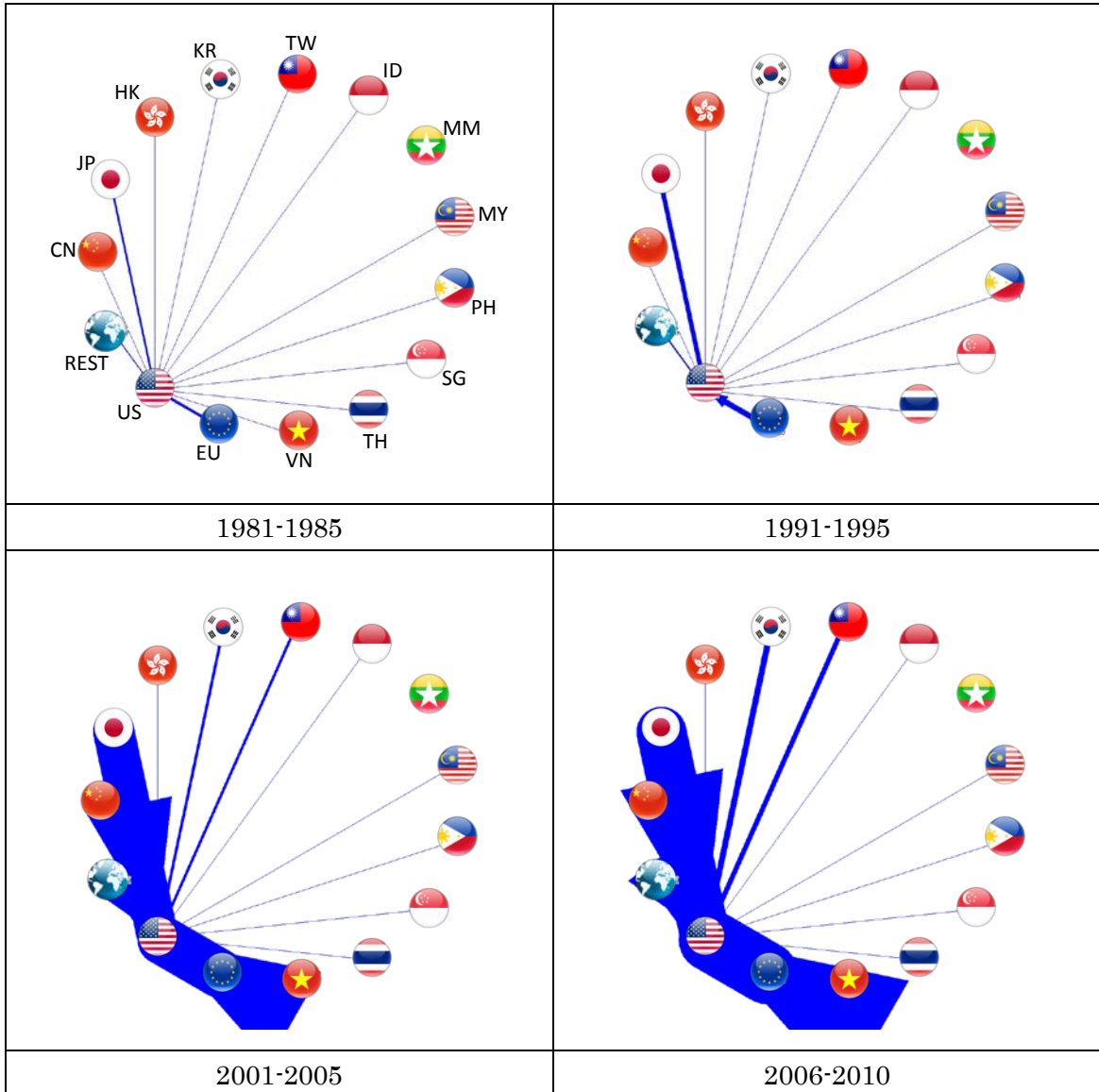
Vietnam



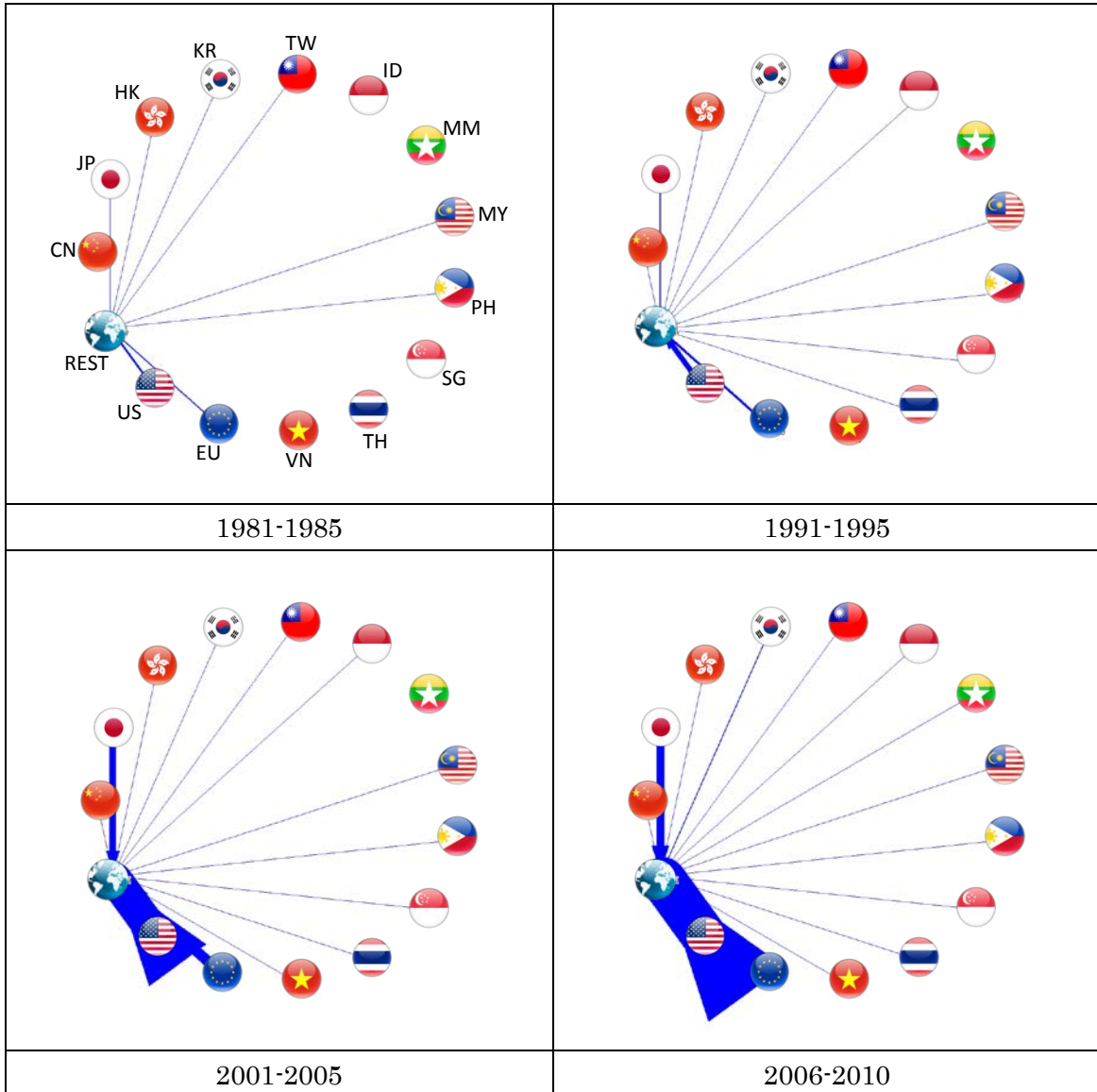
Europe (The 28 member states of European Union)



US



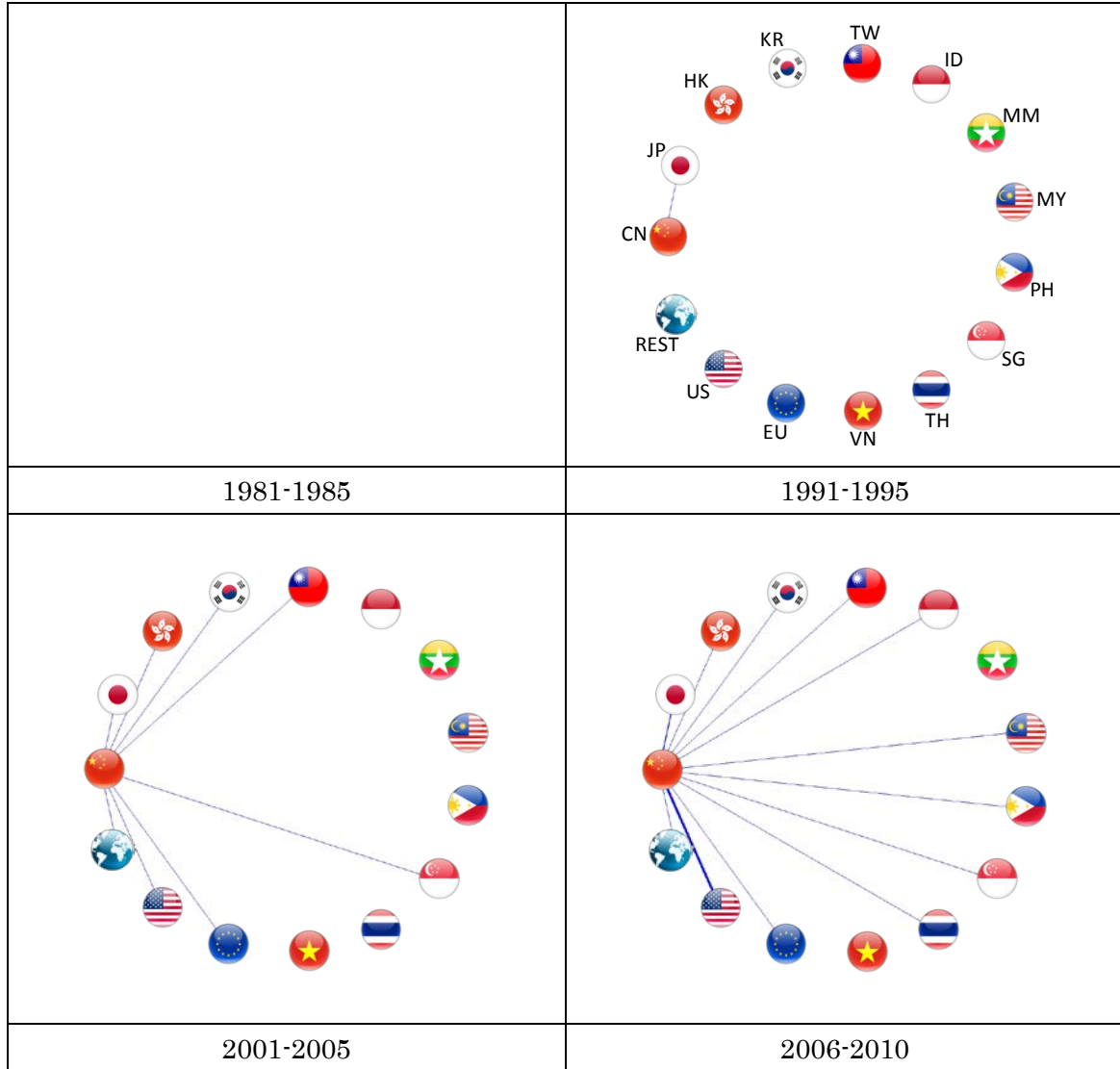
Rest



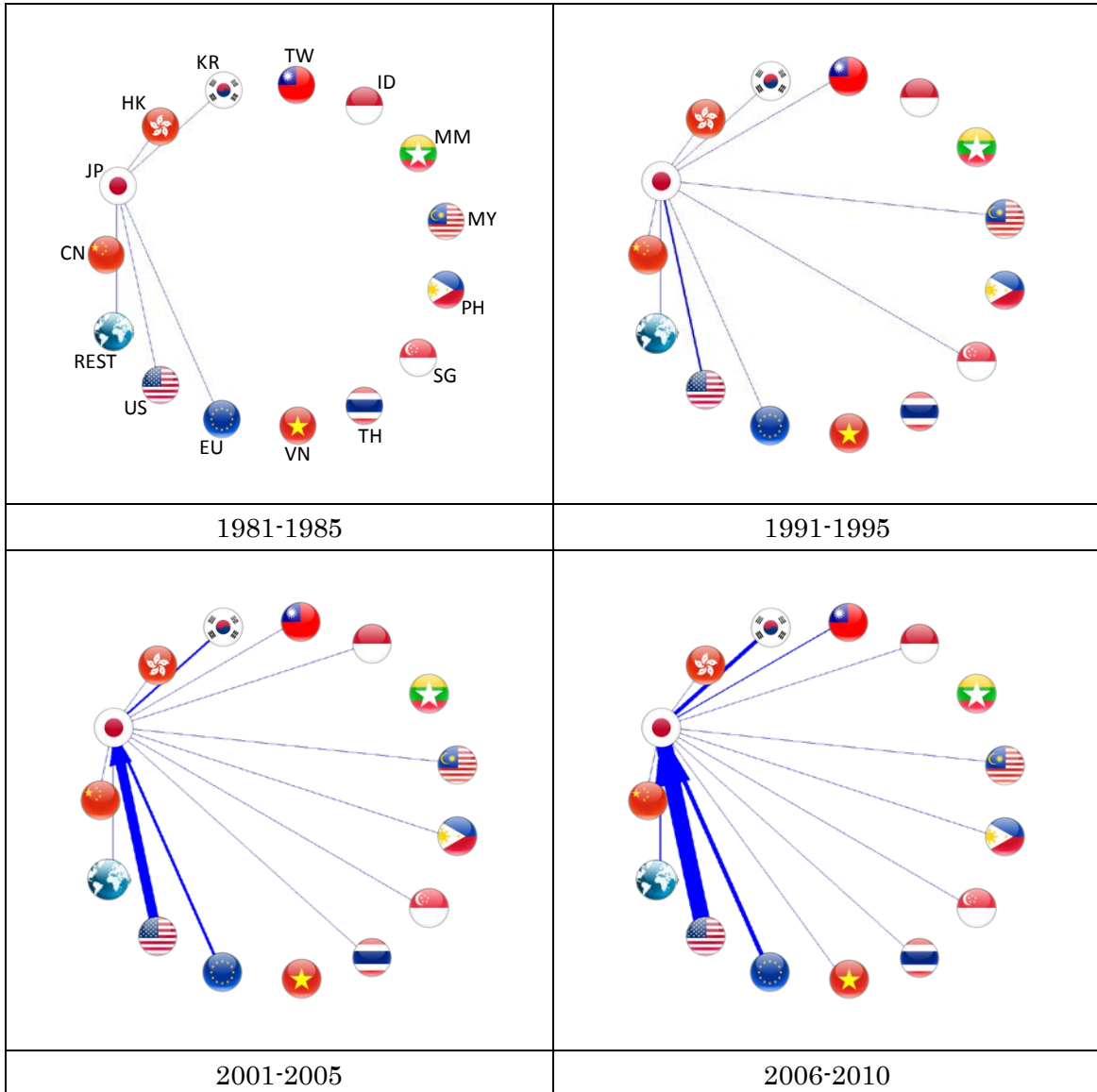
A2. Computer Industry

North East Asia

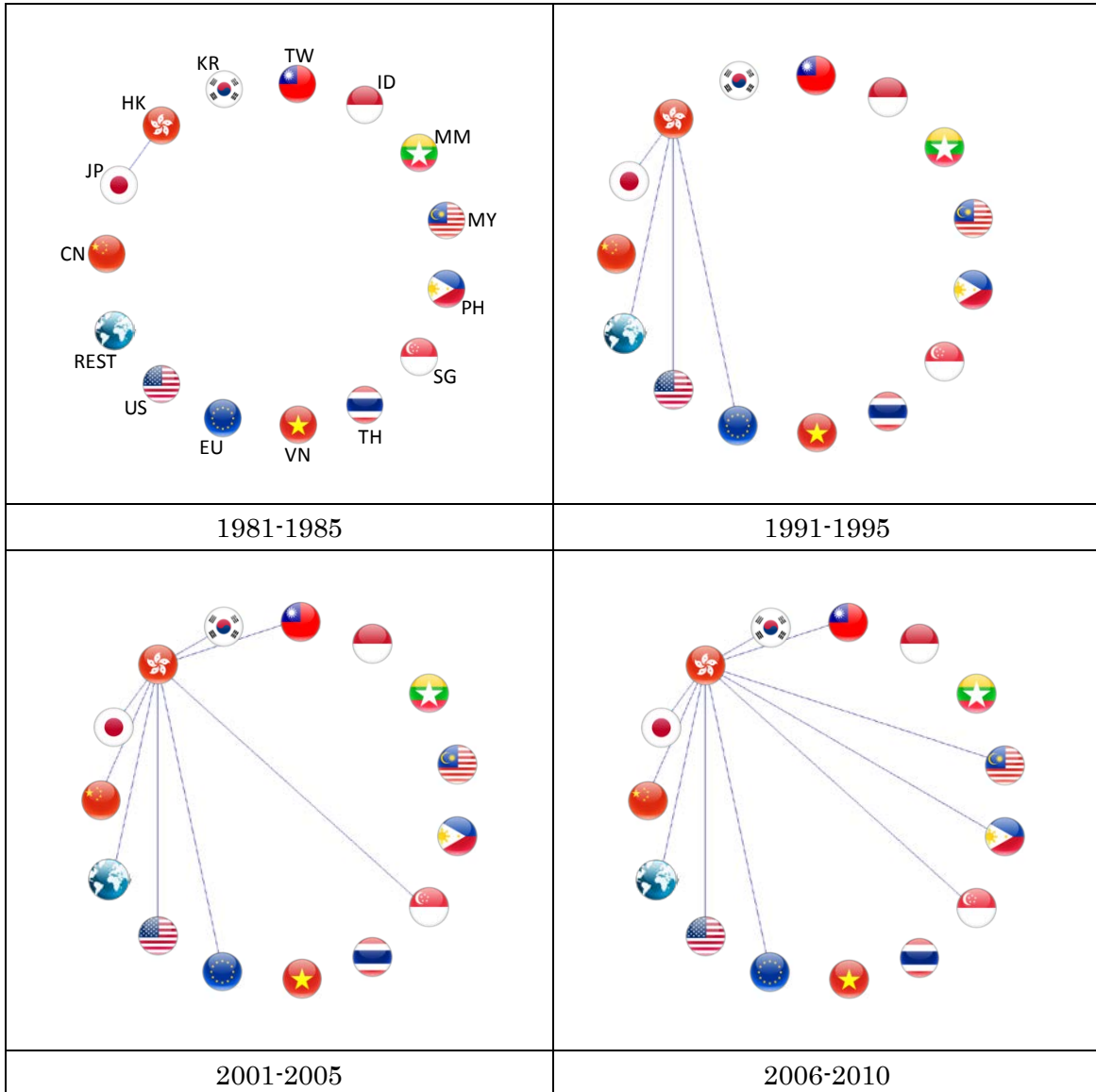
China



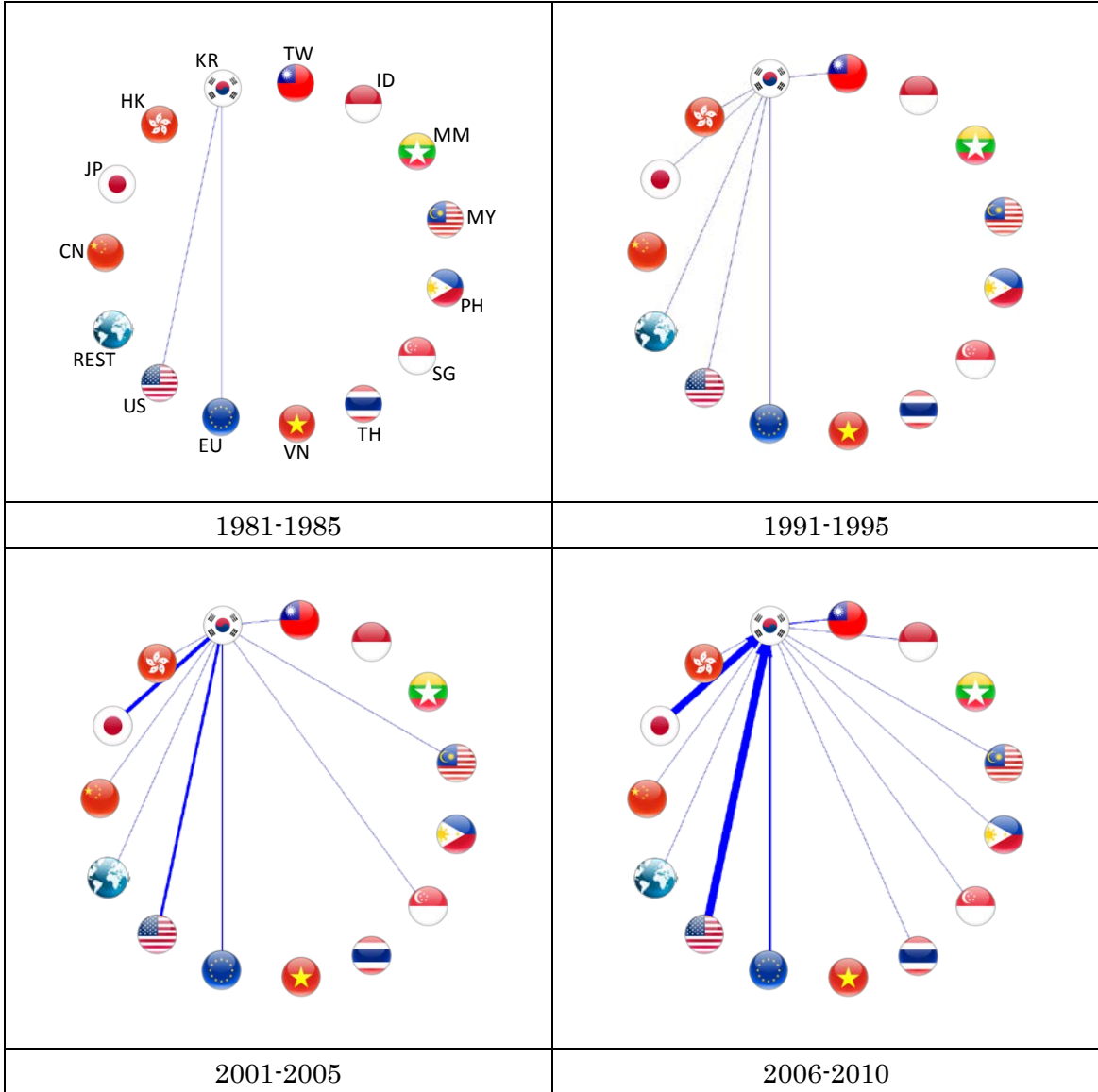
Japan



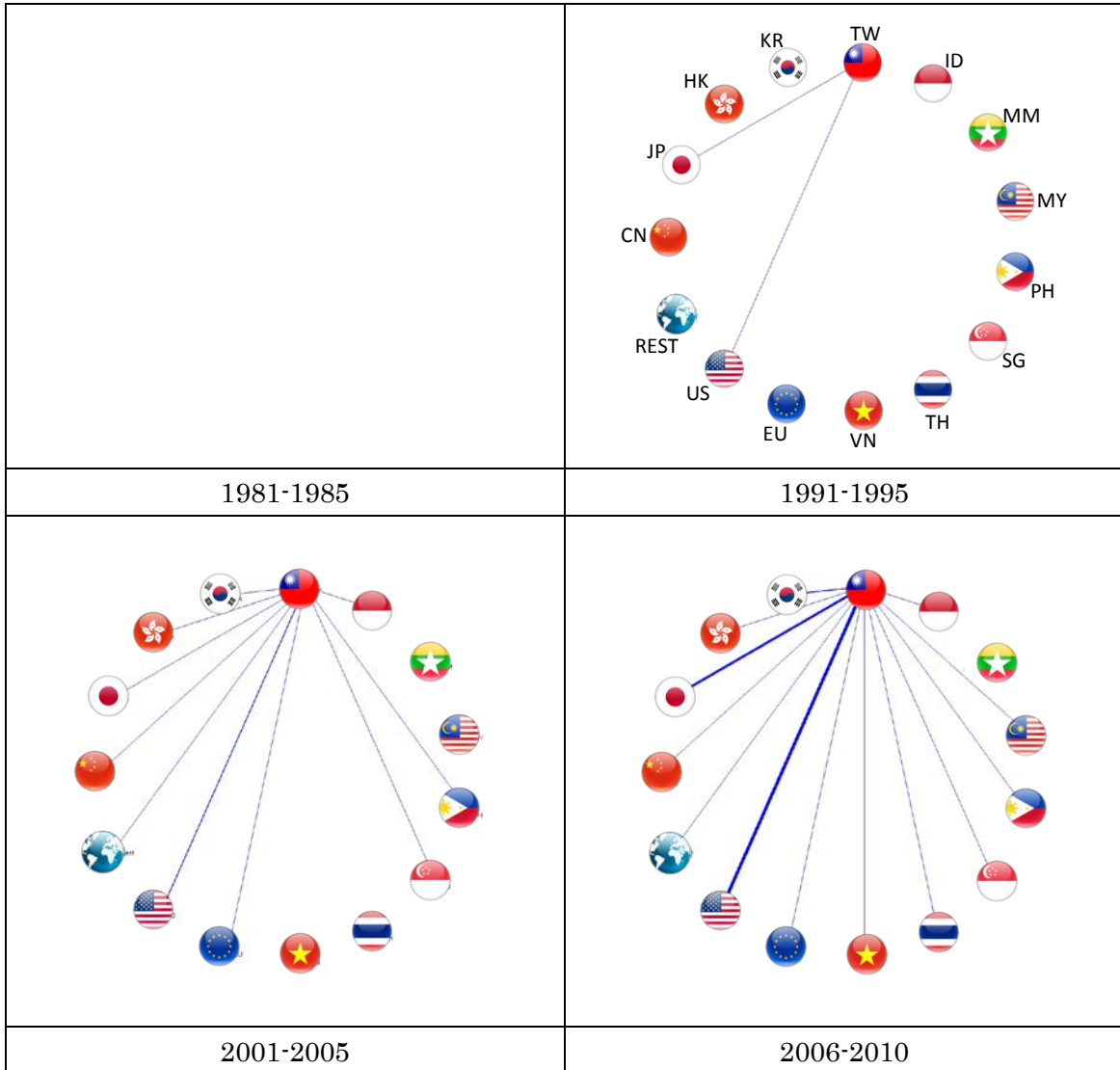
Hong Kong



Korea (Republic of)



Taiwan



South East Asia

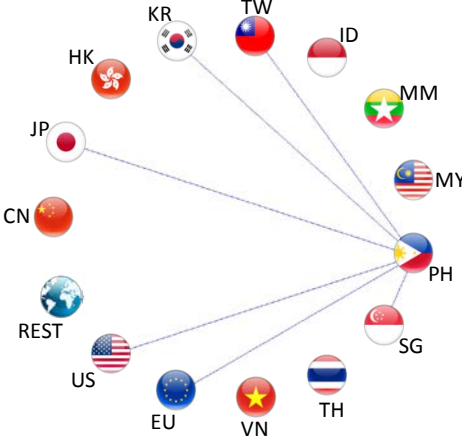
Indonesia

-	-
1981-1985	1991-1995
-	
2001-2005	2006-2010

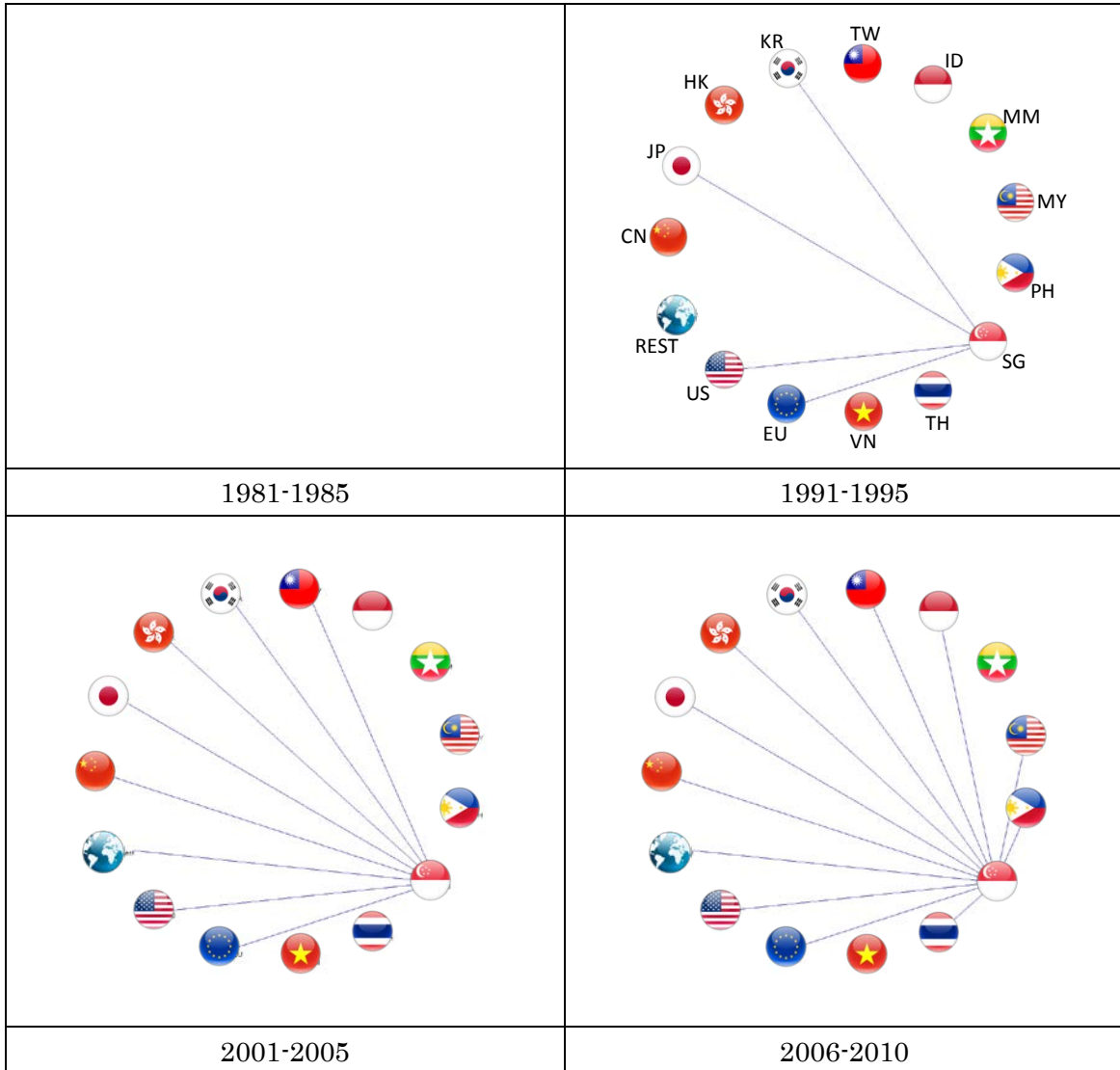
Malaysia

1981-1985	1991-1995
2001-2005	2006-2010

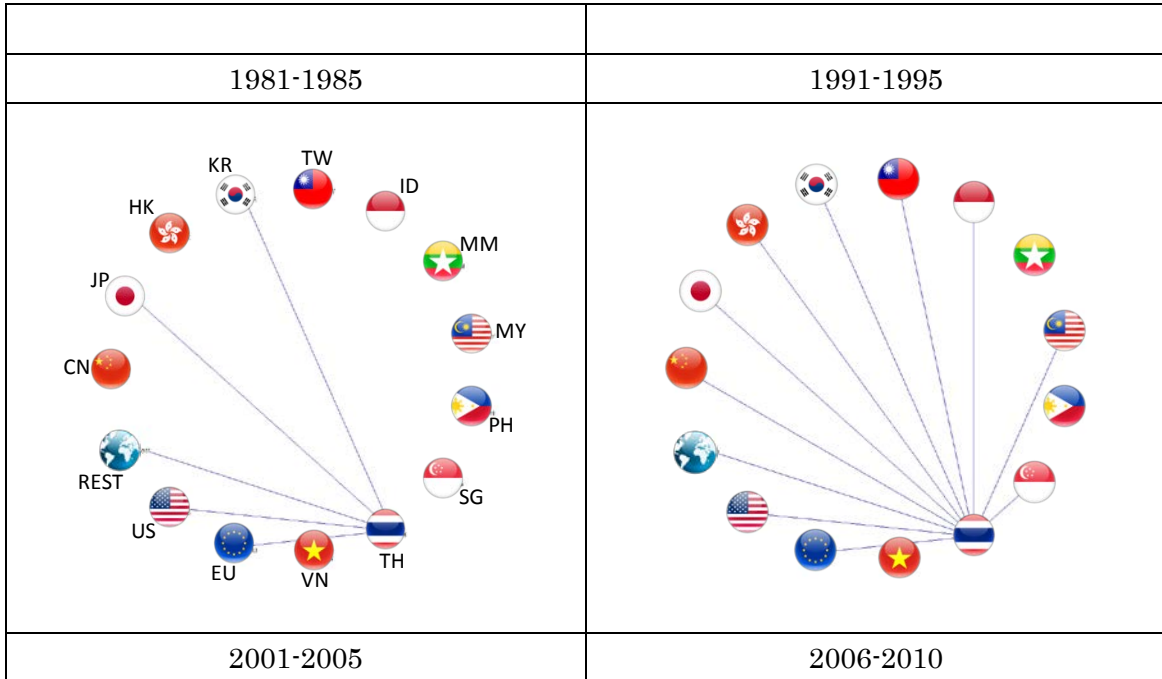
Philippines

1981-1985	1991-1995
	
2001-2005	2006-2010

Singapore



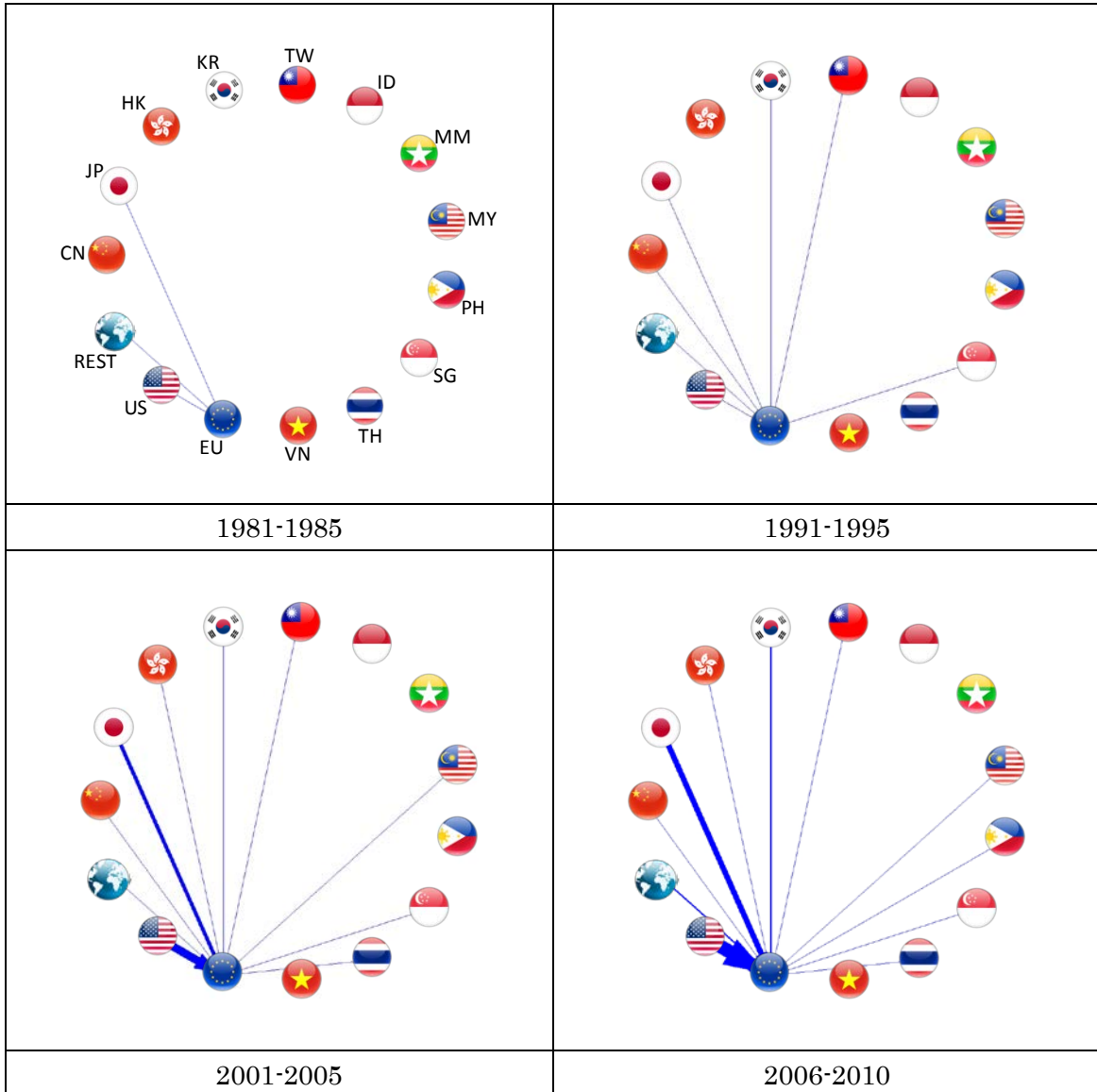
Thailand



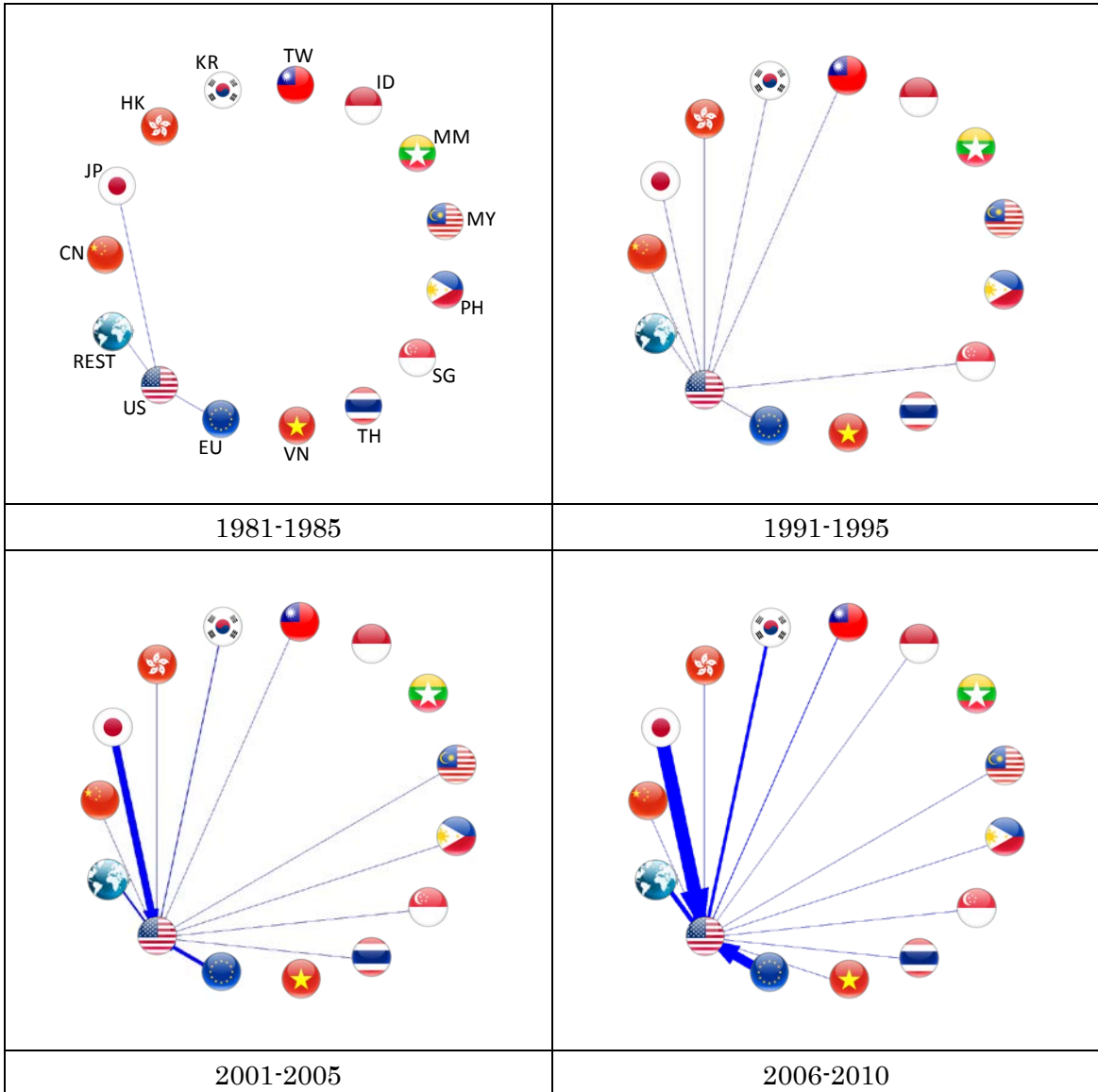
Vietnam

-	-
1981-1985	1991-1995
2001-2005	2006-2010

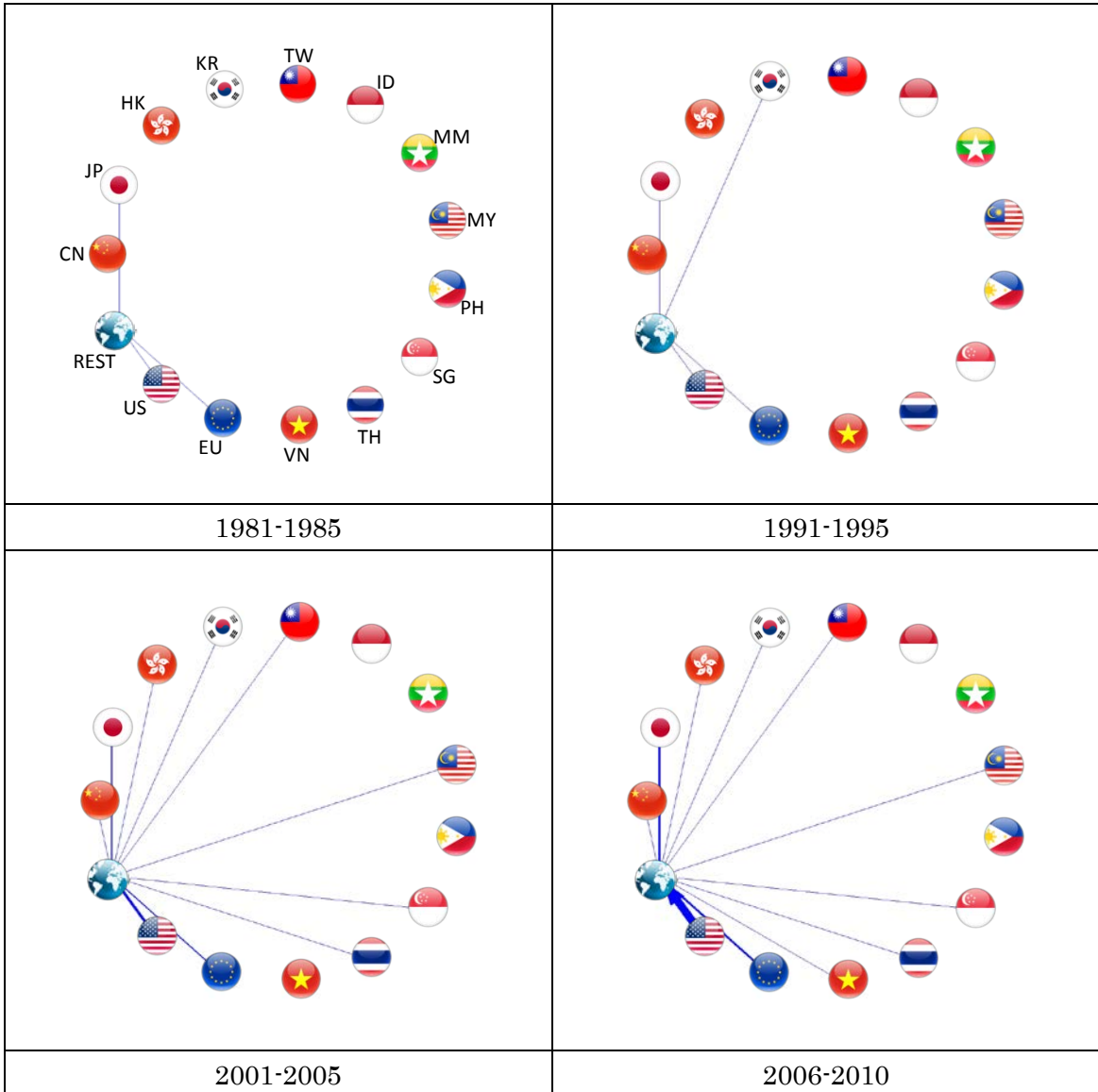
Europe (The 28 member states of European Union)



US



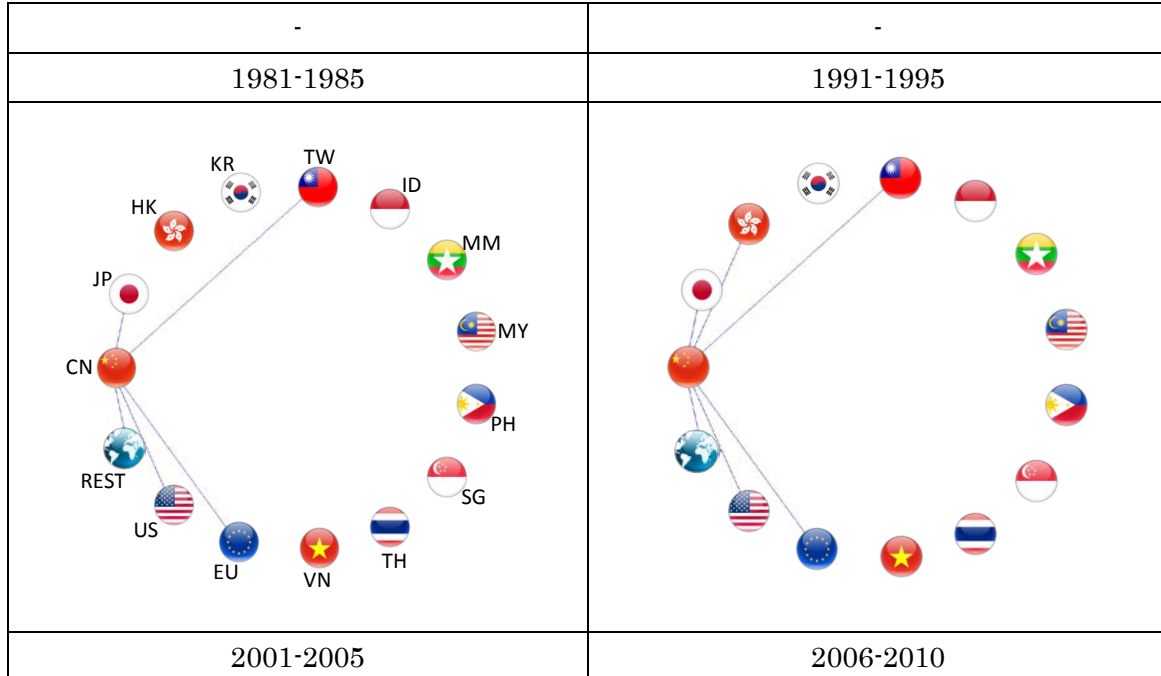
Rest



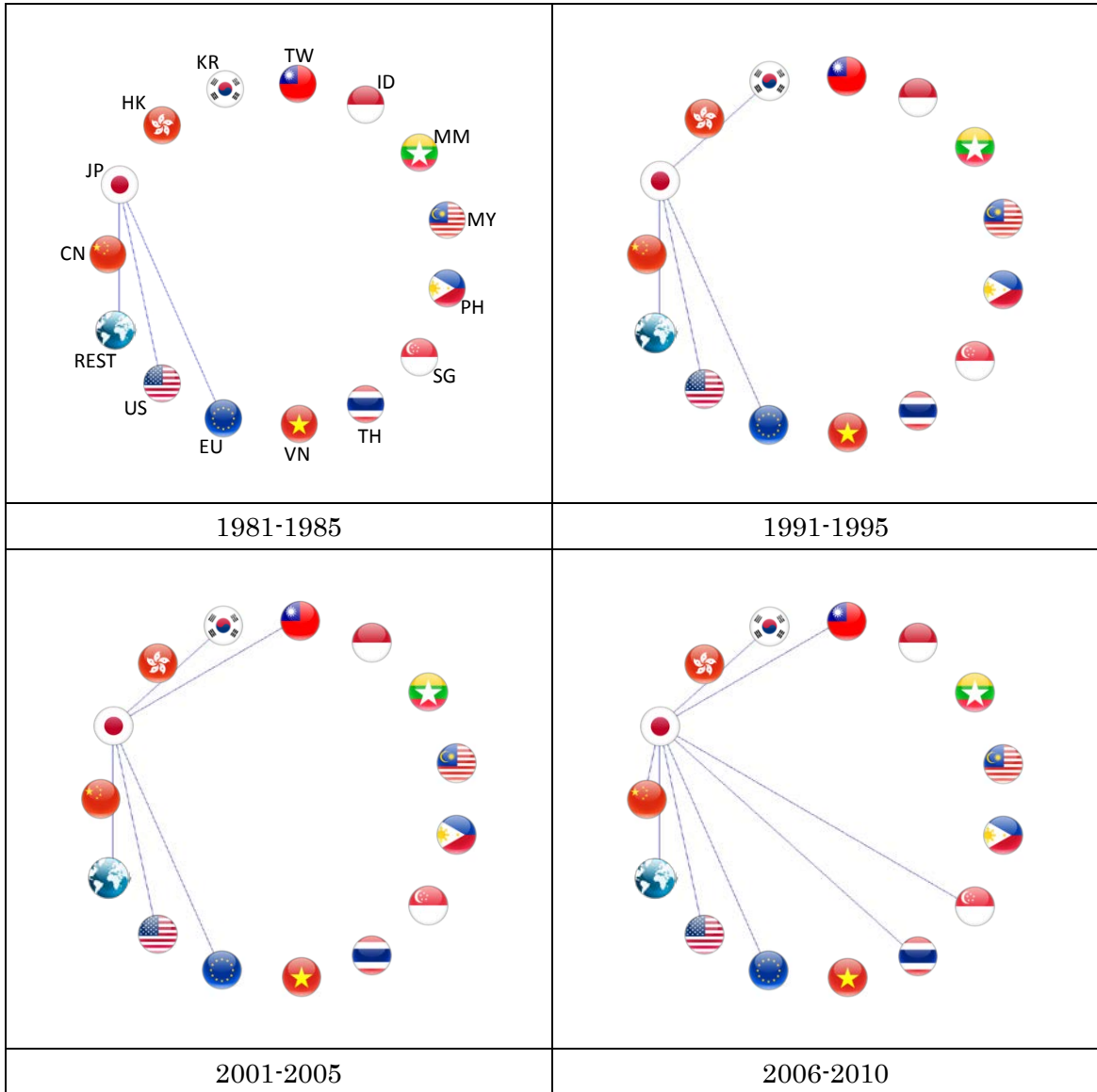
A.3. Transportation equipment industry

North East Asia

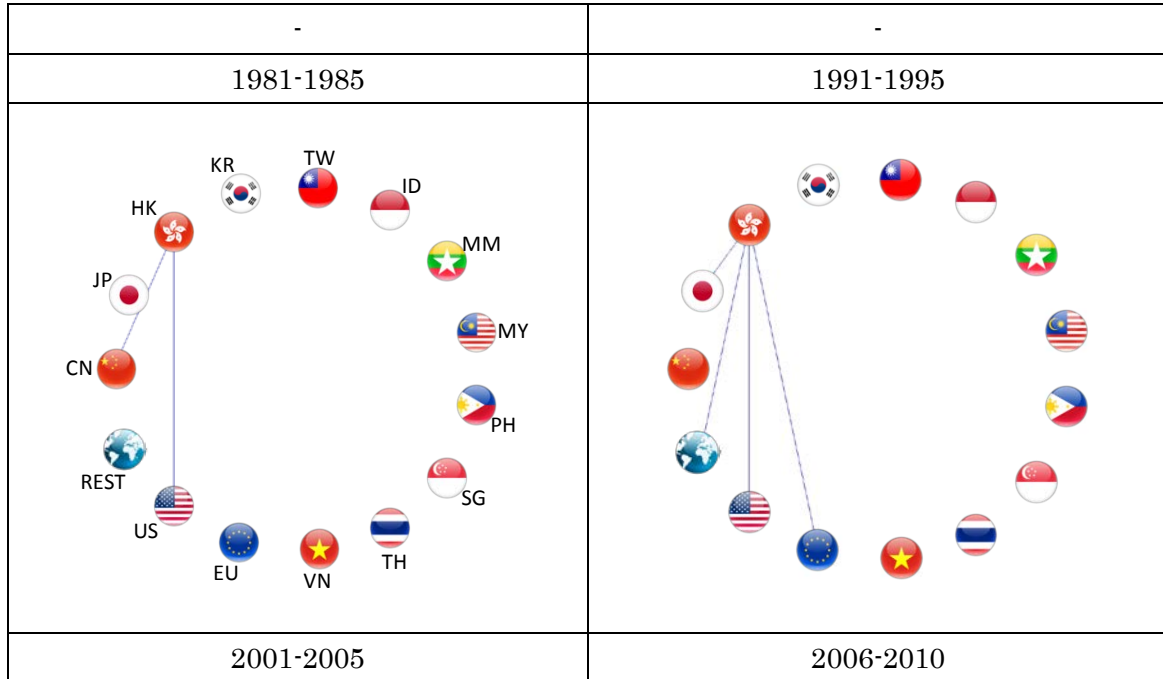
China



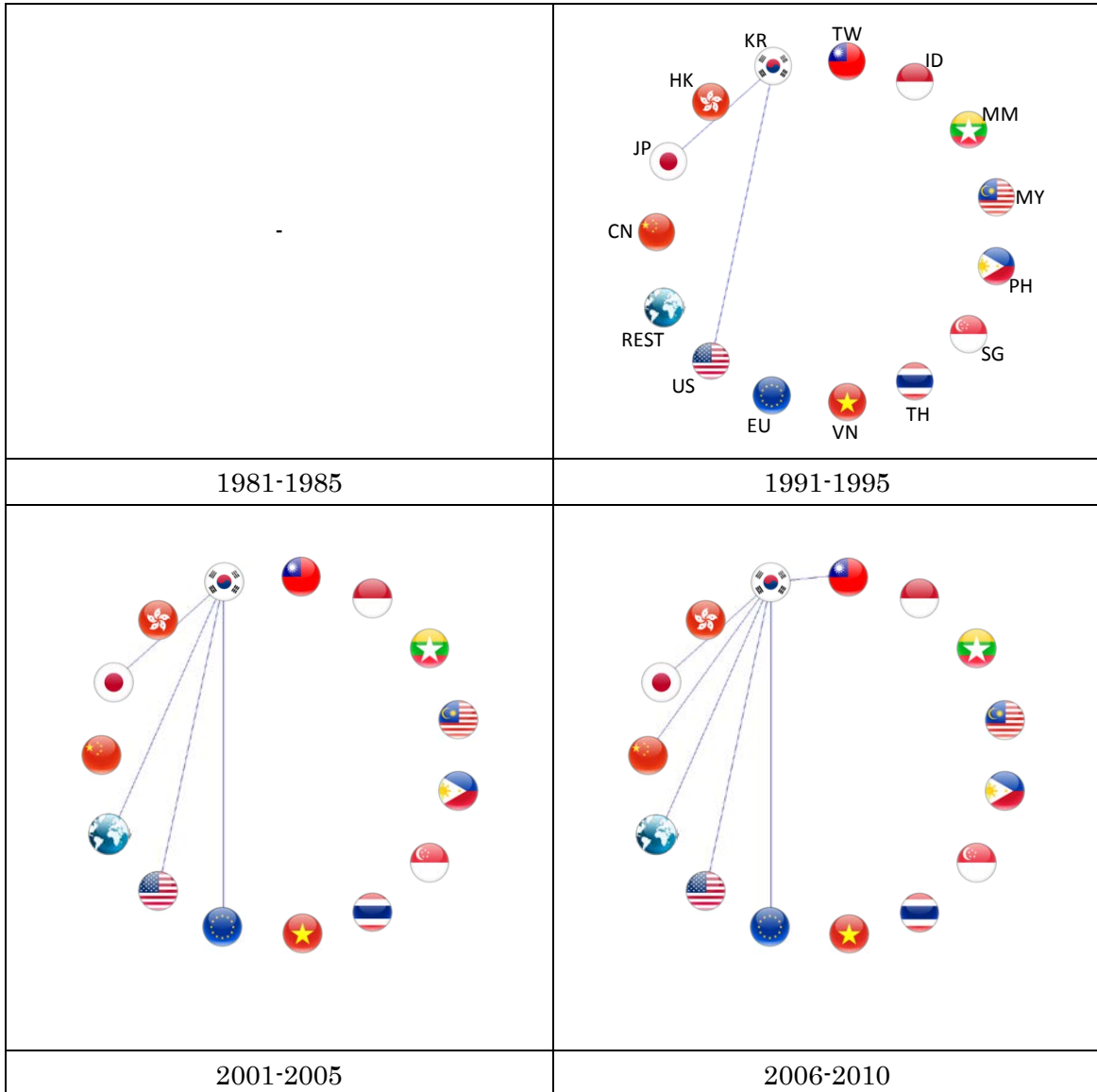
Japan



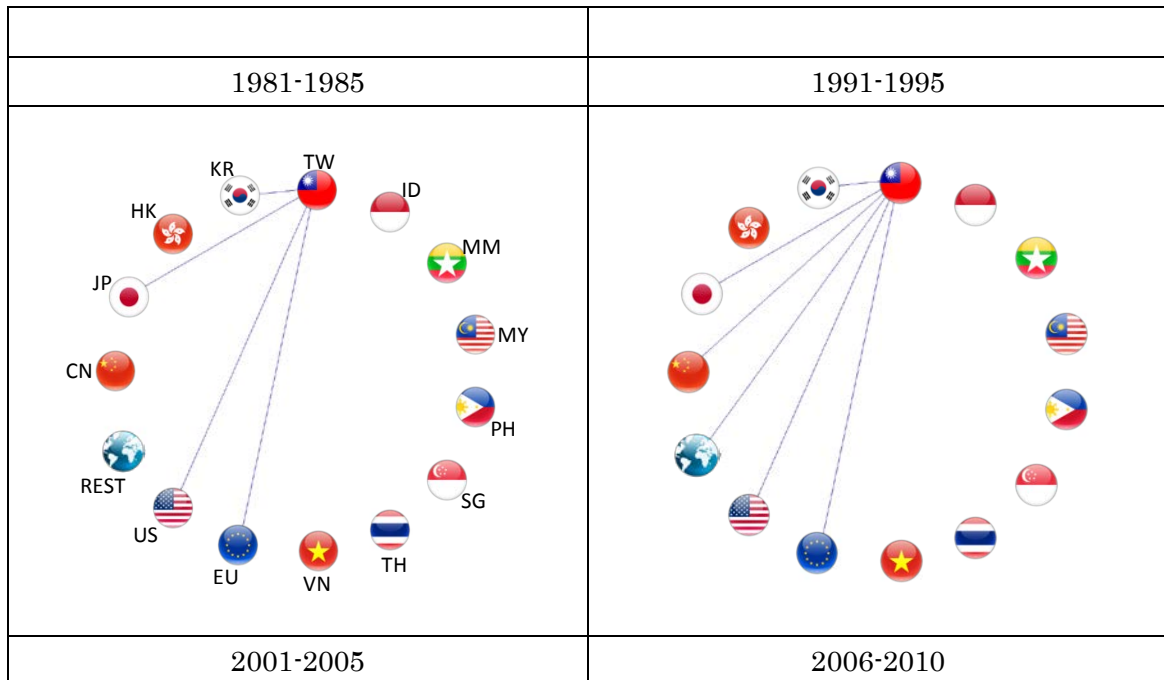
Hong Kong



Korea (Republic of)



Taiwan



South East Asia

Indonesia

-	-
1981-1985	1991-1995
-	-
2001-2005	2006-2010

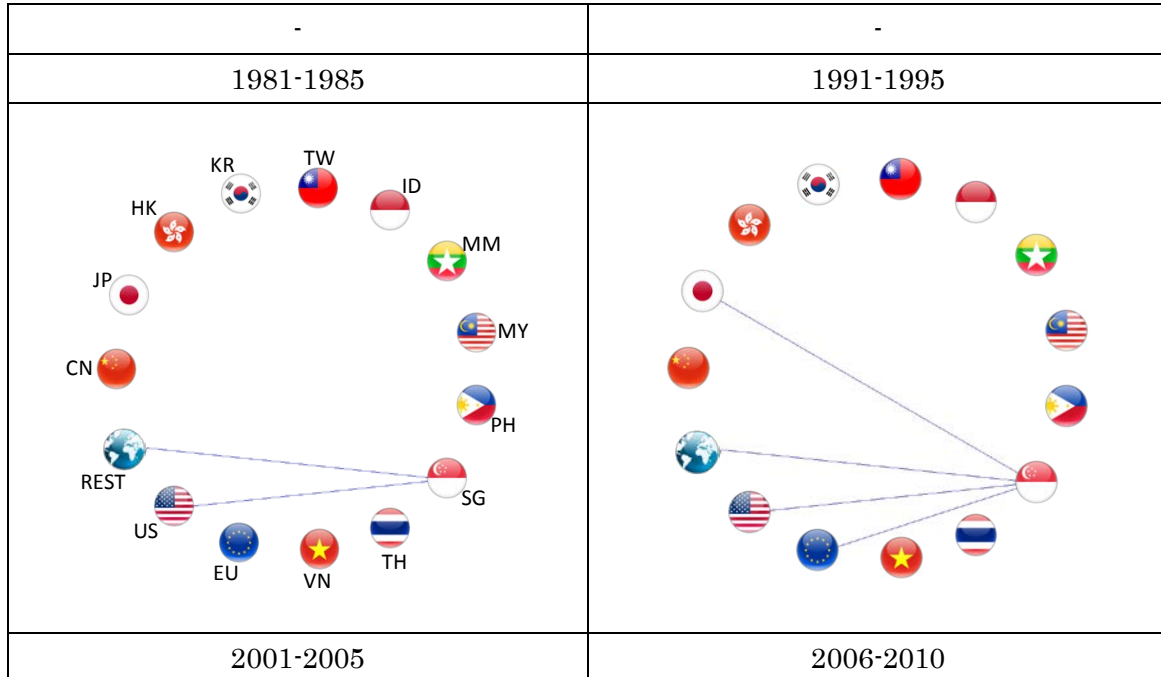
Malaysia

-	-
1981-1985	1991-1995
-	
2001-2005	2006-2010

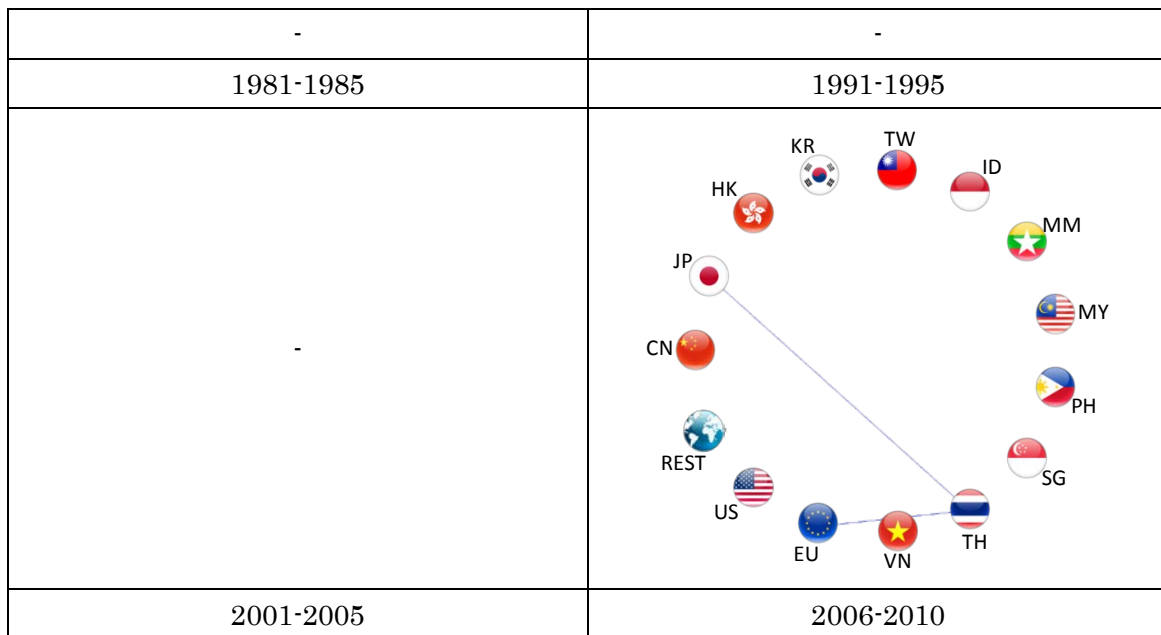
Philippines

-	-
1981-1985	1991-1995
-	-
2001-2005	2006-2010

Singapore



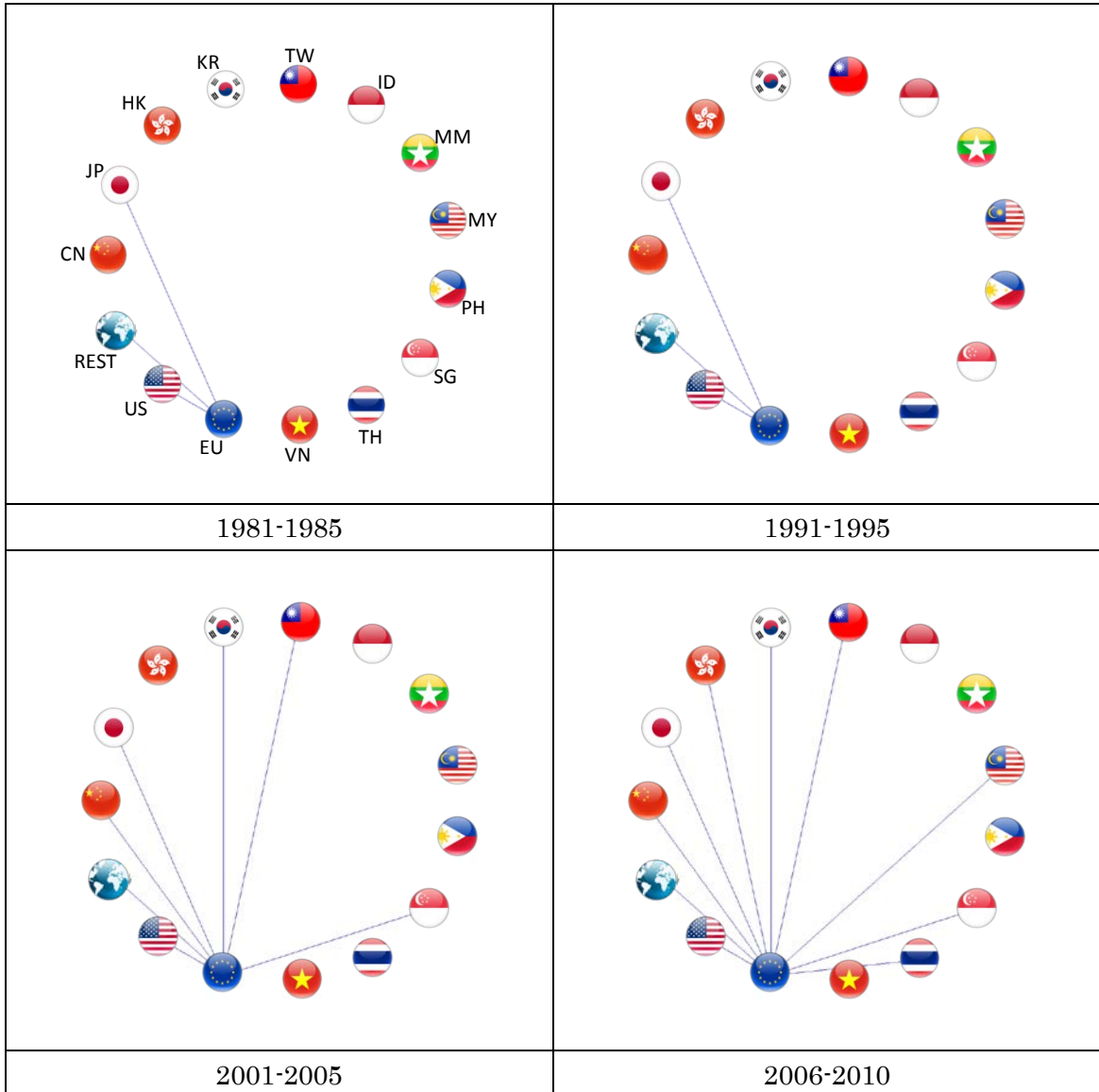
Thailand



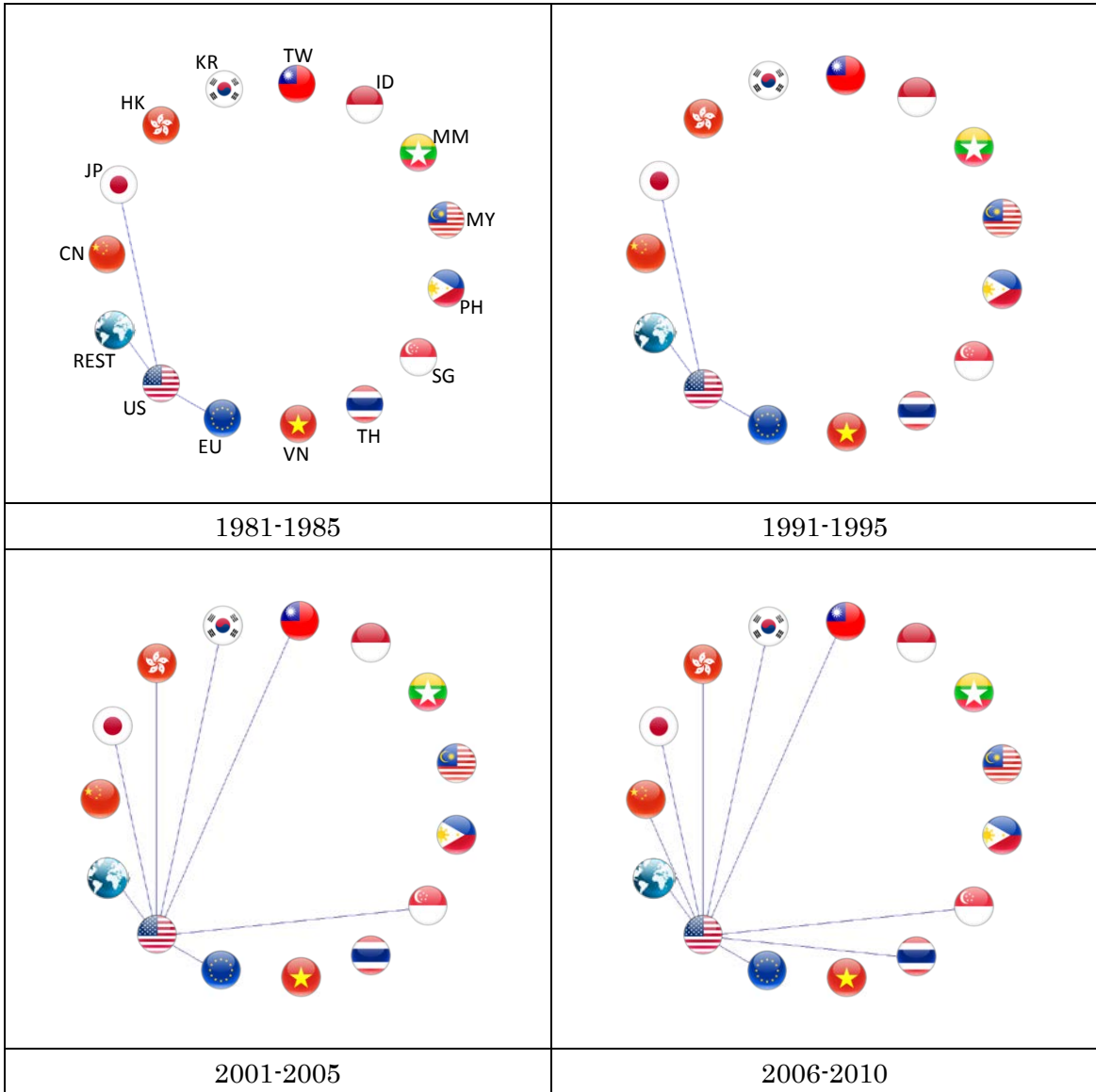
Vietnam



Europe (The 28 member states of European Union)



US



Rest

