Doctor of Philosophy

A Study on Regional Economic Integration via Network Analyses of the International Trade in Value-added and Asian Political Distances

国際付加価値貿易とアジアの政治的距離のネットワーク分析による地域経済統合の研究

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Abbreviations

ABMI Asia Bond Market Initiative

ACLED Armed Conflict Location & Event Data Project

AEC ASEAN Economic Community

AFTA ASEAN Free Trade Area

AMRO ASEAN Plus Three Macroeconomic Research Office

APEC Asia-Pacific Economic Cooperation

APG ASEAN Power Grid

APTERR ASEAN Plus Three Emergence Rice Reserve

ASEAN Association of South East Asian Nations

BRICS Brazil, Russia, India, China

CAMEO Conflict and Mediation Event Observations

CJK China, Japan, and South Korea

CMIM Chiang Mai Initiative Multilateralization

CPTPP Comprehensive and Progressive Agreement for Trans-Pacific Partnership

DAC Development Assistance Committee

EAS East Asia Summit

ERIA Economic Research Institute for ASEAN and East Asia

EU European Union

FTA free trade agreement

FY fiscal year

G7 Group of Seven

G20 Group of Twenty

GDP gross domestic product

GEIDCO Global Energy Interconnection Development and Cooperation Organization

GMS Greater Mekong Subregion

GSC global supply chain

GVAN global value-added network

GVC global value chain

ICEWS Integrated Crisis Early Warning System

IMF International Monetary Fund

IO input-output

IPP independent power plant

ITN international trade network

IVAN international value-added network

JBIC Japan Bank for International Cooperation

KEPCO Kansai Electric Power Company, Inc.

MIC Ministry of Internal Affairs and Communications

MID Militarized Interstate Disputes

MOFA Ministry of Foreign Affairs

MRIO multi-regional input-output table

NAFTA North American Free Trade Agreement

GDELT Global Data on Event, Language, and Tone

ODA Official Development Assistance

OECD Organisation for Economic Co-operation and Development

PPP public-private partnership

RCEP Regional Comprehensive Economic Partnership

RoW rest of the world

RTA regional trade agreement

SITC Standard International Trade Classification

TAC Treaty of Amity and Cooperation in Southeast Asia

TPP Trans-Pacific Partnership

TPSEP Trans-Pacific Strategic Economic Partnership

TiVA Trade in Value-Added

VRA Virtual Research Associates

WIOD World Input-Output Database

WTO World Trade Organization

Chapter 1

Introduction

Globalization is advancing, and people, goods, and money are increasingly moving across borders. International movement of people (migration), goods (trade), and capital (foreign direct investment (FDI)) has increased considerably over the past more than three decades [1–3], and economic activity has become internationally connected. These data suggest that cross-border markets are expanding and economic integration is progressing.

Economic integration is generally classified in five levels of its integration, but this classification does not address such factors as the increase in cross-border movement of people, goods, and money, as discussed above. In 1961, Balassa [4], in integrating Europe, outlined five stages of economic integration: free trade agreement (FTA), customs union, common market, economic union, and full economic integration. Today, the European Union (EU) is the most advanced example of economic integration and is at the fourth stage. Other regions that do not share the same culture as Europe have not yet caught up with Europe in institution-based (*de jure*) integration due to their cultural diversity and economic disparities. Nevertheless, market-led (*de facto*) economic integration is underway in Asia [5], and this movement has begun to manifest itself in institutional moves such as the Trans-Pacific Partnership (TPP) (or current Comprehensive and Progressive Agreement for TPP (CPTPP)) and Regional Comprehensive Economic Partnership (RCEP).

Turning from institutions to the current economic activities, they have become more complex as the volume of cross-border flows has increased and the goods and services have diversified. It is difficult to provide all the materials domestically for the food we eat, the clothes we wear, the cars and trains we use for transportation, and the electronic devices we use, and it is common that at least some of them are composed of materials, services, technology, and capital from other countries. In other words, goods and services are produced through various cross-border economic activities called global supply chains (GSCs) or global value chains (GVCs).

As such, it is difficult to understand the complex, international, intertwined economic activities of

multiple industries. Consumers only know the place of origin or place of processing from the information on a product's label, and it is difficult to grasp information that is not written there. For example, they may not know which country the product was transported through. Furthermore, without inquiring with the producer, there is little way to know which country the parts of a certain product came from. In other words, unless we take the trouble to pay attention to the products we consume and use, we will not know which countries the people and companies that add value to the goods and services that support our life are located in.

Difficulty in understanding a complex economy reveals problems when considering economic policy. For example, if a country is faced with a trade imbalance between two countries and supports a policy of increasing tariffs, not only will this increase the price of final goods, making life difficult for the people, but it may also affect trade conducted through a third country, reducing the exports to other countries. While it is difficult for economically developed countries to see the value of maintaining or deepening economic integration, there are a certain number of citizens and politicians who feel that economic integration will undermine their country's interests. The results are evident in the United Kingdom's withdrawal from the European Union and the United States' withdrawal from the TPP. Politicians can turn away from economic integration by appealing to public sentiment by cutting out the part of the economic phenomenon that is difficult to grasp and appealing to the part that is losing the national interest.

This thesis regards the difficulty of understanding economic phenomena due to their complexity as one of the causes of this backward movement away from economic integration and seeks to resolve this issue. Economic integration simply refers to the operation of economic institutions and policies by a multi-country organization, and any discussion of economic integration requires an understanding of the economic situation in all the countries involved, which is difficult even for a single country to understand. Such a task is difficult and impractical for most citizens. In other words, economic integration is an agenda that cannot be accurately grasped in real terms but requires a political decision. While experts are generally consulted on such issues, history has shown that this has not worked in the case of economic integration. Therefore, this thesis considers how technology can create an environment that can be understood by a large number of citizens. Specifically, this thesis aims to use data and calculations to reduce the cognitive burden on the public and businesses in gathering information in a way that does not rely on experts.

In a complex system such as the international economy, taking away some parts can lead to a distraction from understanding the system. This phenomenon is known in physics, where it has been shown through statistical mechanics and other realms that the sum of the parts does not equal the whole. Later, the idea led to complex systems and network science [6], which are used to understand social phenomena.

We do not have a brain developed enough to understand and analyze every single movement and transaction that occurs daily around the world, so we cannot fully comprehend the complexities of economic activity. Therefore, we estimate the whole from some of the recorded economic data, and we also understand the state of the country and the world by understanding the indicators of the state of the economy. GDP is used in particular, and other indicators such as population, unemployment rate, wages, FDI, and imports/exports (trade) are also utilized. These provide us with a broad understanding of the economic state of a society that is too large for us to comprehend.

On the other hand, recently developed data and computer performance have given rise to methods for computing features while preserving the complexity of large-scale data as much as possible; the aforementioned network science is one of the fields dealing with such methods. For example, the PageRank method, which determines the order in which web pages are displayed after a search on Google, is well known. It calculates their importance based on the structure of citation relationships among web pages, rather than by reading the entire contents of the page. In the same way for international economic relations, could we evaluate the degree of progress in economic integration by calculating based on the structure?

Structure arises from a set of relationships. Indicators of economic relations between countries include, for example, international trade, FDI, and the number of immigrants, of which trade is the most relevant to our lives. International trade is one of the most difficult economic phenomena to grasp because of the variety of goods and services traded in each sector. On the other hand, trade data has been developed around the world since the creation of the U.S. input-output table by Leontieff [7–9], creating an environment conducive to understanding trade phenomena. Now trade among multiple countries on an industry-by-industry basis is recorded in the international input-output table. In other words, data on international economic relations are already developed, and trade, whose actual status is difficult to grasp due to its diversity, is a topic worth tackling.

However, trade alone can only capture the results of economic activity. In order to discuss economic integration in real time, it is also necessary to have a method to ascertain the preliminary stages of economic activity and the efforts currently initiated. An economic policy uncertainty index has already been developed [10], which is calculated from news reports published in newspapers. This has been made possible by the accumulation of previous news reports, their textualization, and the generalization of computers capable of processing and calculating the large volume of data produced daily. Can we capture the movement toward international cooperation on economic integration from the news reports as well?

In addition to the development of the above indicators, their utilization must also be discussed. While the indicators are communicated to the public at large through news reports and other media, how about

companies? Since it is mainly the international expansion of companies that will bring about economic integration, we would like to consider the role that indicators can play in this process by focusing on sectors that are not currently engaged in full-scale international expansion but where such expansion is desired, and by discussing ways in which the government can support the international expansion of these sectors.

The ultimate goal of this thesis is to realize a society in which the international situation of the world as a whole and the region to which the country belongs are displayed daily on television and on each individual's terminal. A measure of central tendency of stock prices is already reported daily in the stock market, and the same could be applied to the international situation. By checking an index of international conditions every morning, citizens can easily learn about global and regional conditions. Then, it would help them avoid living a life of blind economic activity as part of a huge and complex economy.

Conversely, the media's inability to inform citizens about a broad range of international affairs, while adapting their knowledge and understanding, is thought to contribute to their lack of interest in international issues. Or, due to their national backgrounds, the countries they focus on are fixed, creating many countries that are overlooked. In order to confront global issues, we should not only develop a style that can be understood by specialists who devote a large part of their lives to international issues but also a style for the general public. In this way, objective data can correct the problem of biased understanding of a country's international situation by, for example, becoming only familiar with the situation of its allies or by looking for and reporting only the parts of a country that it dislikes, thereby biasing its understanding of international affairs.

There are many missing pieces to the completion of such an ideal puzzle. First, it is necessary to consider whether such an indicator is possible. The requirement is that the target of the indicator calculation can be easily set even by non-experts, while the original data should be publicly available so that experts and others can verify it. Assuming that the method is realized, we would then like to examine how it can assist companies in developing their international operations in order to deepen and expand economic integration. Using the results of the indicators developed for this purpose, we will narrow our focus to an actual economic sector and demonstrate how the sector can contribute to the development of economic integration in the region, up to the derivation of measures to help it do so.

This thesis consists of six chapters. The following chapter establishes three research question for Chapter 3–5 based on a survey of the relevant literature. It then introduces the analytical framework and the analytical process followed to answer the questions. By using an analytical framework that combines academic research and social implementation, this study aims to understand the complex economic integration that occurs on a global scale and to identify the role of sectoral perspectives in the development

of economic integration.

Chapter 3 offers the following essential contributions. First, rather than using trade figures, which can mislead international economic relations, we used the value-added calculations used in an IO analysis to construct a sector-wise network. Next, from the value-added linkage, we confirmed the regional characteristics of Europe and the Pacific Rim. Findings showed that the behavior of this value-added relationship is highly different from that of the sectoral community in the international trade network shown in previous studies. The dense economic relationships within these regions were decomposed into potential and circular relationships, and the countries and sectors that contribute to the strong regional ties were identified. Finally, we propose an economic integration index based on the circular flow component, and the results showed that economic integration was higher in the Pacific Rim than in Europe in 2010, 2013, and 2014. Chapter 3 is organized into three parts. Sections 3.1 and 3.2 describes the IO table and the computational method used to create the network and to analyze the community, explains the decomposition of the potential and circular flow components, and presents the proposed method for measuring economic integration. Then, the characteristics and structure of the network, the potential and circular relationships, and the results of the integration index are presented in Section 3.3, and the international economic linkages are examined in Section 3.4 based on these results.

With the results of Chapter 3 which aimed to understand regional economic integration by analyzing international cooperation based on regional relationships, we constructed a network of international relations from events that occurred bilaterally, identifying periods of regional diplomatic relations and the countries that contributed there in Chapter 4. The chapter made the following contributions. First, the definition of diplomatic centrality has enabled quantitative observation of diplomatic relations within the region. The results revealed that Japan, China, and ASEAN member states in particular contributed to multilateral diplomacy in East Asia. Second, the correlation of diplomatic centrality allowed us to divide countries by their diplomatic stance within the region. The results confirmed that the stances of New Zealand and Australia are close, as well as Japan and South Korea, China, ASEAN, and the United States, in that order. Finally, the extent of synchronization was calculated based on the phase of diplomatic centrality to identify when diplomatic stances were aligned in East Asia. The results showed that diplomatic stances were most aligned in 2003, when some diplomatic events, including the 9th ASEAN Summit, were held. Furthermore, our study quantified the progress of regionalism by calculating diplomatic synchronization. Chapter 4 is also organized into three parts. Sections 4.1 and 4.2 describes the data and the methods of calculating diplomatic centrality and synchronization, and clustering signed network. Section 4.3 illustrates the results of diplomatic centrality, clustering, and synchronization. Section 4.4 discusses the limitations, implications, and applications of our research.

Chapter 5 examined what role the sector level plays in economic integration in the region. The

author interned at the Economic Research Institute for ASEAN and East Asia (ERIA) as an analyst for six months and its results were published by a journal. The thesis (content of Chapter 4) quantified diplomatic contributions by countries to cooperation in the Asia-Pacific region and discovered Japan's high contribution for 36 years. Because of the result and the importance of energy in the region, the author conducted action research to clarify the role of the Japanese energy sector in East Asian economic integration through a project with Kansai Electric Power Company (KEPCO). As the project in action research, the author conducted interviews with its employees, compared its international business with Enel's one, and a workshop. Based on the series of the author's studies, the author discussed the role of the Japanese energy sector in enabling the promotion of East Asian economic integration in balance with China by actively contributing to energy transformation and increased electricity supply in the ASEAN region. The authors then showed how governments and businesses should engage in order for the sector to fulfill its role.

In the final chapter, the author concludes the thesis with the main three distinctive results of this research and future research questions.

Chapter 2

Analytical Framework

2.1 Necessity of indicators of international relations

In order to manage a society, such as a country or a municipality, it is necessary to process information about that society to make decisions, but the amount of information is too large for humans to recognize and process everything about the vast and complex human society. For more than 50 years it has been pointed out that the complexity of life currently reduces what citizens can do [11], and even in recent years, it has been noted that it is difficult for voters to monitor and evaluate politics [12]. Illustrating this fact, a survey that asked Americans whether the U.S. should intervene militarily in response to the 2014 Crimian Crisis showed that those who did not know where Ukraine was were more willing to intervene militarily [13].

Nichols cited the above facts, the anti-vaccine movement, the campaign to endorse unpasteurized milk, and the misunderstanding of international support, and then discussed the antinomianism behind the movement [14]. The disdain in society for commentary by experts, who are less likely to make mistakes than citizens on specific issues, has resulted in problems ranging from personal health problems to major issues involving multiple countries, such as Brexit. A solution to this problem remains elusive.

If interpretation and explanation by experts are dysfunctional, how can citizens discover problems that need to be discussed in society and discuss solutions? One answer to this question is to convert the information into a form that can be interpreted by citizens without having to go through an expert every time, or more specifically, to define indicators to observe a state, automatically calculate them, and periodically display them. In this way, some of the roles that have been performed by experts are transferred to technology. This method would not yield even a solution to the problem, but it is possible to know when and where the problem may have occurred. Therefore, the role of a detector of the existence of a problem to be discussed is left to the indicator, and it is assumed that the discussion about the severity of the problem and its solution will be conducted by citizens, including experts. From the perspective of

the formation process of social problems [15], the indicator would be positioned as an auxiliary tool in the claim-making.

Macroeconomic indicators such as GDP, investment, unemployment, and price indices are already in practical use. In addition to these, population, average stock prices, and exchange rates are also included in the indexes in this thesis, as well as average temperature and atmospheric pressure, which represent the state of the natural environment over a certain area. These values are reported in the media on a daily, quarterly, or yearly basis, and the information is used to determine the behavior of individuals and the policies of the government.

Despite the fact that many indicators are already in use, the main indicators of international relations are bilateral trade volume, immigration, and FDI, and economic and diplomatic relations with multiple countries are not well developed. On the other hand, there has been considerable progress in the development of calculation methods and data for use in calculations. For example, in recent years, economic uncertainty has been calculated from information in news articles [10]. Other methods for evaluating the economy in terms of complexity have been proposed and widely applied [16, 17].

Using these and other methods, such as news data and network science methods for calculating relationships, economic and diplomatic relations among multiple countries can be quantitatively represented. Based on this idea, this study address the quantification of economic integration, a topic involving multiple countries. The next section briefly summarizes the classical account of the most traditional international relationship, international trade, and the latest GVCs research, the state of economic integration, and the application of recently developed network science to the international economy.

2.2 Literature survey

2.2.1 International trade

In 18th century England, the idea of mercantilism was prevalent, in which the amount of exports was greater than the amount of imports, and a trade surplus was used to gain a large amount of wealth. Based on this idea, imports were restricted by high tariffs and other measures, while colonial rule and export promotion policies were used to promote exports and accumulate a currency composed of gold and silver. Under such circumstances, Adam Smith criticized regulations based on heavy mercantilism as the cause of the lack of productivity growth, stating that currency is only a medium and cannot be accumulated and that market prices should converge with natural prices, which are prices where supply and demand are in equilibrium [18].

It is not easy to grow a country's economy without establishing economic relations with other countries. Every year, the amount of international trade increases along with the world's gross domestic

product (GDP). FTAs and regional trade agreements (RTAs) have been created to support this trend, and countries are working to stabilize trade.

Classically, Ricard advocated comparative advantage, which stated that countries specializing in different industries are supposed to trade by taking advantage of their respective strengths [19]. Ricard explained that the value of a commodity can be explained in terms of the amount of money required for exchange, which is proportional to the effort required to produce the commodity. He then explained the case of two countries and two goods, using cloth and wine from Portugal and England as examples. When the amount of labor required to produce cloth and wine in Portugal and England, respectively, is expressed in Table 2.1, consider the case where one unit of woolen fabric in England is exchanged for one unit of wine in Portugal. England can obtain wine which originally required 120 labor for 100 labor,

Table 2.1: Example of a trade of two goods between two countries. Values of cell means the amount of labor (or hours of work) required to produce cloth and wine in Portugal and England.

Country	Product	
	cloth	wine
Portugal	90	80
England	100	120

and Portugal can obtain cloth which originally required 90 labor for 80 labor. In this way, both countries benefit from international trade.

However, in recent years, trade in intermediate goods, which did not exist at that time, has begun and flourished. In other words, there are forms of trade specializing in different industries and global value chains (GVCs) in the same industry to produce complex and sophisticated products. In addition, distance (as represented by the gravity model) and economic integration (such as that promoted by the EU and NAFTA) facilitate international trade.

Since the beginning of the 21st century, world GDP and trade have continued to increase, except during the economic crisis of 2009 (Fig. 2.1). The WIOD created by Timmer et al. [20] was used to

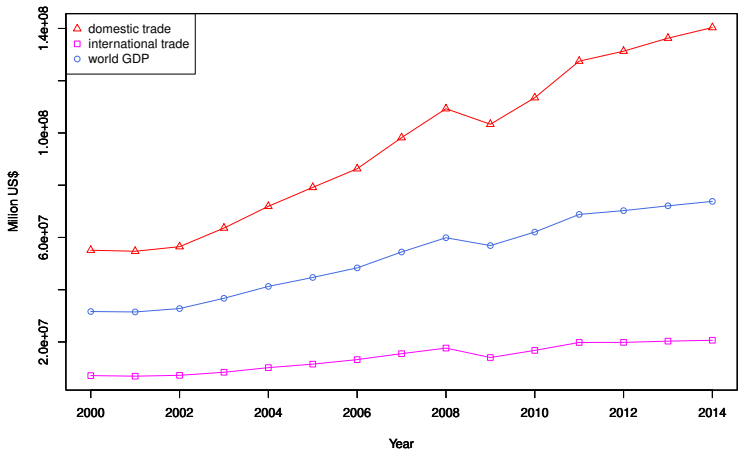


Fig. 2.1: The 15-year trends in international trade, domestic trade, and world GDP.

calculate the values in this figure. They showed the ratio of international trade to world GDP and pointed out that the role of trade in the international economy changed after the economic crisis in 2009 (Fig. 2.2). The ratio of international trade to world GDP has been increasing since 2001 before 2009, but has been stagnant since 2011, when the ratio recovered to its original level, and has been on a declining trend.

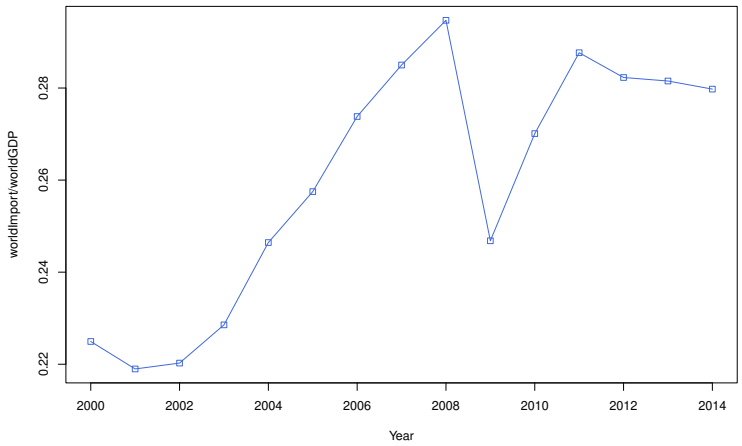


Fig. 2.2: The 15-year trend of international trade per unit of world GDP. After recovering in 2011, this ratio has been decreasing slightly to around 28%.

Many studies have been conducted on measuring international production structures. In the 21st century, the measurement of GVCs became a widely discussed topic after Hummels et al. [21] proposed the vertical specialization index. Moreover, the VAX and FVAiX indices were proposed by Johnson and Noguera [22], and Amador et al. [23], respectively. Koopman et al. [24] decomposed and classified the trade prices into nine terms and clarified double-counted terms.

The abovementioned progress has led to the development of international input–output (IO) tables. After Dietzenbacher et al. [25] and Timmer et al. [26] publicized the World Input–Output Database (WIOD), Cerina et al. [27] and Zhu et al. [28] analyzed the data for measuring GVCs network analysis methods. Los et al. [29] showed that regional value chains had been fragmented more rapidly than global ones in 1995–2011. According to Johnson and Noguera [30], over 40 years, the ratio of value-added to gross exports in non-manufacturing sectors rose, while that in manufacturing sectors fell by 20 percentage points; their study showed that RTAs led to such decline.

Due to international relationship problems in the economy, researchers in international organizations have been analyzing GVCs. Recently comprehensive summary reports of GVCs research have been published by the World Bank [31, 32]. According to these reports, GVCs research aims to address the misunderstanding of trade data and give international trade opportunities and export diversity to developing countries for economic growth [33]. As shown by Degain et al. [34], GVCs had been expanding until the global financial crisis, but they stopped growing in 2011 when they recovered from a decline in equipment. The GVCs expansion seen before the financial crisis has been interpreted as

China's accession to the WTO and participation in GVCs [33]. These GVCs research developments were described in detail by Amador and Cabral [35], and Inomata [36].

2.2.2 Network analysis on international economy

Economic activities are regarded as interactions among various economic agents. Network science is used to understand such a large number of interacting systems.

Network science is a field of study that was born from Watts & Strogatz's work on small-world networks [37], Albert et al.'s work showing that the order distribution of the World Wide Web follows a power law [38], and Barabasi & Albert's work modeling the power law of the order distribution that is universal to networks [39]. The term "network science" was introduced in a 2005 National Research Council report [6].

Networks appear in a variety of situations, such as links on web pages, accounts on social networking services, transportation networks, financial transactions, and cellular connections. Network science focuses on the structures common to these complex phenomena. In the study by Barabasi & Albert mentioned above, the scale-free nature common to networks is mathematically demonstrated through growth and preferential selection.

The studies related to international trade have also become the subject of research in network science due to the spread of international input-output tables. Initially, the scale-free characteristics of international trade networks were clarified [40–42]; then, the virtual nodes in these networks were examined using centrality indices and other measures, and changes over time were analyzed [43–45].

Ikeda et al. [46, 47] studied the international trade network of the WIOD using community analysis of modularity maximization, which combines the synchronization aspect of the G7 production network [48, 49]; then, they found stable sectoral communities that had emerged in 1995–2011.

From an institutional point of view, a study examining interregional agreements and geographic factors in international trade change found no evidence that the WTO has contributed to the increase in international trade and indicated that geographic factors are more significant than interregional agreements [50]. By contrast, other studies show that trade policies contribute to shaping trade networks [51], and the impact of distance by trade is decreasing in industrial sectors [52].

2.2.3 Economic integration in Asia-Pacific

While the EU is a prominent example of economic integration, East Asia and the Asia-Pacific region[1], where various initiatives are multi-layered, have also strengthened their international ties in recent

[1]In this thesis, we often refer the terms: Asia, East Asia, and Asia-Pacific. There are various definitions of the regions, and we do not strictly define them. However, we clarify the difference of their meanings as follows. Asia means all of the Asian countries which locate on Eurasia and islands from the Red Sea to the Pacific Ocean, from Indonesia to Russia. East Asia

years [53]. The development of regionalism commenced at the occasion of the end of the Cold War at the beginning of the 1990s and deepened the trend after the Asian financial crisis in the late 1990s [54]. In 1992, the Association of Southeast Asian Nations (ASEAN), which had previously consisted of Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, and Thailand, declared the establishment of the ASEAN Free Trade Area (AFTA) (Singapore Declaration) [55]. While starting to promote economic integration among the six countries, ASEAN admitted Vietnam in 1995, Lao People's Democratic Republic (PDR) and Myanmar in 1997, and Cambodia in 1999. Subsequently, ASEAN declared to establish the ASEAN Community at the 9th ASEAN Summit in 2003, signaling a commitment to promoting economic integration in the East Asian region. ASEAN has succeeded in concluding FTAs with neighboring countries since the 2000s. Further, East Asia and the Asia-Pacific region promoted the so-called mega-RTAs. One is the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP); the other is RCEP agreement which entered into force on December 30, 2018, and January 1, 2022, respectively.

Regionalism and regional integration have been broadly studied in the field of international relations [56]. The research trend has been firstly based on the economic and political integration of the European countries [57], then the deepening economic interdependence in the world [58], and shifted to the development of preferential trade agreements, mainly after the end of the Cold War [54, 59, 60]. In line with the studies, some studies have an interest in dividing them into countries that are considered to have been central (or leading) in their formation and their neighbors, meaning which country is taking regional leadership in East Asia and the Asia-Pacific [53, 61–64]. While this approach is persuasive as an individual argument, it is difficult to quantitatively answer to what extent the supposedly central country (including multiple countries) was central and whether it is truly considered more central than other countries.

In the literature, there are quantitative studies conducted by applying network analysis methods to political science and international relations [65, 66]. Some research has also been conducted to clarify the economic dynamics of the world as a whole from a micro perspective, based on the three factors of people, goods, and money [67]. Those studies analyzed using network science to quantitatively understand the complex relationships among many factors. Some studies also sought to quantitatively measure progress in regional economic integration. Sada and Ikeda analyzed international value-added networks created from international input-output tables and showed that there has been more substantial economic integration in the Pacific Rim than in Europe since the 2008–2009 Global Financial Crisis [68, 69]. This was the result of regionalism in East Asia and the Asia-Pacific region leading to economic integration, as well as the entry into force of the RTAs. However, while the trade data analysis revealed the results

mainly means China, Japan, (South and North) Korea, Mongolia, and Taiwan; however we use the term includes Southeast Asia in the thesis. Asia-Pacific means East Asia, South Asia and Oceania with the US.

of economic integration, the countries that contributed to the development of economic integration were unclear. It requires an analysis of multilateral cooperation not only from an economic perspective but also from a diplomatic perspective.

2.3 Research questions of Chapters 3–5

Looking back at studies of economic and regional integration, the qualitative narrative and historical accounts are the primary focus. Historical, cultural, and geographical differences have forced economic integration in the Asia-Pacific region to develop differently than in Europe, making comparisons between the regions difficult.

In this thesis, we would like to measure the extent to which Asia, which institutionally has yet to develop beyond the first stage, is in effect more economically connected than Europe and is moving toward further consolidation. We would also like to consider what initiatives are required of the economic sector from the standpoint of promoting more international economic linkages. With these interests in mind, we set the following three research questions.

1. Can we confirm the regional nature of economic integration (especially in Asia) based on international value-added relationships? If so, how has the degree of integration evolved over the course of the economic crisis in each region?

2. Can regional trends be captured from international events? Can the progress of economic integration in East Asia, where substantial economic integration is said to be underway, particularly in ASEAN as seen in the RCEP, be captured from event data? If so, when can progress be confirmed? Comparing each country's attitude toward regional cooperation, which countries are contributing the most?

3. Focusing on a country that is contributing to regional cooperation in Asia, are there contributions at the sectoral level in that country as well? What role can the sector play in further economic integration in the region and what should the sector and government do to achieve it?

Each of these questions is addressed in Chapters 3–5 of this thesis.

By utilizing data documenting recent global society, this study seeks to reduce the dimension from a qualitative understanding to a quantitatively simplified method. To this end, unlike the stages of economic integration by Balassa, *de facto* economic integration in a region is observed by the degree of mutual economic activity stimulated by the demand of other countries in that region, and the movement toward *de jure* economic integration is manifested in cooperative diplomatic events within that region.

Moreover, based on the quantitative results, we explore the role of a sector of a specific economy in economic integration. This is because in considering economic integration in Asia, where *de facto*

economic integration is underway, it is necessary to put the sector, consisting of economic actors, in the subject matter.

2.4 Analytical framework and process

To address the research questions in the previous section, this thesis follows the analytical framework shown in Fig. 2.3. This framework analyzes complex international relations and examines ideal sectorial business in economic integration through the two main phases of academic research and practical application.

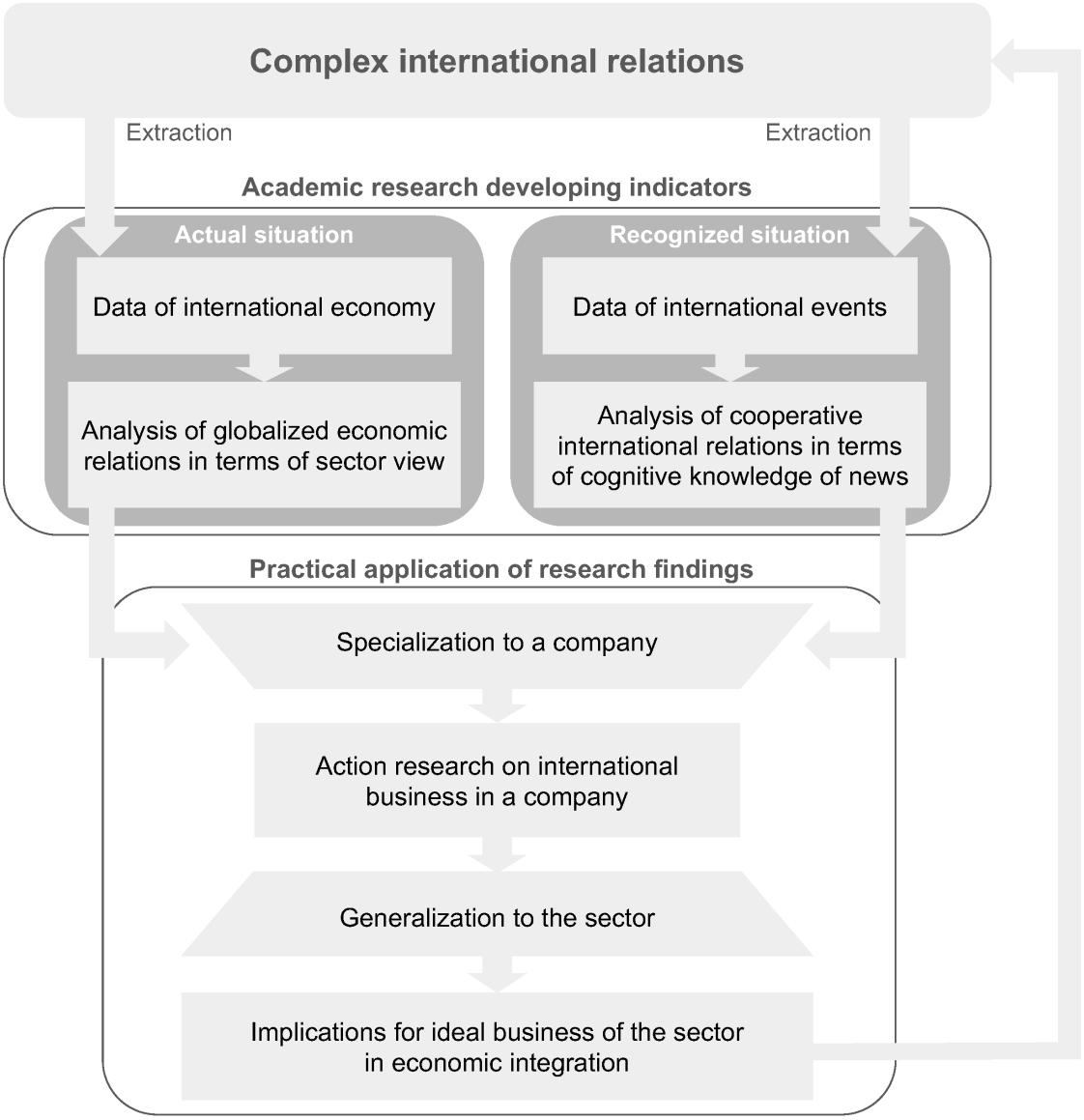


Fig. 2.3: Analytical framework.

The first and second questions in the previous section can be organized as the phase related to the quantification of international relations. This phase is defined as academic research, in which analysis

is conducted from a macroscopic perspective to identify issues, the scope of attention, and actors. In the first phase, we analyzed data that extracted and recorded one aspect of the international relations to study each of the actual and recognized situations of economic integration. In the study of the actual situation, data from the international economy are used to analyze the reality of economic relations globalized by sectoral perspectives; in the study of the recognized situation, data from international events reported in the news are analyzed to reveal regional cooperative diplomacy from the cognitive knowledge perspective.

Then, the practical application phase takes a practical approach from a microscopic perspective, targeting the regions and actors in complex international relations that require special attention for considering the future development of the regional economic integration. In this second phase, based on the academic research of the first phase and an understanding of the actors engaged in economic activities and the policy realities of the area concerned, the author attempts to practice an application for social implementation. Social implementation is an effort to solve social issues by applying research results. In this research, addressing sector issues, the author conducts a project that aims to solve a company's issues for expanding internationally in the sector. The project itself is positioned as a part of action research and by generalizing it, the author summarizes the implications for the sector and government's policy.

The practical research linking academia, citizens (economic actors in this study), and policy through these two phases is based on the approach of Human Survivability Studies [70, 71].

The analytical process undertaken in this thesis is shown in Fig. 2.4. The overall flow corresponds to Fig. 2.3, with the upper half representing macroscopic academic research and the lower half the more microscopic process of practical application. The upper left half, which analyzes the actual situation of economic integration, shows the process of calculating economic integration index by creating a value-added network from multi-regional input-output table. The economic integration index suggests stable development of economic integration around Asia, and furthermore, the existence of Russia, which is located between Europe and Asia, and the high value-added natural resource sector emerged as disturbance factors of regional integration. In the upper right-hand corner of the analysis of the recognized situation of economic integration, a political distance network was created by extracting bilateral cooperation-conflict relations from the event data. The network revealed that Japan, in particular, has contributed to regional cooperative diplomacy in Asia, and that positive relations toward economic integration in the Asia-Pacific region have been observed as a synchronous phenomenon.

Based on the suggestions from academic research with a macroscopic view, we conducted a project consisting of three main activities, focusing on s Japanese electric power company in order to approach more specific issues from a sectoral perspective in the energy sector. First, based on publicly available

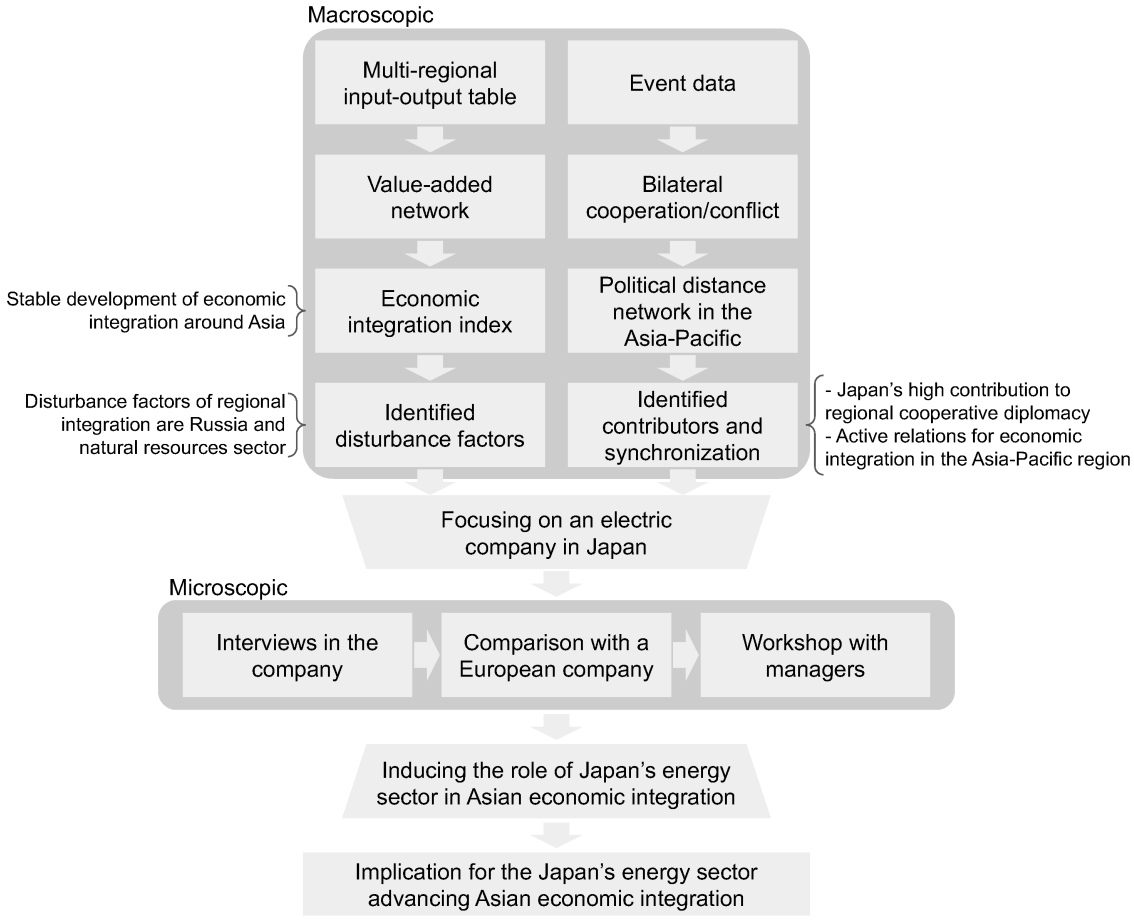


Fig. 2.4: Analytical process.

information, we interviewed employees in the International Business Division to investigate the company's international activities. Then, we compared the company's activities and strategies with those of a European electric power company and held a workshop at the International Business Division. At the workshop, the results of the survey and the tentative proposals obtained from the survey were presented, and feedback was obtained on the results. Through this opinion exchange, specific issues in the Japanese energy sector were identified, and the social roles that should be played in Asia, where economic integration is progressing, were clarified.

Chapter 3

International Value-added Analysis

This chapter addresses the quantification of economic integration in value-added and quantitatively assess the regional structure of the world economy and the extent to which economic integration has progressed. It then identifies regions and sectors to be analyzed in Chapters 4 and 5

3.1 Multi-regional IO data

We used the WIOD released in 2016, which includes 43 countries, and classifies the rest of the world (RoW) into 56 sectors. Codes of ISO 3166-1 alpha-3 express countries as Table 3.1. Here they were also classified into two regions, Europe and the Pacific Rims[1], and Table 3.2 shows all sectors in WIOD.

The WIOD has IO tables for 2000–2014. For each data, each country's sectors are assigned to names of row and column, and the trade value between them is figured in a million US dollars. There are columns of final demands for each country on the IO table's right side and a column of total output. On the downside, there are some rows, such as the value-added and a row of total output, which is the same as the total output of the right side column. The form of statistical tables had been established as international standards and compiled by governments and other organizations in developed countries where statistical data can be collected following these standards. The international IO table was created by combining the IO tables of each country so that there is no need to add import/export items necessary for domestic tables. WIOD was developed by a research group at the University of Groningen and released 2013 version for 40 countries and 35 sectors during 1995–2011 and 2016 version for 43 countries and 56 sectors during 2000–2014.

Table 3.3 shows a simplified example of the table. The IO table was developed by Leontief [8] and is now used globally to estimate economic and environmental conditions. In this chapter, we used the

[1] Although Brazil does not face the Pacific Ocean, we classified it as a Pacific Rim country. Norway, Switzerland and Turkey, which are not members of the EU, were also classified as Europe on the basis of their geographic relationships and conclusions of the EEA and EFTA.

Table 3.1: List of countries in WIOD and regional classification in this thesis.

ISO code	Short name	Region	ISO code	Short name	Region
AUS	Australia	Pacific Rim	IRL	Ireland	Europe
AUT	Austria	Europe	ITA	Italy	Europe
BEL	Belgium	Europe	JPN	Japan	Pacific Rim
BGR	Bulgaria	Europe	KOR	Korea	Pacific Rim
BRA	Brazil	Pacific Rim	LTU	Lithuania	Europe
CAN	Canada	Pacific Rims	LUX	Luxembourg	Europe
CHE	Switzerland	Europe	LVA	Latvia	Europe
CHN	China	Pacific Rim	MEX	Mexico	Pacific Rim
CYP	Cyprus	Europe	MLT	Malta	Europe
CZE	Czechia	Europe	NLD	Netherlands	Europe
DEU	Germany	Europe	NOR	Norway	Europe
DNK	Denmark	Europe	POL	Poland	Europe
ESP	Spain	Europe	PRT	Portugal	Europe
EST	Estonia	Europe	ROU	Romania	Europe
FIN	Finland	Europe	RUS	Russia	Pacific Rim
FRA	France	Europe	SVK	Slovakia	Europe
GBR	United Kingdom	Europe	SVN	Slovenia	Europe
GRC	Greece	Europe	SWE	Sweden	Europe
HRV	Croatia	Europe	TUR	Turkey	Europe
HUN	Hungary	Europe	TWN	Taiwan	Pacific Rim
IDN	Indonesia	Pacific Rim	USA	America	Pacific Rim
IND	India	Pacific Rim			

WIOD without RoW because we aim to analyze the relationships of specific countries.

Initially, there are five categories for each of the final demands, but they have been omitted in Table 3.3. The IO table's row direction shows the supply from the industry of the country, and the column direction shows the demand for the sector, and the final demand on the right side is the final point of all the transactions, as its name suggests. The sum of each row and each column is matched as total output.

IO tables are an economic analysis tool studied and developed by W.W. Leontief, who was awarded the Nobel Memorial Prize in Economics in 1973 for this IO analysis achievements. The IO table's basic concept is that the output produced in one sector is also inputted in another sector or part of the final demand, and these connected economies are considered as crossing threads of the cloth and expressed in a table. For example, processed foods, such as butter, are made by inputting milk, salt, machinery, and electricity. Milk is produced by putting feed and milking machines into cows, and other sectors also produce others: salt, machinery, and electricity. Butter, on the other hand, is also put in at bakeries, supermarkets, and other wholesalers and goes through a variety of processes before it is delivered to the consumer as a final good.

Using the IO table, the influence of a specific sector in the complex economic activities, in which each sector is interconnected through transactions, can be shown with concrete figures. In other words, we can calculate the value generated by a series of butter manufacturing industries, which includes not only the profits generated by butter but also the total value of the profits generated by butter in bakeries

Table 3.2: List of sectors in WIOD.

Code	Description
A01	Crop and animal production, hunting and related service activities
A02	Forestry and logging
A03	Fishing and aquaculture
B	Mining and quarrying
C10.C12	Manufacture of food products, beverages and tobacco products
C13.C15	Manufacture of textiles, wearing apparel and leather products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C19	Manufacture of coke and refined petroleum products
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31_C32	Manufacture of furniture; other manufacturing
C33	Repair and installation of machinery and equipment
D35	Electricity, gas, steam and air conditioning supply
E36	Water collection, treatment and supply
E37.E39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services
F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles
G46	Wholesale trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles
H49	Land transport and transport via pipelines
H50	Water transport
H51	Air transport
H52	Warehousing and support activities for transportation
H53	Postal and courier activities
I	Accommodation and food service activities
J58	Publishing activities
J59_J60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities
J61	Telecommunications
J62_J63	Computer programming, consultancy and related activities; information service activities
K64	Financial service activities, except insurance and pension funding
K65	Insurance, reinsurance and pension funding, except compulsory social security
K66	Activities auxiliary to financial services and insurance activities
L68	Real estate activities
M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities
M71	Architectural and engineering activities; technical testing and analysis
M72	Scientific research and development
M73	Advertising and market research
M74_M75	Other professional, scientific and technical activities; veterinary activities
N	Administrative and support service activities
O84	Public administration and defence; compulsory social security
P85	Education
Q	Human health and social work activities
R_S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organizations and bodies

Table 3.3: Multi-regional input–output table with two sectors in three countries.

		Intermediate demand						Final demand			Total output
		Country A		Country B		Country C					
		Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2	Country A	Country B	Country C	
Country A	Sector 1	$Z_{1,1}$	$Z_{1,2}$	$Z_{1,3}$	$Z_{1,4}$	$Z_{1,5}$	$Z_{1,6}$	$F_{1,1}$	$F_{1,2}$	$F_{1,3}$	T_1
	Sector 2	$Z_{2,1}$	$Z_{2,2}$	$Z_{2,3}$	$Z_{2,4}$	$Z_{2,5}$	$Z_{2,6}$	$F_{2,1}$	$F_{2,2}$	$F_{2,3}$	T_2
Country B	Sector 1	$Z_{3,1}$	$Z_{3,2}$	$Z_{3,3}$	$Z_{3,4}$	$Z_{3,5}$	$Z_{3,6}$	$F_{3,1}$	$F_{3,2}$	$F_{3,3}$	T_3
	Sector 2	$Z_{4,1}$	$Z_{4,2}$	$Z_{4,3}$	$Z_{4,4}$	$Z_{4,5}$	$Z_{4,6}$	$F_{4,1}$	$F_{4,2}$	$F_{4,3}$	T_4
Country C	Sector 1	$Z_{5,1}$	$Z_{5,2}$	$Z_{5,3}$	$Z_{5,4}$	$Z_{5,5}$	$Z_{5,6}$	$F_{5,1}$	$F_{5,2}$	$F_{5,3}$	T_5
	Sector 2	$Z_{6,1}$	$Z_{6,2}$	$Z_{6,3}$	$Z_{6,4}$	$Z_{6,5}$	$Z_{6,6}$	$F_{6,1}$	$F_{6,2}$	$F_{6,3}$	T_6
Value-added		V_1	V_2	V_3	V_4	V_5	V_6				
Total output		T_1	T_2	T_3	T_4	T_5	T_6				

and supermarkets.

It is used not only to understand the industrial structure, but also to estimate the economic effects of an event and environmental issues such as carbon dioxide emissions, and to calculate GDP and price indices [72]. For example, we can calculate how much an increase in the price of milk due to an epidemic in cattle will affect other sectors and an economic loss, or how much each sector's activity in a region emits carbon dioxide directly and indirectly. Thus, the IO table is a handy tool applied to various instances, but the difficulty lies in its creation. Since the data must be collected by dividing the sector items and calculating all the transactions between those sectors, expanding the area covered by the table and increasing sector classifications will be burdensome.

In Japan, the Ministry of Internal Affairs and Communications (MIC) has also created an input-output table for all of Japan in cooperation with ten government agencies, and the IO table for 2015 was released in June 2019. The creation of the IO table requires several years and a large budget. Furthermore, extending the scope beyond within not only a particular region, but also inter-regional, mostly international, construction of the table will require immense information because of differences in currency, criteria for sector classification, and culture [73].

After Leontief had created the US IO table as an empirical study of general equilibrium theory [7–9], world IO tables were developed through the regional IO table by Isard [74] in 1951, multi-regional input-output table (MRIO) by Chenery [75] in 1953 and Moses [76] in 1955, and model by Leontief and Strout [77] in 1963. Thus, inter-country input-output (ICIO) tables, which has 69 countries with 36 sectors for 11 years, and MRIO of Eora26, which has 190 countries with 26 sectors during 1990–2015, were made public by OECD [78] and Lenzen et al. [79–81] besides WIOD we used in this research. Indices of Foreign Value-Added calculated by Eora and WIOD are slightly different in the same country [82]. Data of Trade in Value-Added (TiVA), one of the indices of international trade calculated by the IO table, was made public by OECD and WTO. This history of IO table development was summarized by Miller and Blair [83] and Tamamura and Kuwamori [73].

3.2 Methods

3.2.1 Calculation for adjacency matrix of IVAN

To understand the complex structure of world economy, let each sector in each country be a node of a network, and the structure is analyzed by the network science method without losing sectoral information, which is one of the strength of the IO table. We construct the network using TiVA calculation.

Let n_c be the number of countries and n_s be the number of sectors in the IO table. Then, we define the $n_c n_s \times n_c n_s$ intermediate matrix $\mathbf{Z}$, $n_c n_s \times n_c$ final demand matrix $\mathbf{F}$, $1 \times n_c n_s$ value-added vector $\mathbf{V}$, and $1 \times n_c n_s$ total output matrix $\mathbf{T}$ below.

$$\mathbf{Z} = \begin{pmatrix} Z_{11} & Z_{12} & \cdots & Z_{1,n_c n_s} \\ Z_{21} & Z_{22} & \cdots & Z_{2,n_c n_s} \\ \vdots & \vdots & \ddots & \vdots \\ Z_{n_c n_s,1} & Z_{n_c n_s,2} & \cdots & Z_{n_c n_s,n_c n_s} \end{pmatrix}, \tag{3.1}$$

$$\mathbf{F} = \begin{pmatrix} F_{11} & F_{12} & \cdots & F_{1,n_c} \\ F_{21} & F_{22} & \cdots & F_{2,n_c} \\ \vdots & \vdots & \ddots & \vdots \\ F_{n_c n_s,1} & F_{n_c n_s,2} & \cdots & F_{n_c n_s,N} \end{pmatrix}, \tag{3.2}$$

$$\mathbf{V} = \begin{pmatrix} V_1 & V_2 & \cdots & V_{n_c} \end{pmatrix}, \tag{3.3}$$

$$\mathbf{T} = \begin{pmatrix} T_1 \\ T_2 \\ \vdots \\ T_{n_c n_s} \end{pmatrix}. \tag{3.4}$$

The sum of intermediates and final demands in a row direction equals total output,

$$T_i = \sum_j (Z_{ij} + F_{ij}) \tag{3.5}$$

for optimal $i = 1, 2, \ldots, n_c n_s$. Using these matrices, furthermore, we defined the coefficient matrix

$\mathbf{A} = \mathbf{Z}/\mathbf{T}^\top$, which can be represented as:

$$\begin{aligned}\mathbf{A} &= \begin{pmatrix} \frac{Z_{11}}{T_1} & \frac{Z_{12}}{T_2} & \cdots & \frac{Z_{1,n_cn_s}}{T_{n_cn_s}} \\ \frac{Z_{21}}{T_1} & \frac{Z_{22}}{T_2} & \cdots & \frac{Z_{2,n_cn_s}}{T_{n_cn_s}} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{Z_{n_cn_s,1}}{T_1} & \frac{Z_{n_cn_s,1}}{T_2} & \cdots & \frac{Z_{n_cn_s,n_cn_s}}{T_{n_cn_s}} \end{pmatrix} \\ &= \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1,n_cn_s} \\ A_{21} & A_{22} & \cdots & A_{2,n_cn_s} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n_cn_s,1} & A_{n_cn_s,2} & \cdots & A_{n_cn_s,n_cn_s} \end{pmatrix}. \end{aligned} \tag{3.6}$$

Therefore,

$$\mathbf{T} = \mathbf{A} \cdot \mathbf{T} + \mathbf{D} \tag{3.7}$$

where $\mathbf{D}$ is $1 \times n_cn_s$ row vector for optimal $j = 1, 2, \ldots, n_cn_s$, satisfies

$$D_j = \sum_i F_{ij}. \tag{3.8}$$

Moreover, let $\mathbf{I}$ be $n_cn_s \times n_cn_s$ identity matrix, and the equation can be transformed into:

$$\begin{aligned}\mathbf{T} &= (\mathbf{I} - \mathbf{A})^{-1} \cdot \mathbf{D} \\ &\equiv \mathbf{L} \cdot \mathbf{D}, \end{aligned} \tag{3.9}$$

where the matrix $\mathbf{L}$ is called Leontief inverse, which means trade prices induced by a unit of final demand since total output vector $\mathbf{T}$ is derived from multiplying $\mathbf{L}$ by final demand vector $\mathbf{D}$ on the right-hand side of $\mathbf{L}$.

The Leontief inverse evaluates the sum of ripple effects of productions on trade. To explain this adequately, we consider the case where there is a final demand of f_2 dollar in only Sector 2. In this case, the vector of the direct effect $\mathbf{E}$ on each country-sector is:

$$\begin{pmatrix} E_1 \\ E_2 \\ E_3 \\ \vdots \\ E_{n_cn_s} \end{pmatrix} = \begin{pmatrix} 0 \\ f_2 \\ 0 \\ \vdots \\ 0 \end{pmatrix}. \tag{3.10}$$

In other words, only Sector 2 produces f_2 dollar's worth of goods in demand. However, when Sector

2 trades with other sectors, ripple effects in which production f_2 in Sector 2 induces productions in others happen. Multiplying a vector of direct production effect by the right-hand to coefficient matrix $\mathbf{A}$, production induced by the first indirect effect are:

$$\begin{aligned}\mathbf{A}\cdot\mathbf{E} &= \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1,n_cn_s} \\ A_{21} & A_{22} & \cdots & A_{2,n_cn_s} \\ A_{31} & A_{32} & \cdots & A_{3,n_cn_s} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n_cn_s,1} & A_{n_cn_s,2} & \cdots & A_{n_cn_s,n_cn_s} \end{pmatrix} \cdot \begin{pmatrix} 0 \\ f_2 \\ 0 \\ \vdots \\ 0 \end{pmatrix} \\ &= \begin{pmatrix} f_2A_{12} \\ f_2A_{22} \\ f_2A_{32} \\ \vdots \\ f_2A_{n_cn_s,2} \end{pmatrix}. \end{aligned} \tag{3.11}$$

In the same way, the second indirect effect of production in Sector 2 can be written

$$\begin{aligned}\mathbf{A}^2\cdot\mathbf{E} &= \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1,n_cn_s} \\ A_{21} & A_{22} & \cdots & A_{2,n_cn_s} \\ A_{31} & A_{32} & \cdots & A_{3,n_cn_s} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n_cn_s,1} & A_{n_cn_s,2} & \cdots & A_{n_cn_s,n_cn_s} \end{pmatrix} \cdot \begin{pmatrix} f_2A_{12} \\ f_2A_{22} \\ f_2A_{32} \\ \vdots \\ f_2A_{NK,2} \end{pmatrix} \\ &= f_2 \begin{pmatrix} A_{12}A_{11} + A_{22}A_{12} + \cdots + A_{n_cn_s,2}A_{1,n_cn_s} \\ A_{12}A_{21} + A_{22}A_{22} + \cdots + A_{n_cn_s,2}A_{2,n_cn_s} \\ A_{12}A_{31} + A_{22}A_{32} + \cdots + A_{n_cn_s,2}A_{3,n_cn_s} \\ \vdots \\ A_{12}A_{n_cn_s,1} + A_{22}A_{n_cn_s,2} + \cdots + A_{n_cn_s,2}A_{n_cn_s,n_cn_s} \end{pmatrix} \end{aligned} \tag{3.12}$$

and the indirect effects are followed infinitely, such as the tenth effect and hundredth effect. However, the indirect effects converges to zero because of $0 \leqq \mathbf{A}_{ij} \leqq 1$ where $i, j = 1, 2, \ldots, n_cn_s$. Therefore the sum of these ripple effects also converge to a value that can be written

$$\begin{aligned}\mathbf{ID} + \mathbf{AD} + \mathbf{A}^2\mathbf{D} + \cdots + \mathbf{A}^n\mathbf{D} + \cdots &= (\mathbf{I} - \mathbf{A})^{-1}\cdot\mathbf{D} \\ &= \mathbf{L}\cdot\mathbf{D} \end{aligned} \tag{3.13}$$

as a matrix equation. Leontief inverse $\mathbf{L}$ means a matrix of prices induced by a unit of final demand in

each country–sector.

Using a value-added vector and a total output vector, value-added coefficient vector $\mathbf{C} = \mathbf{V}/(\mathbf{T})^{\top}$ is transformed to:

$$\begin{aligned}\mathbf{C} &= \begin{pmatrix} \frac{V_{11}}{T_1} & \frac{V_{12}}{T_2} & \cdots & \frac{V_{1,n_c n_s}}{T_{n_c n_s}} \end{pmatrix} \\ &= \begin{pmatrix} C_1 & C_2 & \cdots & C_{n_c n_s} \end{pmatrix} \end{aligned} \tag{3.14}$$

as a matrix equation. Therefore, we calculate an induced value-added vector $\hat{\mathbf{C}}\mathbf{L}\mathbf{D}$ by a vector $\mathbf{L}\mathbf{D}$ left-hand multiplied by the $n_c n_s \times n_c n_s$ diagonal matrix $\hat{\mathbf{C}}$, where the diagonal components are the vector $\mathbf{C}$ and $\mathbf{L}$ is well-known Leontief matrix which calculated by $(\mathbf{I} - \mathbf{A})^{-1}$, where $\mathbf{I}$ is the identity matrix. In this thesis, we use '^' as a symbol of diagonal matrix.

Then, the adjacency matrix of the global value-added network (GVAN) $\mathbf{G}$ is calculated as

$$\boldsymbol{G} = \hat{\mathbf{C}}\mathbf{L}\hat{\mathbf{D}} = \begin{pmatrix} C_1 L_{11} D_1 & C_1 L_{12} D_2 & \cdots & C_1 L_{1,n_c n_s} D_{n_c n_s} \\ C_2 L_{21} D_1 & C_2 L_{22} D_2 & \cdots & C_2 L_{2,n_c n_s} D_{n_c n_s} \\ \vdots & \vdots & \ddots & \vdots \\ C_{n_c n_s} L_{n_c n_s,1} D_1 & C_{n_c n_s} L_{n_c n_s,2} D_2 & \cdots & C_{n_c n_s} L_{n_c n_s,n_c n_s} D_{n_c n_s} \end{pmatrix}, \tag{3.15}$$

where $\hat{\mathbf{D}}$ is a diagonal matrix whose diagonal components are the vector $\mathbf{D}$. This operation $\hat{\mathbf{C}}\mathbf{L}\hat{\mathbf{D}}$ calculates the value called trade in value-added (TiVA) [84]. Eliminating components of 43 on-diagonal 56×56 blocks (which mean domestic components) as zero from $\mathbf{G}$, we obtained the IVAN's adjacency matrix $\mathbf{Y}$. This matrix represents the sum of all the ripple effects of value-added induced by the final demand in foreign sectors. The GVAN and IVAN nodes comprise 56 sectors in 43 countries. Tables 3.1 and 3.2 list these countries and sectors.

The right side of Eq.3.2.1 is a general equation for measuring value-added, which is, for example, written as eq. (7) in Wang et al. [85], and $\hat{\mathbf{C}}\mathbf{L}\mathbf{D}$ is written as eq. (3.2') in Tamamura et al. [73], which is also the same as TiVA [84]. However, this calculation is different from similar research, one which measured effects of value-added from WIOD such as Frohm E. & Gunnella V. [86], Zhu Z. et al. [28], and Amador et al. [87, 88]. Frohm E. & Gunnella V. used $\hat{\mathbf{C}}\mathbf{L}\hat{\mathbf{T}}$ matrix as a value-added contribution to total output [86] where $\hat{\mathbf{T}}$ is a diagonal matrix which has $\mathbf{T}$ vector as a diagonal component, and Zhu et al. used $\hat{\mathbf{C}}\mathbf{L}$ matrix as a value-added contribution matrix [28] which was not multiplied by final demand on the right-hand side against $\mathbf{Y}$ matrix we used. FVAiX index used by Amador is similar to the Vertical Specialization index [21], which calculates Value-Added in Trade (which is different from TiVA [84]) explained in Foster-McGregor & Stehrer [89].

However, $\mathbf{L}$ is a matrix for calculating production ripple effects induced by final demand. It means

Table 3.4: An example of a multi-regional input-output table which includes only two sectors in three countries.

		Intermediate demand						Final demand			Total Output
		Country A		Country B		Country C					
		Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2	Country A	Country B	Country C	
Country A	Sector 1	50	5	60	0	40	0	65	20	30	270
	Sector 2	5	30	5	50	0	40	55	30	45	260
Country B	Sector 1	10	0	105	10	80	5	5	55	20	290
	Sector 2	0	55	10	200	0	75	10	70	30	450
Country C	Sector 1	15	0	40	0	135	10	10	25	85	320
	Sector 2	0	40	5	55	10	100	5	40	75	330
Value-Added		190	130	65	135	55	100				
Total Output		270	260	290	450	320	330				

multiplying exports or total output instead of final demand is not suitable for analyzing the actual situation of international trade. There is another option of not multiplying anything to $\mathbf{L}$ on the right-hand side, $\hat{\mathbf{C}}\mathbf{L}$, but this means that connections of value-added efficiency are unrelated to demand. That is why we chose the most basic calculation following a method on IO analysis for constructing a value-added network that is genuinely produced. Moreover, focusing on economic activities between countries, we constructed IVAN as $\mathbf{Y}$, which eliminated components of trade within each country from $\hat{\mathbf{C}}\mathbf{L}\hat{\mathbf{D}}$ is the adjacency matrix.

In summary, IVANs are directed and weighted networks constructed by the adjacency matrix $\mathbf{Y}$, which does not have domestic links. By contrast, GVANs have domestic and international links. In the example of Table 3.3, $\mathbf{Y}$ is written as

$$\mathbf{Y} = \begin{pmatrix} 0 & 0 & G_{1,3} & G_{1,4} & G_{1,5} & G_{1,6} \\ 0 & 0 & G_{2,3} & G_{2,4} & G_{2,5} & G_{2,6} \\ G_{3,1} & G_{3,2} & 0 & 0 & G_{3,5} & G_{3,6} \\ G_{4,1} & G_{4,2} & 0 & 0 & G_{3,5} & G_{3,6} \\ G_{5,1} & G_{5,2} & G_{5,3} & G_{5,4} & 0 & 0 \\ G_{6,1} & G_{6,2} & G_{6,3} & G_{6,4} & 0 & 0 \end{pmatrix}. \tag{3.16}$$

3.2.2 Illustrative example of calculating IVAN

Here we show an example of a world IO table (Table 3.4) as two sectors in three countries and its value-added network using. From the table, matrix $\mathbf{Z}$, $\mathbf{F}$, and vector $\mathbf{V}$, $\mathbf{T}$ are:

$$\mathbf{Z} = \begin{pmatrix} 50 & 5 & 60 & 0 & 40 & 0 \\ 5 & 30 & 5 & 50 & 0 & 40 \\ 10 & 0 & 105 & 10 & 80 & 5 \\ 0 & 55 & 10 & 200 & 0 & 75 \\ 15 & 0 & 40 & 0 & 135 & 10 \\ 0 & 40 & 5 & 55 & 10 & 100 \end{pmatrix}, \tag{3.17}$$

$$\mathbf{F} = \begin{pmatrix} 65 & 20 & 30 \\ 55 & 30 & 45 \\ 5 & 55 & 20 \\ 10 & 70 & 30 \\ 10 & 25 & 85 \\ 5 & 40 & 75 \end{pmatrix}, \tag{3.18}$$

$$\mathbf{V} = \begin{pmatrix} 190 & 130 & 65 & 135 & 55 & 100 \end{pmatrix}, \tag{3.19}$$

$$\mathbf{T} = \begin{pmatrix} 270 \\ 260 \\ 290 \\ 450 \\ 320 \\ 330 \end{pmatrix}. \tag{3.20}$$

Then, calculate matrix $\mathbf{A}$ as:

$$\mathbf{A} = \begin{pmatrix} 0.185 & 0.019 & 0.206 & 0 & 0.125 & 0 \\ 0.018 & 0.115 & 0.017 & 0.111 & 0 & 0.121 \\ 0.037 & 0 & 0.362 & 0.022 & 0.25 & 0.015 \\ 0 & 0.211 & 0.034 & 0.444 & 0 & 0.227 \\ 0.055 & 0 & 0.137 & 0 & 0.421 & 0.030 \\ 0 & 0.153 & 0.017 & 0.122 & 0.031 & 0.303 \end{pmatrix}, \tag{3.21}$$

and get Leontief Inverse:

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$$
$$= \begin{pmatrix} 1.287 & 0.048 & 0.533 & 0.043 & 0.512 & 0.056 \\ 0.037 & 1.268 & 0.086 & 0.330 & 0.063 & 4332 \\ 0.138 & 0.049 & 1.798 & 0.107 & 0.814 & 0.118 \\ 0.032 & 0.648 & 0.193 & 2.116 & 0.134 & 0.812 \\ 0.158 & 0.037 & 0.486 & 0.053 & 1.980 & 0.120 \\ 0.024 & 0.396 & 0.119 & 0.449 & 0.146 & 1.659 \end{pmatrix}. \tag{3.22}$$

Using matrix $\mathbf{L}$ and

$$\hat{\mathbf{C}} = \begin{pmatrix} 0.703 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.224 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.171 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.303 \end{pmatrix}, \tag{3.23}$$

$$\hat{\mathbf{D}} = \begin{pmatrix} 115 & 0 & 0 & 0 & 0 & 0 \\ 0 & 130 & 0 & 0 & 0 & 0 \\ 0 & 0 & 80 & 0 & 0 & 0 \\ 0 & 0 & 0 & 110 & 0 & 0 \\ 0 & 0 & 0 & 0 & 120 & 0 \\ 0 & 0 & 0 & 0 & 0 & 120 \end{pmatrix}, \tag{3.24}$$

the adjacency matrix of IVAN in this example is:

$$\mathbf{Y} = \begin{pmatrix} 0 & 0 & 30.032 & 3.357 & 43.246 & 4.761 \\ 0 & 0 & 3.476 & 18.169 & 3.816 & 19.975 \\ 3.567 & 1.438 & 0 & 0 & 21.899 & 3.18 \\ 1.1287 & 25.276 & 0 & 0 & 4.85 & 29.262 \\ 3.123 & 0.83 & 6.692 & 1.01 & 0 & 0 \\ 0.851 & 15.618 & 2.896 & 14.969 & 0 & 0 \end{pmatrix}, \tag{3.25}$$

except for the intra-country loops from $\mathbf{Y}$. Thus, network (a) in Fig. 3.1 is created from adjacency matrix $\mathbf{Z}$ of Eq. (3.17) and network (b) is created from adjacency matrix $\hat{\mathbf{Y}}$ of Eq. (3.25). It clarifies the

(a) Trade network

(b) Value added network

Fig. 3.1: Examples of the trade network and value-added network. A_1 means sector 1 in country A as shown in table 3.4. We can see the difference in network topology from a table.

difference between a trade network and a value-added network.

3.2.3 Community detection

To know how each network has developed a community structure, we apply community analysis to IVANs. Some community analysis methods have been developed, and their features were summarized by Fortunato and Hric [90] and Barabási [6]. We used Infomap, which is an application of random walk and Huffman coding [91] to analyze the communities in the studied network [92]. Let a random walker run in the network where this analysis will be applied; the random walker transitions with a probability dependent on the path weights (plus a constant transposition probability) [93]. The map equation establishes communities and renames the node in which the random walk track's code length is minimized. In comparison, the well-known method of modularity maximization clusters a network by counting nodes' link weights, inflows, and outflows, whereas the map equation method clusters a network by the remaining time of the random walker in the nodes; this difference leads to variations in results [92, 94].

We explain the Infomap method of Rosvall, M. et al. [94] in this subsection. The feature of the method is that an optimization problem for community segmentation in a network is replaced with a problem for minimization of code length describing a segmented network.

Consider segmentation of a network composed of n nodes into m communities with a community partition M. Let the mean code length of segmented communities (index code length) be $H(\mathcal{Q})$ and the mean code length of nodes within a community i be $H(\mathcal{P}^i)$, then by use of Shannon's source coding

theorem [95], average description length of a single step of the random walk $L(M)$ is:

$$L(\mathsf{M}) = q_{\curvearrowright} H(\mathcal{Q}) + \sum_{i=1}^{m} p^i_{\circlearrowright} H(\mathcal{P}^i) \tag{3.26}$$

where $q_{\curvearrowright}$ is a probability which the random walker moves to another community and $p^i_{\circlearrowright}$ is a probability that the random walker moves within a community $i = 1, 2, \ldots, m$ plus an exit probability from i. Each of the probabilities is defined as:

$$q_{\curvearrowright} = \sum_{i=1}^{m} q_{i\curvearrowright}, \tag{3.27}$$

$$p^i_{\circlearrowright} = \sum_{\alpha \in i} p_\alpha + q_{i\curvearrowright}, \tag{3.28}$$

where p_α is a probability of visiting node $\alpha = 1, 2, \ldots, n$ and $q_{i\curvearrowright}$ is an exit probability from community i. Equation (3.26) is called the map equation [94]. Also, using p_α and $q_{i\curvearrowright}$, the entropy of index code length $H(\mathcal{Q})$ and module code length $H(\mathcal{P}^i)$ are expressed as:

$$H(\mathcal{Q}) = -\sum_{i=1}^{m} \frac{q_{i\curvearrowright}}{\sum_{j=1}^{m} q_{j\curvearrowright}} \log \left(\frac{q_{i\curvearrowright}}{\sum_{j=1}^{m} q_{j\curvearrowright}} \right), \tag{3.29}$$

$$\begin{aligned} H(\mathcal{P}^i) = &- \frac{q_{i\curvearrowright}}{q_{i\curvearrowright} + \sum_{\beta \in i} p_\beta} \log \left(\frac{q_{i\curvearrowright}}{q_{i\curvearrowright} + \sum_{\beta \in i} p_\beta} \right) \\ &- \sum_{\alpha \in i} \frac{p_\alpha}{q_{i\curvearrowright} + \sum_{\beta \in i} p_\beta} \log \left(\frac{p_\alpha}{q_{i\curvearrowright} + \sum_{\beta \in i} p_\beta} \right), \end{aligned} \tag{3.30}$$

which is explained by the use of probabilities p_α and $q_{i\curvearrowright}$. Next, consider p_α and $q_{i\curvearrowright}$ in detail.

The network we applied the map equation in this study is weighted and directed. When a network is directed, a random walker on the network tend to be trapped in a community or node and disable to move across the network. Therefore, considering the transition probability of a random walker, Rosvall et al. make a random walker teleport to any node in the network with probability τ. They call teleporting random walkers random surfers and assume that their movements can be explained by irreducible and acyclic Markov chains (i.e., they are ergotic). The random surfer moves along the link with a remaining probability $1 - \tau$ and transitions from node α to adjacent node β with probability $w_{\alpha\beta}$, where $w_{\alpha\beta}$ is the weight of the link from the node α to the adjacent node β and is normalized by $\sum_\beta w_{\alpha\beta} = 1$.

Considering the above, the probability of exiting the community i is:

$$q_{i\curvearrowright} = \tau \frac{n - n_i}{n} \sum_{\alpha \in i} p_\alpha + (1 - \tau) \sum_{\alpha \in i} \sum_{\beta \notin i} p_\alpha w_{\alpha\beta}, \tag{3.31}$$

where n_i is the number of nodes in community i. The first term is a probability of teleporting to a node

in a community other than the community i, and the second term is a probability of moving to a node in aother community through a link which the node has.

In doing the analysis, the teleportation probability was set $\tau = 0.15$ because the default value of 0.15 used for PageRank [96] is also valid for the map equation [93]. Let initial probabilities that random surfer is on a node α be $p_\alpha = 1/n$. On each trial, a transferred probability $1 - \tau$ is distributed proportionally to the link weight $w_{\alpha\beta}$ among nodes β adjacent to the node α where there is a random surfer, and the rest is distributed equally among all nodes in the network. The trials continue until the sum of the absolute differences between the sequential estimates of p_α is 10^{-15} and the probability distribution converges.

Segmentation by map equation (Eq.3.26) may produce multilevel communities. The situation is explained by expanding M and m in Eq.3.26 into submap M^i and submodule m^{ij} [97]. The interpretation of the communities is difficult though multilevel communities are natural [98].

Using the map equation in https://www.mapequation.org/apps.html, it calculates PageRank and can plot an alluvial diagram with connecting communities in a network at each time [99, 100].

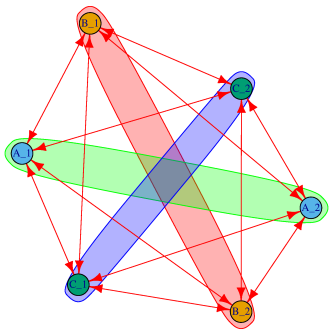
3.2.4 Illustrative example of community detection

Constructing an edge list of $\mathbf{Y}$ and apply it to a software of the map equation (see [99]), a weighted directed network IVAN is analyzed as Fig. 3.2c which is divided into two communities: sector one community (blue) and sector two community (red). Minimizing the code length describing the random surfer's movement on the network decides this kind of segmentation of the network. Since this method depends on the probability in a try of iteration, each analysis was iterated five times and chose the result with a minimum code length.

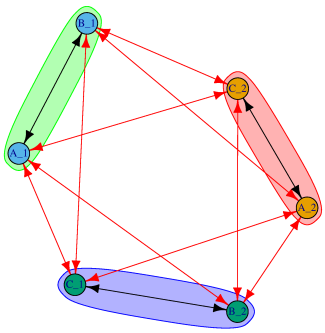
In these examples, we used the Monte Carlo simulation to run a random walker on the network for 100 steps:

$$
\begin{aligned}
&\text{A\_2} \to \text{B\_2} \to \text{C\_2} \to \text{B\_2} \to \text{C\_1} \to \text{A\_1} \to \text{B\_1} \to \text{C\_2} \to \text{B\_2} \to \text{A\_2} \to \text{C\_1} \to \text{B\_1} \\
&\to \text{C\_1} \to \text{B\_2} \to \text{C\_2} \to \text{A\_2} \to \text{C\_2} \to \text{B\_2} \to \text{A\_2} \to \text{C\_1} \to \text{B\_2} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \\
&\to \text{B\_1} \to \text{C\_1} \to \text{B\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{B\_1} \to \text{C\_1} \\
&\to \text{B\_1} \to \text{A\_1} \to \text{C\_1} \to \text{A\_2} \to \text{C\_2} \to \text{A\_1} \to \text{B\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{B\_1} \to \text{A\_1} \\
&\to \text{C\_2} \to \text{A\_2} \to \text{B\_2} \to \text{C\_2} \to \text{B\_1} \to \text{A\_2} \to \text{C\_1} \to \text{B\_2} \to \text{A\_2} \to \text{C\_2} \to \text{B\_2} \to \text{C\_2} \\
&\to \text{B\_2} \to \text{A\_2} \to \text{B\_1} \to \text{C\_1} \to \text{B\_1} \to \text{C\_1} \to \text{A\_1} \to \text{B\_1} \to \text{C\_1} \to \text{A\_1} \to \text{B\_1} \to \text{C\_1} \\
&\to \text{B\_1} \to \text{C\_1} \to \text{B\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{A\_1} \to \text{C\_1} \to \text{B\_1} \to \text{C\_1} \\
&\to \text{A\_1} \to \text{B\_1} \to \text{C\_2} \to \text{B\_2} \to \text{A\_2} \to \text{C\_2} \to \text{A\_2} \to \text{C\_2} \to \text{A\_2} \to \text{C\_2} \to \text{B\_2} \to \text{C\_2} \\
&\to \text{A\_2} \to \text{B\_2} \to \text{C\_2} \to \text{B\_1},
\end{aligned}
$$

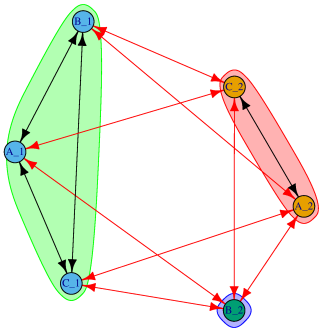
where $\to$ indicates random walker's movement between the nodes. After the 100 steps above, we recorded the movement and applied four community cases into the description of movement; then, we



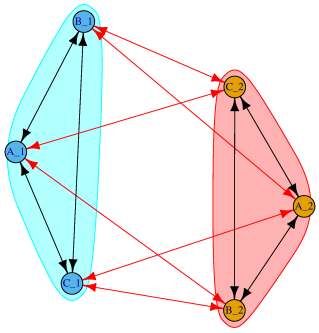
(a) Each pair in a country is a community



(b) Each two nodes is a community



(c) Three kinds of communities, and one of which has three nodes.



(d) Two communities have three nodes, which is a final result of community analysis.

Fig. 3.2: Illustrative examples of community detection. Using Huffman coding and map equation, we calculated the average code length of each network. When letting a random walker move on the path with the probability of path weight, per-step description length of (a) is 4.58, of (b) is 3.99, of (c) is 2.75 and of (d) is 2.52.

compared the average description length of each division. In the movement, each visiting probability p_α is A_1: 0.15; A_2: 0.13; B_1: 0.18; B_2: 0.13; C_1: 0.26; C_2: 0.15. And among the nodes, $q_{i\curvearrowright}$ and $p^i_{\circlearrowright}$ of each situation in Fig.3.2 can be calculated below by assigning binary digits names to the nodes and communities using Huffman coding.

(a) Let A_1 & A_2 be 10 & 11 in community-11, B_1 & B_2 be 10 & 11 in community-10 and C_1 & C_2 be 10 & 11 in community-0, and let the exit code in each community be 0. Thus, the probabilities are: $q_{10\curvearrowright} = 0.28, q_{11\curvearrowright} = 0.31, q_{0\curvearrowright} = 0.41$; $p^{11}_{\circlearrowright} = 0.15 + 0.13 + 0.28$, $p^{10}_{\circlearrowright} = 0.18 + 0.13 + 0.31, p^{0}_{\circlearrowright} = 0.26 + 0.15 + 0.41$, and the average description length is 4.58.

(b) Let A_1 & B_1 be 10 & 11 in community-11, A_2 & C_2 be 10 & 11 in community-10 and B_2 & C_1 be 10 & 11 in community-0, and let the exit code in each community be 0. Thus, the probabilities are: $q_{10\curvearrowright} = 0.26, q_{11\curvearrowright} = 0.17, q_{0\curvearrowright} = 0.34$; $p^{11}_{\circlearrowright} = 0.15 + 0.18 + 0.26, p^{10}_{\circlearrowright} =$

$0.13 + 0.15 + 0.17, p^0_{\circlearrowleft} = 0.13 + 0.26 + 0.34$, and the average description length is 3.96.

(c) Let A_1 & B_1 & C_1 be 00 & 01 & 10 in community-0, A_2 & C_2 be 10 & 11 in community-10 and B_2 be 11, and let the exit code in community-0 and community-10 be 11 and 0, respectively. Thus, the probabilities are: $q_{0\curvearrowright} = 0.08, q_{10\curvearrowright} = 0.17$; $p^0_{\circlearrowleft} = 0.15 + 0.18 + 0.26 + 0.08, p^{10}_{\circlearrowleft} = 0.13 + 0.15 + 0.17, p_{11} = 0.13$, and the average description length is 2.76.

(d) Let A_1 & B_1 & C_1 be 00 & 01 & 10 in community-0, A_2 & B_2 & C_2 be 00 & 01 & 10 in community-1, and let exit code in each community be 11. The probabilities are: $q_{0\curvearrowright} = 0.08, q_{1\curvearrowright} = 0.09$; $p^0_{\circlearrowleft} = 0.15 + 0.18 + 0.26 + 0.08, p^{10}_{\circlearrowleft} = 0.13 + 0.13 + 0.15 + 0.17$, and the average description length is 2.52.

Thus, the average description length of (d) is minimum. When the map equation applies to the value-added network (Fig. 3.1b), the result is (d) in Fig. 3.2d, which is the same as the Monte Carlo simulation result above.

3.2.5 Structural characteristics of networks

Specific indices reveal network characteristics. We used eleven indices: (1) density, reciprocity, diameter, average path length, average betweenness, assortativity, average in-degree, and average out-degree are calculated as unweighted and directed networks; (2) in-strength and out-strength are weighted and directed ones; (3) the clustering coefficient is calculated as unweighted and undirected [6].

The density of a network is the proportion of the number of links to the number of maximum possible links in the network. Thus, it is calculated as $l/n(n-1)$, where n and l are the numbers of nodes and links in the network, respectively.

The reciprocity of a network is the proportion of the reciprocal links to the total number of links in the network. It is calculated as l_m/l, where l_m is the number of reciprocal links (two directed links between two nodes in the network).

The clustering coefficient indicates how each node is connected to its neighbors. The clustering coefficient c_i of a node i is calculated as $c_i = l_i/k_i(k_i-1)$, where l_i (k_i) is the number of links (neighbors) of node i. Thus, the clustering coefficient of a network is $\sum c_i/n$.

The diameter of a network is the maximum number of shortest paths for all pairs of nodes in the network.

The average path length of a network is the mean of the shortest path length in the network: $\sum_{i,j;i\neq j} d_{ij}/n(n-1)$, where d_{ij} is the shortest path length between nodes i and j.

The betweenness is calculated by the number of the shortest paths through a node. The betweenness b_i of node i is $\sum_{j\neq k\neq i} s_{jk}(i)/s_{jk}$, where s_{jk} is the number of the shortest paths between nodes j and k,

and $s_{jk}(i)$ is the number of the shortest paths through node i. Therefore, the average betweenness of a network is the mean of b_i.

The degree of a node means the sum of the number of links in the node. There are two kinds of degrees in a directed network, namely, in-degree and out-degree, which are the sums of the links to the node from the other nodes (inflow) and links from the node to other nodes (outflow), respectively. Thus, the in-degree and out-degree are represented as: $\sum_j l_{j,i}$ and $\sum_j l_{i,j}$, respectively, where $l_{i,j}$ is a link (flow) from node i to node j.

The assortativity of a network scores the similarity of the connections in the network as -1 to 1, which is calculated by $(\sum_{jk} jke_{jk} - \mu)/\sigma^2$, where e_{jk} is the probability of the two nodes of degrees j and k are at the end of a randomly chosen link, and μ and σ are the mean and standard deviation, respectively, of the excess degree distribution. Assortativity close to -1 (1) indicates that high-degree nodes in a network are connected to low-degree nodes (high-degree nodes).

The strength of a node is the total weight of the links in the node. There are two kinds of strength in a directed network, namely, in-strength and out-strength, which are the summed weights of the inflow and outflow, respectively. Thus, the in-strength and out-strength are represented as: $\sum_j l^w_{j,i}$ and $\sum_j l^w_{i,j}$, respectively, where $l^w_{i,j}$ is the flow amount from node i to node j.

3.2.6 Decomposition to potential and circular flows

Firstly, we define flows as directed and weighted links, and the flow of IVANs as value flow. We used Helmholtz–Hodge decomposition [101] to extract potential and circular relationships from IVANs. This method was also used by Kichikawa et al. [102] to clarify the potential relationships in corporate transaction networks. With Helmholtz–Hodge decomposition, the flow F_{ij} from node i to node j can be separated into the circular flow $F^{(c)}_{ij}$ and potential flow $F^{(p)}_{ij}$: $F_{ij} = F^{(c)}_{ij} + F^{(g)}_{ij}$. Here the potential flow $F^{(p)}_{ij}$ is given by $F^{(p)}_{ij} = w_{ij}(\phi_i - \phi_j)$, where ϕ_i is the Helmholtz–Hodge potential and w_{ij} is a positive weight for the link between node i and node j. The circular flow satisfies $\sum_j F^{(c)}_{ij} = 0$, in which the inflows and outflows are balanced in each node. $F^{(p)}_{ij}$ represents the difference in potentials between the nodes, whereas $F^{(c)}_{ij}$ represents the number of feedback loops among the nodes.

An IVAN captures the value-added chain of various international sectors to their respective final goods. The potential of a sector is the difference between the amount of value added by the sector for final foreign production and the amount of value added by the foreign sector for the sector's final production. In other words, if the value-added potential is positive, the sector contributes more to the production of the final goods of the foreign sector, and if it is negative, the sector is contributed more to the own production of the final goods by foreign sectors. This can indicate the degree of asymmetric dependence or co-dependence. Moreover, the circular flow component indicates the amount of contribution to (from)

the foreign sector, that is, the degree of interdependence.

3.2.7 Economic integration in value-added index

When several economies proceed with economic integration in value-added by some factors such as establishing FTAs or RTAs, the value added in a country becomes increasingly induced by other countries, and vice versa. In other words, higher economic integration in value-added makes a larger feedback loop within an IVAN. Based on this assumption, we define the economic integration in value-added index E as the aggregate amount of circular flow divided by the total flow of the GVAN in a specific community.

$$E = \frac{\sum_{i>j} Y_{ij}^{(c)}}{\sum G_{ij}} \tag{3.32}$$

The range of applications of this index covers communities detected by Infomap, which also detects communities using flow. The detected communities are interpreted as the circulation observed when random walkers rotate in the community. The degree of circulation is quantified and divided by the economic scale of the community; then, the economic integration in value-added is measured as the amount of value-added circulation per economic scale.

The index defined here indicates how much of the domestic and international value-added chain toward final demand can be extracted as international interdependence. The higher the value of the index, the greater the value-added induced in the community across national borders (economic activities performed by sectors in other countries), and this value measures economic integration in value-added in this study.

This economic integration in value-added index can decompose into sectoral indices arbitrarily. For sector k, the sectoral economic integration in value-added index is

$$E_k = \frac{\sum_{i>j;i,j\in S_k} Y_{ij}^{(c)}}{\sum_{i,j\in S_k} G_{ij}}, \tag{3.33}$$

where S_k is a set of nodes in sector k.

In summary, the economic integration in value-added index is the circular magnitude of the cross-border value-added contribution of economic activities in a country (other countries) toward the final production of sectors in other countries (home country), compared with the circular magnitude of the value-added contribution of economic activities in the community, including circulation within a country.

3.3 Results

This section is composed of three subsections. The first subsection shows the community structure of the IVANs, the threshold set for community detection, and the resulting 15-year change in regional communities. The second subsection shows the essential characteristics of the original IVAN, the cut IVAN, and the IVAN of the regional communities in selected years. The third subsection confirms the value-added potential and circular relationships revealed by Helmholtz–Hodge decomposition for countries and sectors in Europe and the Pacific Rim. The last subsection shows the evolution of economic integration in value-added in the regional communities and the results of decomposing the economic integration indicators into key sectoral components.

3.3.1 Communities of IVANs

Infomap detected only a giant community from IVAN without thresholds for 15 years. This result differs from the community of international trade networks (see Table A.1 and Figs. A.1-A.3 in Appendix A) also shown in a previous study [46] which illustrated 7–12 communities. Next, thresholds are set to exclude the branches and leaves of the IVANs to see any concealed community structure. In the range of 6,500–11,000 remaining links, several large communities appear (Fig. 3.3). Here, the thresholds are set by the number of the most extensive links to be retained, as the threshold value set by USD is inappropriate for the weight of the IVAN links, which fluctuates due to the economic growth and economic crisis that occurred in those 15 years. In Fig. 3.3, each cell colored on the number of communities with more than 240 nodes which is 10% of the total nodes in the IVANs. We named these communities major communities. The remaining number of links in 2014 is almost half of that in 2004–2009.

By using the abovementioned threshold values, we can detect the communities from the IVANs as shown in Fig. 3.4 which shows four years' heat maps and represents each cell as a node of the IVANs. Fig. 3.4 illustrates the results of the red-bordered cells of Fig. 3.3. In the maps, the separated communities are indicated by different colors; the gray cells are the nodes that do not belong to any of those two communities. The figure shows orange horizontal stripes, including most of the sectors in countries such as Australia, Brazil, and Canada. The green nodes include the sectors A01: agriculture, C29: manufacture of motor vehicles, and C30: manufacture of other transport equipment of mainly European countries. The gray area includes many other sectors in Europe, especially in small countries. Thus, we name the two major communities European and Pacific Rim communities, which are the automatically detected communities with Infomap mainly formed by nodes from Europe and Pacific Rim, respectively. We note that the community names: European and the Pacific Rim communities do not mean the countries of their components (nodes) are of Europe and the Pacific Rim, respectively.

The results of community detection 15 years are shown in Fig. 3.5 as a Sankey diagram, where orange

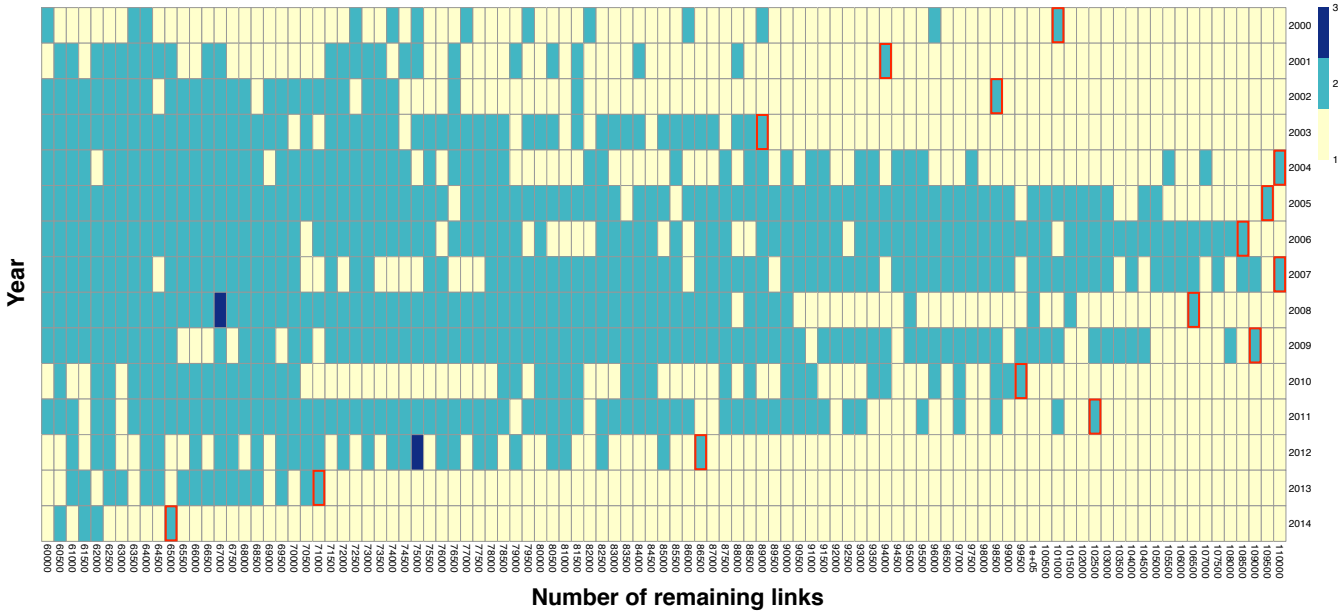


Fig. 3.3: Heat map of the number of major communities in the IVANs cut by each threshold, in 2000–2014. This research uses the thresholds represented as a red-bordered cell in each year. Colors mean the number of major communities.

represents the Pacific Rim sectors, and green represents the European sectors (nodes) (the details of the classification are in Table 3.1). In Fig. 3.3, we illustrate the number of major communities, which include more than 10% of all (2,408) nodes of IVAN. However, Fig. 3.5 also represents minor communities that include less than 10% of all nodes. The relatively larger two communities at the bottom are the regional communities.

3.3.2 Observed structural characteristics

Table 3.5 shows the structural features for 2000, 2008, and 2014. The densities and cluster coefficients show that the IVANs are dense, and the reciprocity shows that more than 97% of the links are mutual. The density of the IVANs that are cut at the threshold in Fig. 3.3 is reduced by about 82%. In terms of reciprocities, the cut IVANs are about 20% of the remaining links that are cut. This indicates that the IVAN has many asymmetric mutualities with large values in only one direction. In the two local communities, the cluster coefficients and reciprocities are at the same level as those of the IVANs, although the densities are about 10% higher than those of the entire IVANs.

Each IVAN has a diameter of 2, which means that any sector in any country is connected to all sectors through one sector in another country. The minimum diameter is two because links to sectors

Fig. 3.4: Community maps in 2000, 2004, 2009, and 2014. Each cell is a node of IVAN, the gray cells are the nodes that do not belong to any of two communities, while the other colors indicate community. The green ones belong to the community dominated by sectors of European countries and the orange ones to the community dominated by sectors of the Pacific Rim countries. The regional classification is in Table 3.1.

in the same country are not included, but since the average path length is close to 1, most sectors are directly connected. In the cut IVANs, the diameter is about 5, and the average betweenness is more than 50 times larger than that of the original IVANs because the diameter and average path length are long, and a particular node mediates many shortest paths. In the regional communities, the average path length is slightly longer, and the betweenness is roughly half of the original IVANs.

The number of nodes in the IVANs is 2,408, and the average in-degree and out-degree value are

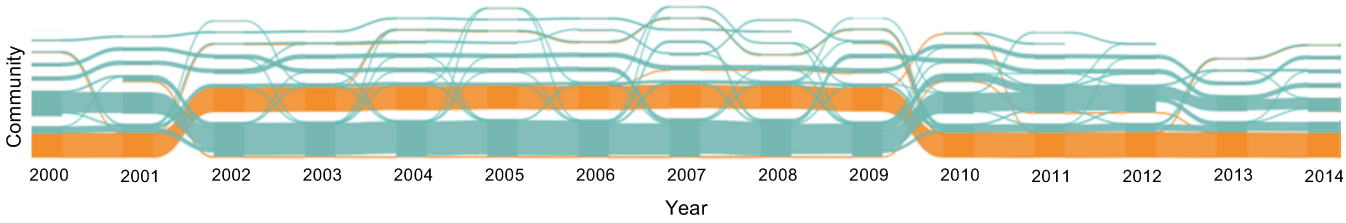


Fig. 3.5: Sankey diagram of communities colored by actual regions where nodes are situated. Communities in each year are ordered by their size, from the largest to the smallest, from the bottom to the top. Green and orange in Fig. 3.5 do not mean regional communities but mean the regions in which the node is positioned. The crossings of the major communities in 2001–2002 and 2009–2010 mean changes in the order of their size. Their classification of them is in Table 3.1. The two bottom communities are major regional communities, but there had been other small European communities over the years.

Table 3.5: Structural characteristics of IVANs, IVANs cut with the threshold, IVANs in the regional communities: Europe and the Pacific Rim.

	2000				2008				2014			
	IVAN	Cut IVAN	Europe	Pacific Rim	IVAN	Cut IVAN	Europe	Pacific Rim	IVAN	Cut IVAN	Europe	Pacific Rim
Density	0.831	0.0174	0.942	0.921	0.841	0.0184	0.955	0.925	0.831	0.0112	0.945	0.929
Reciprocity	0.972	0.231	0.987	0.976	0.982	0.192	0.990	0.987	0.974	0.169	0.993	0.975
Clustering coefficient	0.976	0.321	0.953	0.941	0.976	0.319	0.963	0.934	0.976	0.278	0.950	0.950
Diameter	2	5	2	2	2	4	2	2	2	6	2	2
Average path length	1.023	2.474	1.046	1.056	1.023	2.55	1.035	1.063	1.023	2.656	1.048	1.048
Average betweenness*	51.70	2644	24.62	37.14	51.72	3053	28.99	37.37	51.64	2835	14.32	35.82
Assortativity	-0.0167	-0.436	-0.0394	-0.0304	-0.0179	-0.427	-0.0294	-0.0305	-0.0170	-0.424	-0.0505	-0.0304
Average in-degree*	2196	71.68	516.4	622	2198	71	788	556.8	2193	52.59	281.7	715.3
Average out-degree*	2143	68.71	509.7	610.7	2164	65.5	780.3	553	2147	45.61	279.8	703

*These averages were calculated for nonzero values.

over 2,100. Since most of the sectors are connected, the assortativity is close to zero. In the cut IVANs, the degrees and assortativity are around 70 and -0.43, respectively, indicating that sectors with degree differences are connected by high values flows. In the regional communities, the degree varies according to the size of the detected regional community, and the assortativity is negative, close to zero.

Table 3.5 includes three points: 1) no much difference in characteristics of IVANs between around 2006 (the lowest threshold year) and 2014 (the highest threshold year) are 2) influences of threshold on IVAN in each year 3) regional communities with similar characteristics, except for average betweenness and degrees, which are affected by size in each year. For the first point, the features of IVANs in 2014 and 2000 are almost the same, and the IVANs in 2008 have relatively higher density and assortativity. For the second point, we mentioned above the differences between original IVAN and cut IVAN. For the third point, most characteristics of the regional communities were similar, but there were significant differences in degrees that reflect the size of the community, especially in 2014.

Fig. 3.6 shows a wide strength distribution of the IVAN's. The distribution of Fig. 3.6 partly fits a log-normal distribution, especially in the right tail. The probability density function of a log-normal distribution $p(x)$ for $x > 0$ is:

$$p(x) = \frac{1}{\sqrt{2\pi}\sigma x} \exp\left[-\frac{(\log x - \mu)^2}{2\sigma^2}\right], \tag{3.34}$$

where μ and σ are the mean and standard deviation of the logarithm, respectively. As seen in Fig. 3.6, the mean and standard deviation of the logarithm of strength distribution in 2014 are $\mu = 5.959$ and $\sigma = 2.129$ in in-strength, and $\mu = 6.146$ and $\sigma = 2.001$ in out-strength, respectively.

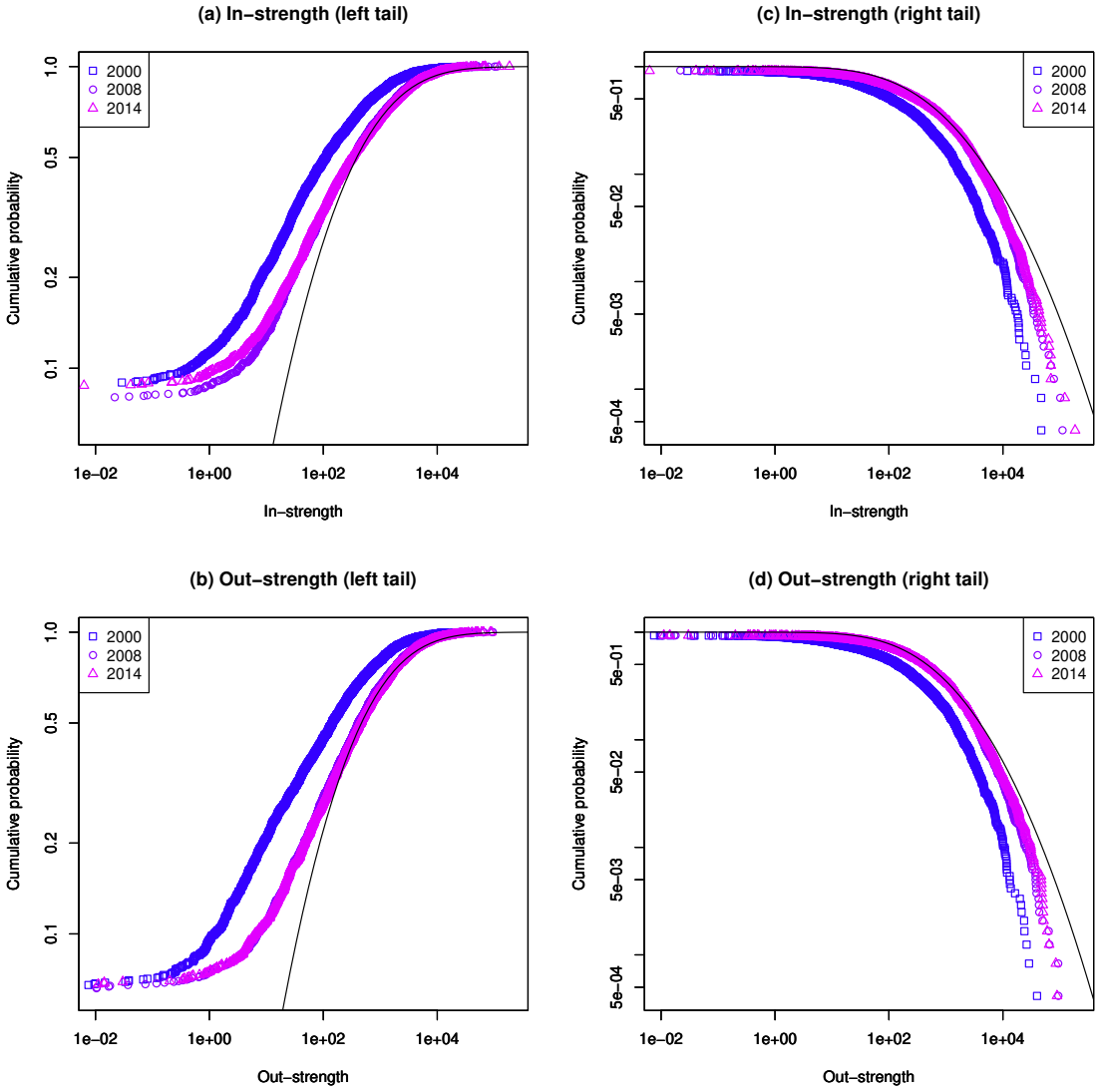


Fig. 3.6: Cumulative probability of strength of IVAN in 2000, 2008, and 2014. The black lines are plots of the cumulative density function of the log-normal distribution whose μ and σ are equal to the average and the standard deviation, respectively, of the logarithm of strength distribution in 2014. Their right tails are almost fitted, but the left tails are not, especially at the bottom.

We examined whether the difference in the threshold values before and after the economic crisis in Fig. 3.3 was due to the difference in the network features. Fig. 3.6 shows that the strength distributions in 2008 and 2014 are almost equal. Therefore, this indicates that there is no significant change in the IVAN as a network structure, which does not appear in the features used in this study.

3.3.3 Potential and circular relationships in two regional communities

We applied Helmholtz–Hodge decomposition to the two regional communities detected by Infomap. The size of the circular flow component and the value of the IVAN link (value flow) are well correlated in the range where the value flow is greater than 100 million USD, as shown in Fig. 3.7. In the economic integration in value-added index, the amount of circular flow is divided by the GVAN weights; thus, the economic scale does not appear directly.

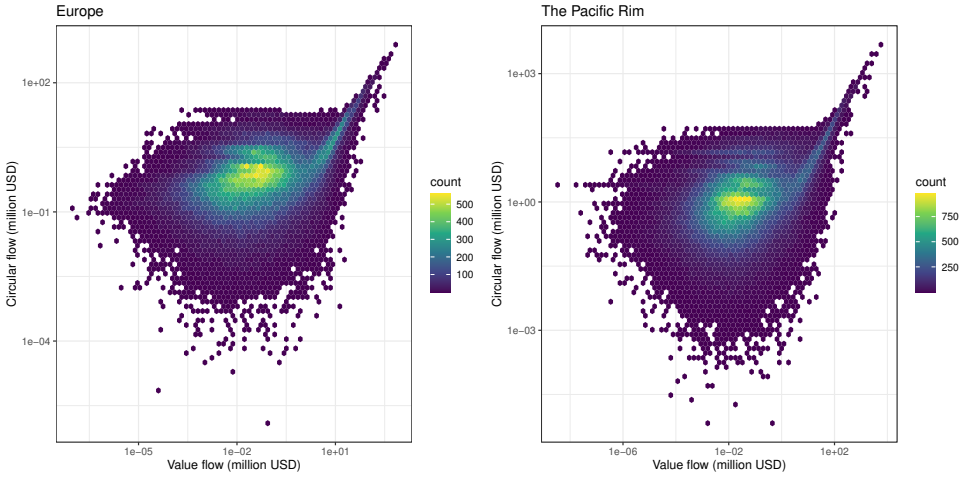


Fig. 3.7: Scatter plot of correlation between circular flow and value flow of two regional communities in 2000. The larger circular flows are in proportion to the original value flows, but the lower flows are disarranged.

The potential and circular relationships in European and the Pacific Rim communities can be analyzed from the international and intersectoral perspectives by aggregating nodes into countries and sectors. As Fig. 3.4 illustrates, some countries were present with a smaller number of sectors in each community.

European community

Tables 3.6–3.11 show the breakdown of the potential and circular relationships in Europe, which is obtained from the Helmholtz–Hodge decomposition. In terms of countries, the value potential is mainly high in Russia, Norway, and Germany (Table 3.6) and low in France, Spain, and Italy (Table 3.7). From 2003 to 2012, Russia and Norway mainly have the first and second highest potential, respectively. In 2001, 2002, and 2010, with changes in the ranking of the communities in Fig. 3.5, Germany shows the highest potential. In 2000 and 2001, 2010, and 2013, when the European community was relatively small (Fig. 3.5), Russia had not been in Table 3.6. In addition, Belgium, Switzerland, and the Netherlands were the other high-potential countries that were ranked repeatedly in Table 3.6. Non-European countries, such as the United States, had also been ranked because of specific industries in the European Community. The United States was ranked as a high-potential country in 2002–2005, before the economic crisis,

and China was ranked as a high-potential country in the European Community in 2009–2010, during the economic crisis. As for low-potential countries (Table 3.7), basically France had the lowest potential, and Spain had the lowest potential in 2002 and 2003. Table 3.7 also represented Italy, Portugal, and Turkey as low-potential countries in half of the years, and the United Kingdom as a low-potential country after 2007. Tables 3.6 and 3.7 show that Germany is both a high-potential (in 2001–2007, 2009, 2010, 2014) and low-potential country (in 2008, 2011–2013).

In general, Russia was ranked first in the high-potential table (Table 3.6) when sector B: mining and quarrying was ranked first (Table 3.8). The other highest-potential sectors in Europe were M69: legal, accounting, and consultancy activities in 2000 and 2010; C24: manufacture of basic metals in 2001; C25: manufacture of fabricated metal products, except machinery and equipment in 2013; and G46: wholesale trade except that of motor vehicles and motorcycles in 2014. In addition, sectors N: administrative and support service activities and C20: manufacture of chemicals and chemical products were often ranked high. In terms of low potential (Tables 3.7 and 3.9), sector F: construction had been ranked first throughout the 15 years, followed by sectors C28: manufacture of machinery and equipment, C19: manufacture of coke and refined petroleum products, C29: manufacture of motor vehicles, which occupy the second and subsequent positions; O84: public administration and defense, and compulsory social security, which appears in the third and subsequent positions; and L68: real estate activities, which often appears in the fifth position.

According to the amount of circulation (Table 3.10), Germany had been the top country for the 15 years, followed by France, the United Kingdom, Italy, and Russia. In terms of sectoral ranking (Table 3.11), sector F: construction is consistently ranked first until 2010. In 2011 and 2012, sector B: mining and quarrying, which often ranked second, was ranked first. In 2013, sector C29: manufacture of the motor vehicle was first. Russia was ranked second in the year that sector B: mining and quarrying was ranked first. Throughout the whole years, F: construction was first, followed by B: mining and quarrying, C28: manufacture of machinery and equipment, C19: manufacture of coke and refined petroleum products, and G46: wholesale trade except for that of motor vehicles and motorcycles.

For both countries and sectors, those ranked higher or lower in terms of potential are also greater in terms of circular strength, which is the strength of the circular network decomposed from an IVAN. The relationship between the circular strength and the Helmholtz–Hodge potential is shown in Fig. 3.8. The relationship is V-shaped; in other words, the larger the absolute value of the potential, the higher the circular strength.

Table 3.6: Five highest-potential countries in European community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	NLD	DEU	DEU	RUS	RUS	RUS	RUS	RUS	RUS	RUS	DEU	RUS	RUS	POL	DEU
2	DEU	BEL	RUS	NOR	NOR	NOR	NOR	NOR	NOR	NOR	GBR	NOR	NOR	ITA	RUS
3	CHE	CHE	NOR	DEU	DEU	DEU	DEU	DEU	NLD	DEU	BEL	NLD	NLD	CZE	NLD
4	BEL	NLD	USA	USA	USA	USA	NLD	NLD	CHE	CHN	CHN	IRL	DNK	AUT	GBR
5	NOR	FIN	NLD	NLD	BEL	BEL	USA	BEL	AUT	BEL	AUT	CYP	USA	NLD	HUN

Table 3.7: Five lowest-potential countries in European community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	FRA	FRA	ESP	ESP	FRA	FRA	FRA	ESP	FRA	FRA	FRA	FRA	FRA	FRA	FRA
2	ESP	ESP	ITA	FRA	ESP	ESP	ESP	FRA	ESP	ITA	ITA	DEU	DEU	BEL	CHE
3	ITA	DNK	FRA	ITA	ITA	ITA	ITA	GBR	DEU	ESP	ESP	ITA	GBR	GBR	DNK
4	PRT	PRT	POL	POL	HUN	TUR	TUR	TUR	TUR	GBR	LUX	GBR	TUR	RUS	ESP
5	DNK	POL	PRT	HUN	POL	HUN	POL	ITA	POL	LUX	DNK	POL	POL	DEU	TUR

Table 3.8: Five highest-potential sectors in European community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	M69	C24	B	B	B	B	B	B	B	B	M69	B	B	C25	G46
2	C24	N	N	N	N	N	N	C24	C24	M69	G46	G46	G46	C24	C24
3	N	M69	M69	M69	M69	C24	C24	N	G46	N	N	N	N	C22	C25
4	C20	C20	C24	C24	C24	M69	M69	G46	M69	G46	C24	C24	M69	G46	C20
5	K64	C25	C20	C20	C20	G46	G46	M69	H49	C24	C20	H49	C24	C27	C22

B: mining and quarrying; C20: manufacture of chemicals and chemical products; C22: manufacture of rubber and plastic products; C24: manufacture of basic metals; C25: manufacture of fabricated metal products except machinery and equipment; C27: manufacture of electrical equipment; G46: wholesale trade except trade of motor vehicles and motorcycles; H49: land transport and transport via pipelines; K64: financial service activities except insurance and pension funding; M69: legal and accounting activities; activities of head offices, and management consultancy activities; N: administrative and support service activities.

Table 3.9: Five lowest-potential sectors in European community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
2	C28	C28	C28	C28	C19	C19	C19	C29	C29	C19	C28	C19	C19	C29	C28
3	C19	O84	O84	O84	C28	C28	C28	C19	C19	C28	O84	C28	C28	C28	O84
4	O84	C31	C19	C19	O84	O84	O84	C28	C28	O84	G47	D35	D35	O84	G47
5	C31	L68	L68	L68	L68	R_S	R_S	O84	O84	L68	C31	O84	O84	R_S	C33

C19: manufacture of coke and refined petroleum products; C28: manufacture of machinery and equipment n.e.c.; C29: manufacture of motor vehicles, and trailers, and semi-trailers; C31: manufacture of furniture, and other manufacturing; C33: repair and installation of machinery and equipment; D35: electricity, gas, steam and air conditioning supply; F: construction; G47: retail trade except that of motor vehicles and motorcycles; L68: real estate activities; O84: public administration and defense, and compulsory social security; R_S: other service activities.

The Pacific Rim community

The characteristics of the potential and circular flows of the IVANs in the Pacific Rim are shown in Tables 3.12–3.17. Japan, which had the maximum potential in 2000 and 2002, had been out of the ranking since 2012; Canada showed the maximum potential from 2003 to 2007, and Australia had been

Table 3.10: Five-highest circulated countries in European community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU	DEU
2	FRA	FRA	GBR	FRA	FRA	FRA	FRA	FRA	RUS	FRA	FRA	RUS	RUS	FRA	FRA
3	NLD	ITA	FRA	ITA	GBR	GBR	GBR	ITA	FRA	RUS	ITA	NOR	GBR	ITA	ITA
4	ITA	ESP	ITA	GBR	ITA	ITA	RUS	RUS	ITA	GBR	ESP	FRA	NOR	ESP	POL
5	ESP	GBR	ESP	ESP	NLD	RUS	ITA	GBR	NOR	ITA	NLD	GBR	FRA	POL	AUT

Table 3.11: Five-highest circulated sectors in European community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	F	F	F	F	F	F	F	F	B	F	F	B	B	C29	F
2	C28	C28	B	B	B	B	B	B	F	B	C28	F	F	F	C28
3	G46	G46	N	N	C19	C19	C19	C29	C19	C19	G46	C19	C19	C28	G46
4	K64	C20	G46	G46	N	G46	G46	C19	C29	G46	M69	G46	D35	C25	C25
5	C20	C24	C28	C28	G46	C28	C28	G46	G46	D35	K64	D35	G46	C24	C20

B: mining and quarrying; C19: manufacture of coke and refined petroleum products; C20: manufacture of chemicals and chemical products; C24: manufacture of basic metals; C25: manufacture of fabricated metal products, except machinery and equipment; C28: manufacture of machinery and equipment n.e.c.; C29: manufacture of motor vehicles, and trailers and semi-trailers; D35: electricity, gas, steam and air conditioning supply; F: construction; G46: wholesale trade except that of motor vehicles and motorcycles; K64: financial service activities except insurance and pension funding; M69: legal and accounting activities, activities of head offices, and management consultancy activities; N: administrative and support service activities.

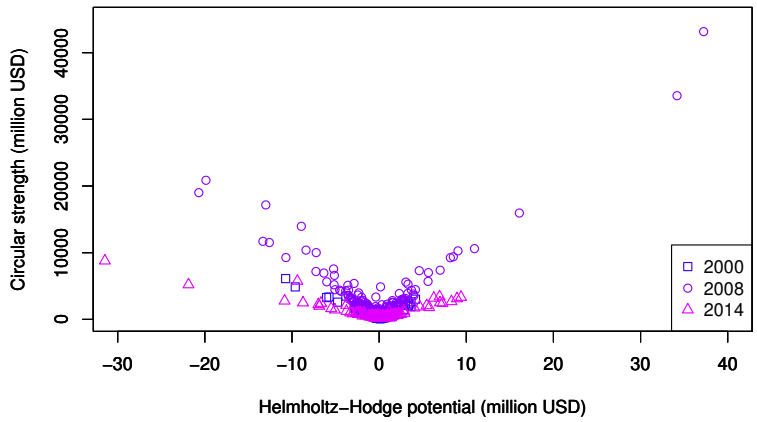


Fig. 3.8: Scatter plot of correlation between circular strength and Helmholtz–Hodge potential in European community in 2000, 2008, and 2014. Each year shows a V-shaped pattern, but the inclination is changed (sharpest in 2008 and gentlest in 2014).

the highest-potential country since then (Table 3.12). Indonesia, Taiwan, and India were also among the five highest-potential countries. In terms of low potential, Mexico was the top-ranked country until 2002, the United States from 2004 to 2006, and China in 2003 and 2007 to 2013. In addition, India, the United Kingdom, and France appeared in Table 3.13 numerous times.

In terms of sectoral potential (Tables 3.14 and 3.15), as in Europe, B: mining and quarrying was the highest-potential sector, and F: construction was the lowest-potential sector. The relationship was more stable than that in Europe and remained unchanged over the 15 years. In addition, as shown in Table 3.14,

Table 3.12: Five highest-potential countries in the Pacific Rim community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	JPN	CAN	JPN	CAN	CAN	CAN	CAN	CAN	AUS	AUS	AUS	AUS	AUS	AUS	AUS
2	CAN	JPN	CAN	JPN	JPN	JPN	AUS	AUS	CAN	CAN	JPN	CAN	CAN	CAN	CAN
3	AUS	AUS	AUS	AUS	AUS	AUS	JPN	JPN	IDN	JPN	CAN	IDN	IDN	TWN	TWN
4	IDN	IDN	TWN	IDN	IDN	IDN	IDN	TWN	TWN	TWN	IDN	JPN	TWN	RUS	KOR
5	TWN	TWN	IDN	TWN	KOR	TWN	TWN	IDN	BRA	IDN	TWN	TWN	BRA	IDN	DEU

Table 3.13: Five lowest-potential countries in the Pacific Rim community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	MEX	MEX	MEX	CHN	USA	USA	USA	CHN	CHN	CHN	CHN	CHN	CHN	CHN	USA
2	CHN	CHN	USA	USA	CHN	CHN	CHN	USA	USA	MEX	MEX	IND	USA	USA	CHN
3	USA	GBR	CHN	MEX	MEX	MEX	MEX	MEX	MEX	IND	GBR	MEX	IND	MEX	MEX
4	GBR	IND	IND	IND	GBR	IRL	IRL	IND	KOR	GBR	IND	KOR	MEX	IDN	IND
5	IND	USA	FRA	FRA	IND	IND	GBR	HUN	HUN	DEU	KOR	USA	FRA	GBR	GBR

Table 3.14: Five highest-potential sectors in the Pacific Rim community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
2	C20	C20	C20	C20	C20	C24	C24	C24	C24	C24	C20	C24	C24	G46	G46
3	C24	C24	C24	C24	C24	C20	C20	G46	G46	C20	G46	C20	G46	C24	C24
4	G46	G46	G46	G46	G46	G46	G46	C20	C20	G46	C24	G46	C20	C20	C20
5	N	N	C25	K64	K64	K64	K64	K64	K64	K64	N	N	K64	K64	K64

B: mining and quarrying; C20: manufacture of chemicals and chemical products; C24: manufacture of basic metals; C25: manufacture of fabricated metal products except machinery and equipment; G46: wholesale trade except that of motor vehicles and motorcycles; K64: financial service activities except insurance and pension funding; N: administrative and support service activities.

Table 3.15: Five lowest-potential sectors in the Pacific Rim community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F
2	O84	O84	O84	O84	O84	O84	O84	O84	O84	O84	O84	O84	O84	Q	O84
3	C29	C29	C29	C29	C29	C29	C29	C29	C29	C29	Q	Q	Q	O84	Q
4	C10	Q	C10	C10	C10	C10	C10	C10	C10	C10	C29	C29	C29	C29	C29
5	Q	C10	Q	Q	Q	Q	Q	Q	Q	Q	C10	C10	C10	C10	C10

C10: manufacture of food products, beverages and tobacco products; C29: manufacture of motor vehicles, and trailers and semi-trailers; F: construction; O84: public administration and defense, and compulsory social security; Q: human health and social work activities.

sectors B: mining and quarrying, C20: manufacture of chemicals and chemical products, C24: manufacture of basic metals, G46: wholesale trade, K64: financial service activities, and N: administrative and support service activities were included in the high-potential sectors. Sectors F: construction; O84: public administration and defense, and compulsory social security; C29: manufacture of motor vehicles; C10: manufacture of food products, beverages, and tobacco products; and Q: human health and social work activities were among the lowest-potential sectors until 2009 except 2001. Since 2010, Q: human health and social work activities had risen to higher than third place.

In terms of circulation (Tables 3.16 and 3.17), the United States had been consistently in the first

Table 3.16: Five highest-circulated countries in the Pacific Rim community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA
2	JPN	CAN	CAN	CAN	CAN	CAN	CAN	CHN	CHN	CHN	CHN	CHN	CHN	CHN	CHN
3	CAN	JPN	JPN	JPN	JPN	CHN	CHN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN
4	MEX	MEX	MEX	CHN	CHN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN
5	CHN	CHN	CHN	MEX	MEX	MEX	MEX	MEX	MEX	MEX	MEX	MEX	MEX	MEX	MEX

Table 3.17: Five highest-circulated sectors in the Pacific Rim community.

Rank	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	C26	F	F	F	F	F	F	C26	B	F	F	B	B	F	F
2	F	C26	C26	C26	B	B	B	F	C26	B	B	F	F	B	B
3	B	B	B	B	C26	C26	C26	B	F	C26	C26	C26	C26	C26	C26
4	C29	O84	C29	O84	O84	C29	O84	O84	O84	O84	O84	O84	O84	O84	O84
5	O84	C29	O84	C29	C29	O84	C29	C29	C29	C29	C29	Q	Q	Q	Q

B: mining and quarrying; C26: manufacture of computer, electronic, and optical products; C29: manufacture of motor vehicles, and trailers and semi-trailers; F: construction; O84: public administration and defense, and compulsory social security; Q: human health and social work activities.

place, followed by Japan, Canada, and China since 2007. Since 2005, Japan had been in the fourth place, followed by Mexico. By contrast, the sector rankings in Table 3.17 were not as consistent as those of the countries. In 2000 and 2007, C26: manufacture of computer, electronic, and optical products was ranked first; in 2008 and 2011, B: mining and quarrying was ranked first. These three sectors remained in the top three positions over the 15 years. They were followed by C29: manufacture of motor vehicles and O84: public administration and defense, and compulsory social security until 2009, and by O84: public administration and defense, and compulsory social security and Q: human health and social work activities since 2010.

As in European community, the high- or low-potential countries and sectors in the Pacific Rim community were high in circular strength. The relationship between the circular strength and the Helmholtz–Hodge potential is shown in Fig. 3.9. The V-shaped relationship between them is the same as that in European community. However, there is a difference in Tables 3.6–3.17. Sector C26: manufacture of computer, electronic, and optical products did not appear in Tables 3.14 and 3.15, which indicates a large value-added circulation in the midstream of the Pacific Rim's value flow, although all high-circular-strength sectors in Europe were also in the value-added potential ranking.

3.3.4 Economic integration in value-added index

The results of applying the economic integration in value-added index to the two regional communities are shown in Fig. 3.10. The Pacific Rim community showed a stable and upward trend for economic integration in value-added, while European community showed a higher but more unstable integration level. In particular, there was a large decline in the level of integration in value-added in 2009 and 2010,

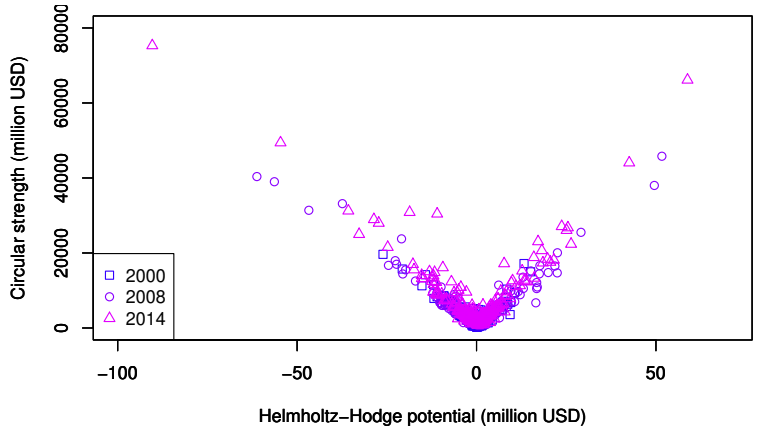


Fig. 3.9: Scatter plot of correlation between circular strength and Helmholtz-Hodge potential in the Pacific Rim community in 2000, 2008, and 2014. The years show the similar inclinations of the V shape.

after the economic crisis, while the Pacific Rim community was slightly affected in 2009.

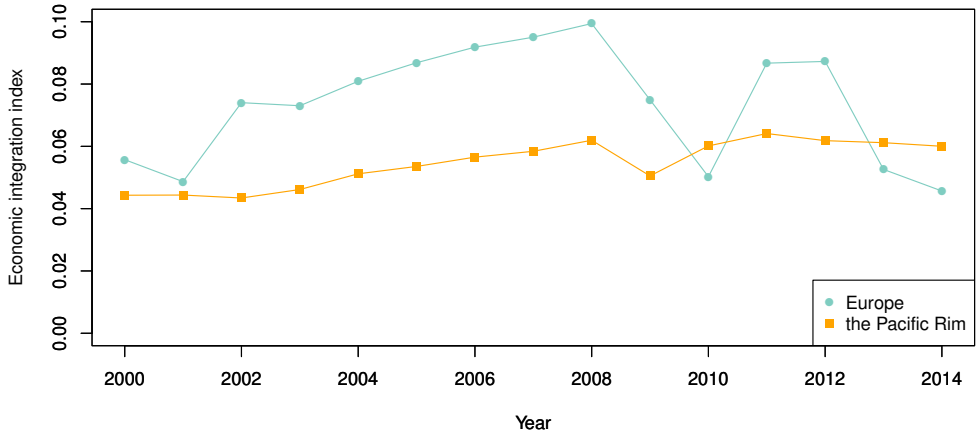


Fig. 3.10: Economic integration in value-added estimation of the two regional communities in 2000–2014.

Figs. 3.11, 3.12, and 3.13 show the sector-wise economic integration in value-added indices, focusing on the sectors that showed high circulation in Tables 3.11 and 3.17. As illustrated in Fig. 3.11, European community exhibited a fivefold increase in 2007 and 2008 (just before the economic crisis) in sector B: mining and quarrying and F: construction (the top-ranking sectors in terms of potential and circular flows) compared with 2000, then a sharp decline from 2009 to 2010 (below 2000 level). The low values in 2010, 2013, and 2014 were partly due to a decline in F: construction, but the circulation within B: mining and quarrying was almost zero. By contrast, in the Pacific Rim, these values were tripled between 2007 and 2008; they began to decline in 2011, but they remained above 2007 levels in 2014.

Fig. 3.12 shows the sectoral economic integration in value-added indices of the manufacturing sectors ranked in Tables 3.11 and 3.17. The figure illustrates that the increase in circulation in the manufacturing sectors played a major role in Europe having the largest economic integration in value-added index in 2008. Sector C29: manufacture of motor vehicles made a significant contribution in 2007 and 2008. Sectors C24: manufacture of basic metals, C25: manufacture of fabricated metal products, and C29:

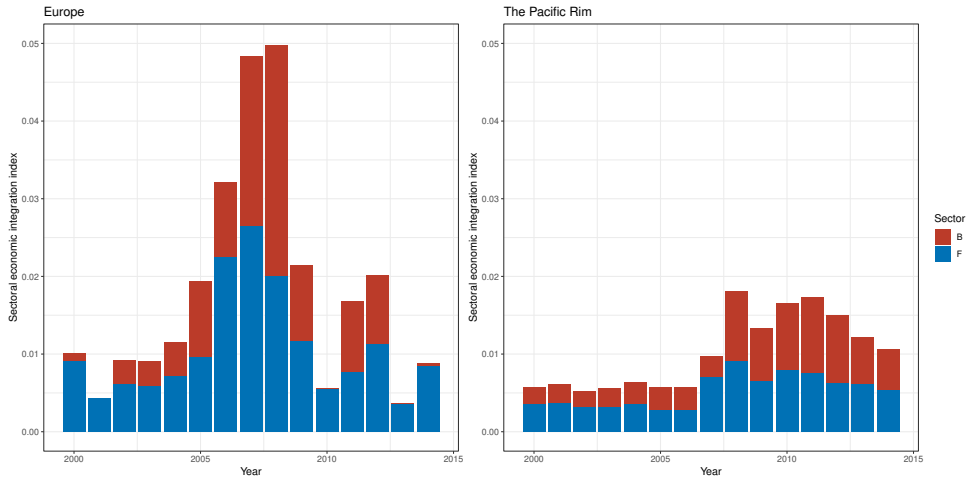


Fig. 3.11: Sectoral economic integration in value-added index of mining and quarrying and construction in two regional communities. B: mining and quarrying, F: construction.

manufacture of motor vehicles exhibited the highest values in 2008. The high value in 2008 can be seen from the fact that C24: manufacture of basic metals, C25: manufacture of fabricated metal products, and C29: manufacture of motor vehicles showed the highest values throughout the 15 years. As for the manufacturing sectors, C19: manufacture of coke and refined petroleum products disappeared from the European community when the economic integration in value-added index for B: mining and quarrying was nearly zero. On the contrary, in the Pacific Rim, the manufacturing sector steadily increased its contribution to economic integration in value-added. In the years with large values in the economic integration in value-added index, C19: manufacture of coke and refined petroleum products, C20: manufacture of chemicals and chemical products, and C29: manufacture of motor vehicles were large in sectoral indices.

Finally, Fig. 3.13 shows the other sectors that are ranked three or more times in Tables 3.11 and 3.17. When European community showed a high degree of economic integration in value-added, the contributions of G46: wholesale trade, K64: financial service activities, and N: administrative and support service activities were large. The contributions of K64: financial service activities and N: administrative and support service activities became so small after 2013, when the level of integration in value-added was low, that they are barely visible. In the Pacific Rim, the contributions of G46: wholesale trade; O84: public administration and defense, and compulsory social security; and Q: human health and social work activities are large, although they tend to peak and decline every three years except for 2009 when the economic crisis occurred.

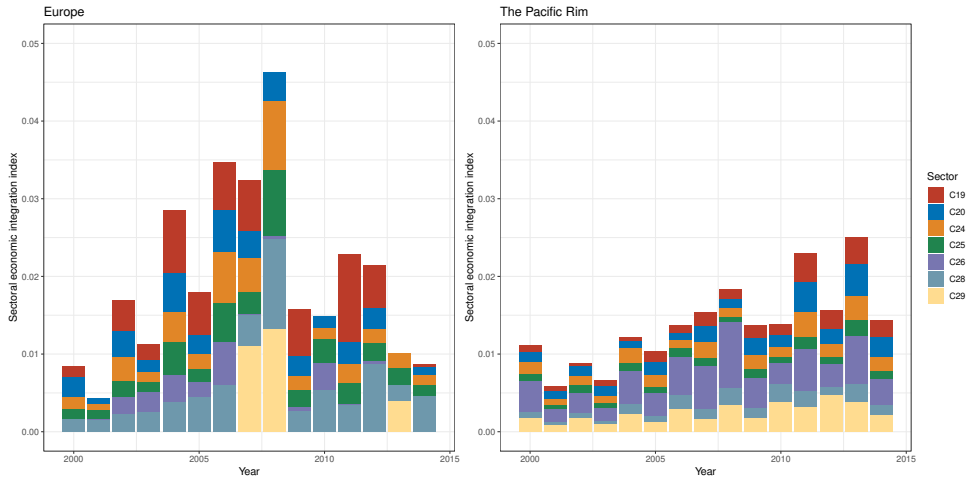


Fig. 3.12: Sectoral economic integration in value-added index of manufacture in two regional communities. C19: manufacture of coke and refined petroleum products; C20: manufacture of chemicals and chemical products; C24: manufacture of basic metals, C25: manufacture of fabricated metal products except for machinery and equipment; C26: manufacture of computer, electronic, and optical products; C28: manufacture of machinery and equipment n.e.c.; C29: manufacture of motor vehicles, and trailers and semi-trailers.

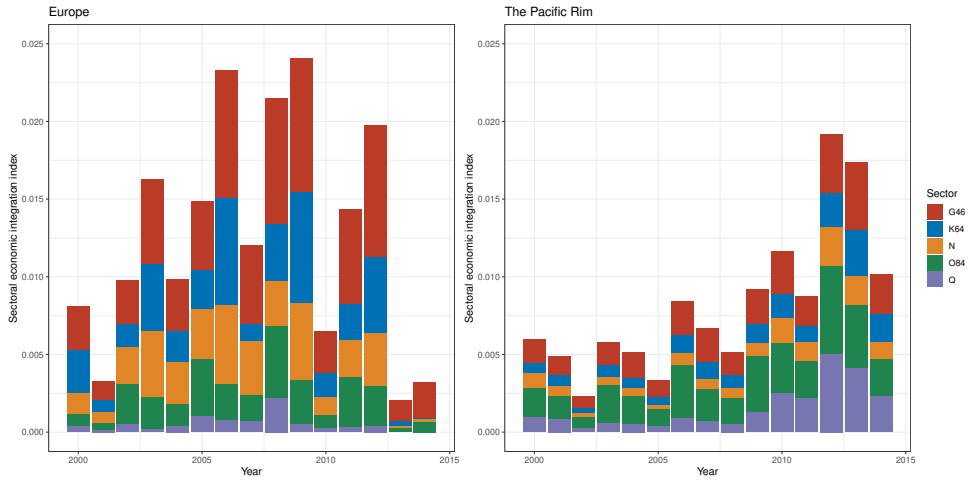


Fig. 3.13: Sectoral economic integration in value-added index of other important sectors in two regional communities. G46: wholesale trade except motor vehicles and motorcycles; K64: financial service activities except for insurance and pension funding; N: administrative and support service activities; O84: public administration and defense, and compulsory social security; Q: human health and social work activities.

3.4 Discussion

In the international trade networks used by Ikeda et al. [47], the communities are divided into industries (see Table A.1 and Figs. A.1-A.3 in Appendix A); in original IVANs, the entire world is connected. Two buried communities—Europe and the Pacific Rim—were identified in this chapter by eliminating low flows with a threshold. However, since the IVAN included only 43 countries (excludes RoW), a more extensive international economic network, including other countries, may reveal more than two regional communities.

The variability between the threshold and the community detection results is also important. In this study, we did not set the threshold as a specific weight to see the change over the 15 studied years. This is because the weights of IVAN links increase or decrease depending on economic growth or crisis; thus, it was inappropriate to use the same value as the threshold throughout the 15 years. In addition, as seen in Fig. 3.3, the results of the detected communities are unstable, even for close threshold values. The number of large communities is not determined by a certain value, but rather the distribution of the number of communities detected depends on the structure of the network created by the remaining links. In this study, we used a resolution of every 500 links for cutting links, but more detailed research is needed on the relationship between the number of remaining links and the number of detected communities. Thus, the threshold with the most remaining links was used for this analysis. The impact of this approach on the results is limited because the threshold was only applied for detecting concealed communities; it was not adopted for calculating the economic integration in value-added. With the threshold value we adopted, two communities with more than 240 nodes appeared, around 10% of the 2408 nodes included by the IVAN, and those communities were analyzed as regional communities. Therefore, the sector-specific European communities shown as gray nodes in Fig. 3.4 and green small communities in Fig. 3.5 were not treated as the regional community of Europe. In other words, the European community does not include sector-specific European communities because Europe has substantial value flows that have mainly the same type of sector, not different types of sectors.

In addition, the relationship between threshold and regional community detection shows a large difference before and after the economic crisis, but Table 3.5 or Fig. 3.6 do not represent such a difference. More research is needed to understand how the threshold for the appearance of regional characteristics in IVAN can be interpreted from international trade, and whether it is related to the economic crisis.

In this study, we set a threshold for detecting major communities and calculated the degree of economic integration in value-added within the range found by the Infomap algorithm. Therefore, we interpreted that the economic integration in value-added of European communities is unstable because the industries that contribute the most to the level of economic integration in value-added are not continuously detected as European communities. However, since the results differ depending on the threshold value and the community detection algorithm, it remains to research how to set the appropriate threshold value when Infomap needs to detect communities in a real weighted directed network such as IVAN.

Originally, the smile curve [103] was observed in terms of the production stage of a particular product or its relative position from a specific sector. In a broad sense, the smile curve in this study appears as a V-shaped curve when its relative position to the final goods of various sectors is considered as a whole. Not surprisingly, Helmholtz–Hodge decomposition shows a cross-country potential flow with high (low) potential in B: mining and quarrying (F: construction), which is in the upstream (downstream) stage of

production. As seen from the circular relationship, the contributions of B: mining and quarrying and F: construction to international economic integration in value-added also indicate that the manufacture of each country depends on the resources and development demands (such as construction) of other countries.

To examine the implications of the economic integration in value-added index, we focused on the period of 2008–2011, which has exhibited substantial changes in economic integration in value-added (Fig. 3.10); we also analyzed 2000 and 2014, which are the first and last years of the analyzed WIOD. Fig. 3.14 shows the changes in the international and intersectoral relationships of circular flow in Europe. The circulation in 2008, the year of the highest economic integration in value-added index in Europe for the 15 years, is higher between Germany, France, Italy, and Russia compared with that in 2000. However, in 2011 and 2014, which has the lowest economic integration in value-added, Russia is absent in European community, as shown in Tables 3.6 and 3.10. From a sectoral point of view, Fig. 3.15 shows sector B: mining and quarrying as a hub of sectors F: construction; C19: manufacture of coke and refined petroleum products; and D35: electricity, gas, steam, and air conditioning supply. Therefore, the role of Russia and sector B: mining and quarrying is important for the high economic integration in value-added index in Europe. The loss of the Russian mining industry's important position within the European community in 2009 can be attributed to the approximately 30% drop in the value of imports of materials such as mineral fuels from Russia to EU member states[1].

Figs. 3.16 and 3.17 show the changes in international and intersectoral relationships in the Pacific Rim. According to Fig. 3.16, the center of the value-added circulation in the Pacific Rim changed from the United States and Japan to the United States and China. This also means that the Pacific Rim, as a regional community of IVANs, was detected stably because of the strong value-added circulation around the United States and China despite the economic crisis around 2009. From the sectoral perspective, Fig. 3.17 shows that there are three crucial points in the circular structure of the Pacific Rim; these are the strongest stable circulations from B: mining and quarrying to F: construction, those within C26: manufacture of computer, electronic, and optical products, and those within C29: manufacture of motor vehicles, and trailers and semi-trailers for the years 2000–2014.

In Europe, the circulation between sectors B: mining and quarrying and F: construction is unstable because sector B mainly occurs in Russia, which is not an EU member country. Therefore, the extent of economic integration in value-added tends to be unstable. By contrast, the Pacific Rim has mineral resources. It also has neutral- and low-potential sectors with high circulation, namely, manufacturing high-tech and motor vehicles, respectively, which produces the high-value-added products as parts of GVCs.

[1]Source: imports of Standard International Trade Classification (SITC) 3 in Eurostat [104]

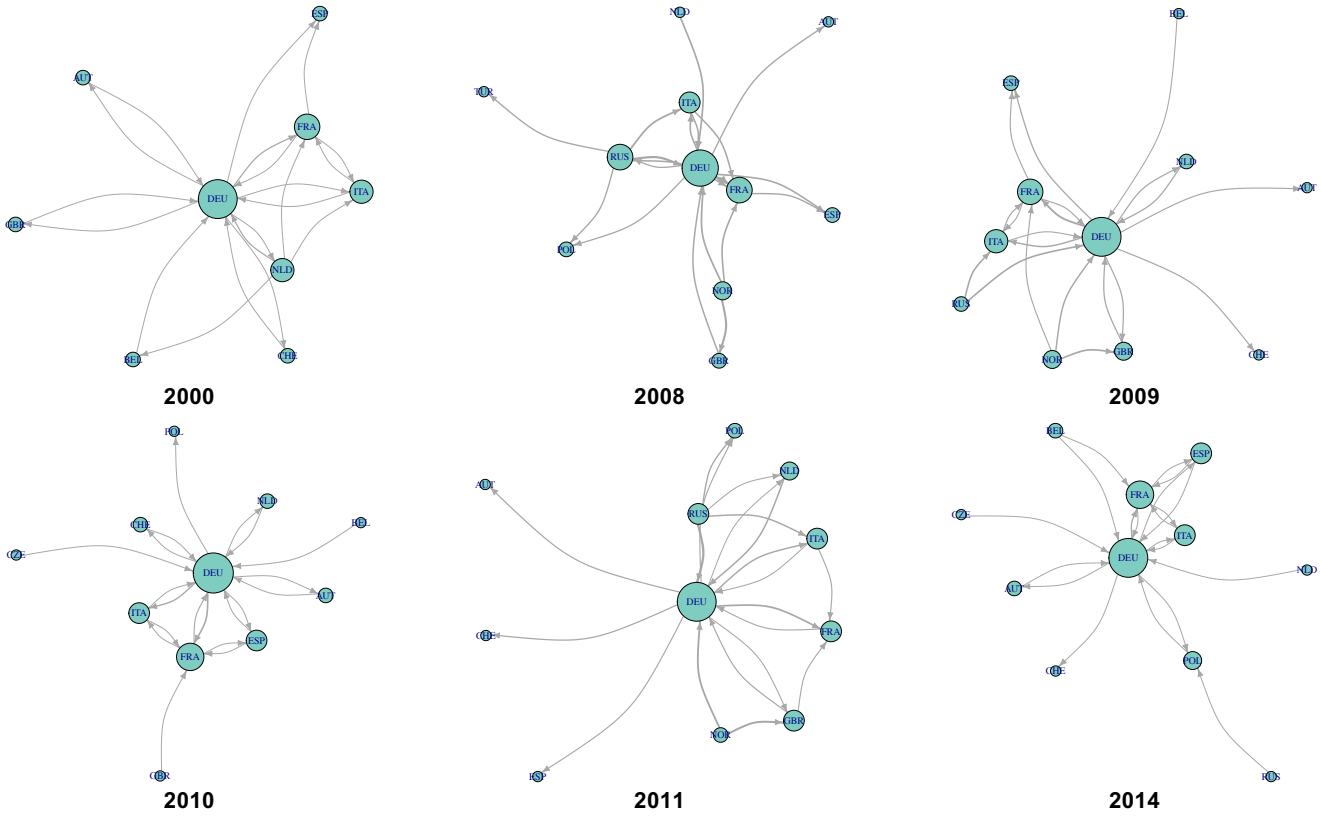


Fig. 3.14: International value-added circulation of European community in 2000, 2008–2011, and 2014. These graphs illustrate the top 20 links. Their node sizes and link widths are in proportion to the square root of the degree and the amount of circular flow, respectively. Table 3.1 shows a detailed list of the sectors.

These results suggest that the stable growth of economic integration in value-added in the Pacific Rim has been driven by the relationship of the value-added circulation of these resources and international division in the manufacture of high value-added products. Furthermore, in the Pacific Rim, the international division of labor is advancing, and value-added circulation occurs across countries. This may be explained by the fact that, the free mobility of labor in the EU has led to the specialization of sectors; in the Pacific Rim, labor mobility is limited, and the international division of labor has led to the free movement of goods. The relationship between labor mobility and industrial structure is left for future research.

3.5 Summary

The purpose of this chapter is to clarify how international economic integration is occurring from the perspective of trade in value-added. For this purpose, we used the WIOD released in 2016 to construct and analyze IVANs, which show the international relationship of sector-wise trade in value-added. First, the scope of economic integration in value-added was identified by Infomap, a community detection

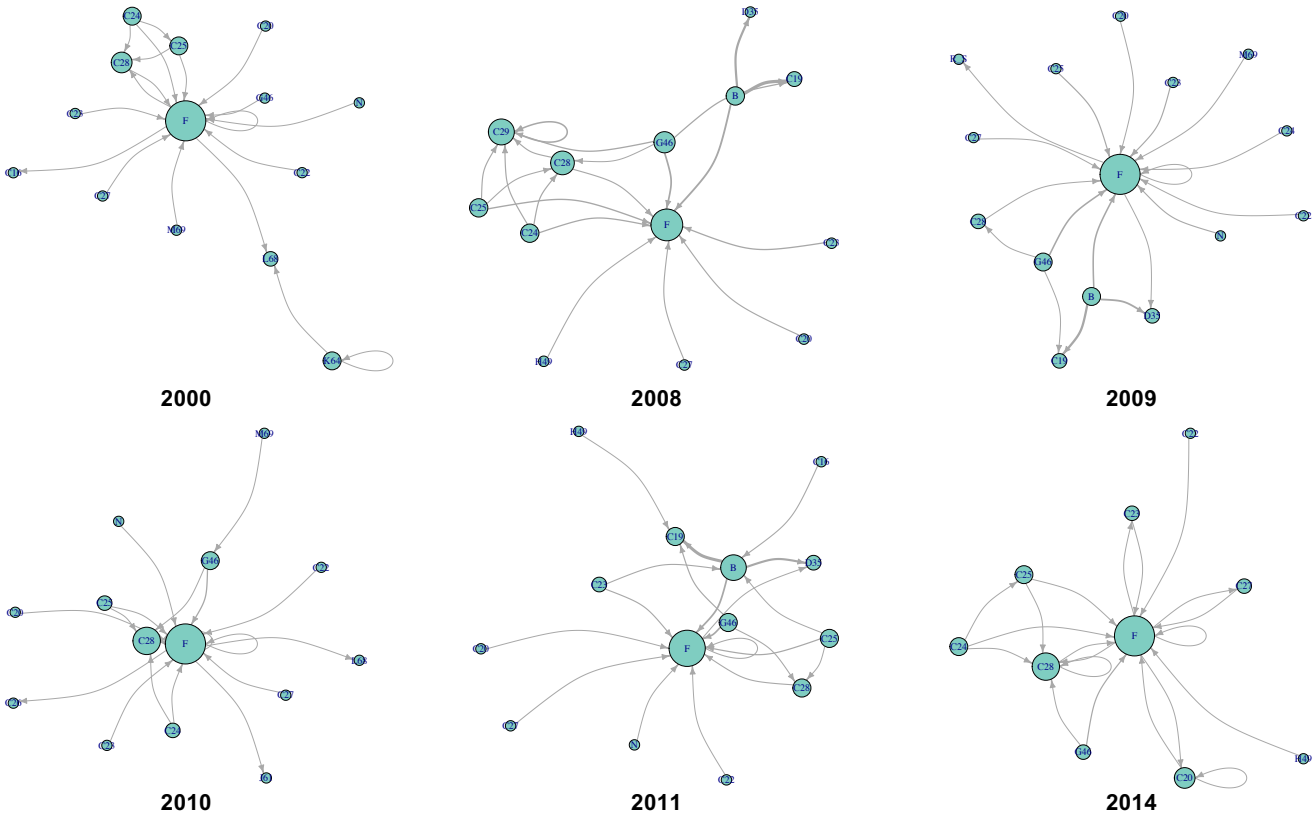


Fig. 3.15: Intersectoral value-added circulation of European community in 2000, 2008–2011, and 2014. These graphs illustrate the top 20 links. Their node sizes and link widths are in proportion to the square root of the degree and the amount of circular flow, respectively. Table 3.2 shows a detailed list of the sectors.

method that uses network flows. With threshold setting in the IVANs, regional communities in Europe and the Pacific Rim were detected throughout the 15 studied years. These two communities have not been found in studies that analyzed international trade networks constructed from the WIOD. To analyze how value flows within these two regions, we used Helmholtz–Hodge decomposition to extract the potential and circular relationships and clarified the annual changes in the roles played by the countries and sectors within these regions. In addition, we defined an economic integration in value-added index using the circular flow and applied it to both regions. We found that the level of economic integration in value-added in Europe, which had been increasing until 2008, dropped sharply after the economic crisis in 2009 to a level lower than that of the Pacific Rim in 2010, recovered in 2011, and dropped again after 2012 to a level below that of the Pacific Rim in 2013 and 2014. While the level of economic integration in value-added in Europe has been unstable, that in the Pacific Rim has been on a stable upward trend.

Moreover, the sectoral economic integration in value-added index provides a background to the changes in the extent of the economic integration in value-added of these two regions. In Europe, the extent of economic integration in value-added declined in 2009, 2010, and 2013 due to the decrease of intra-European value-added circulation through the industries of mining, construction, petroleum, metal,

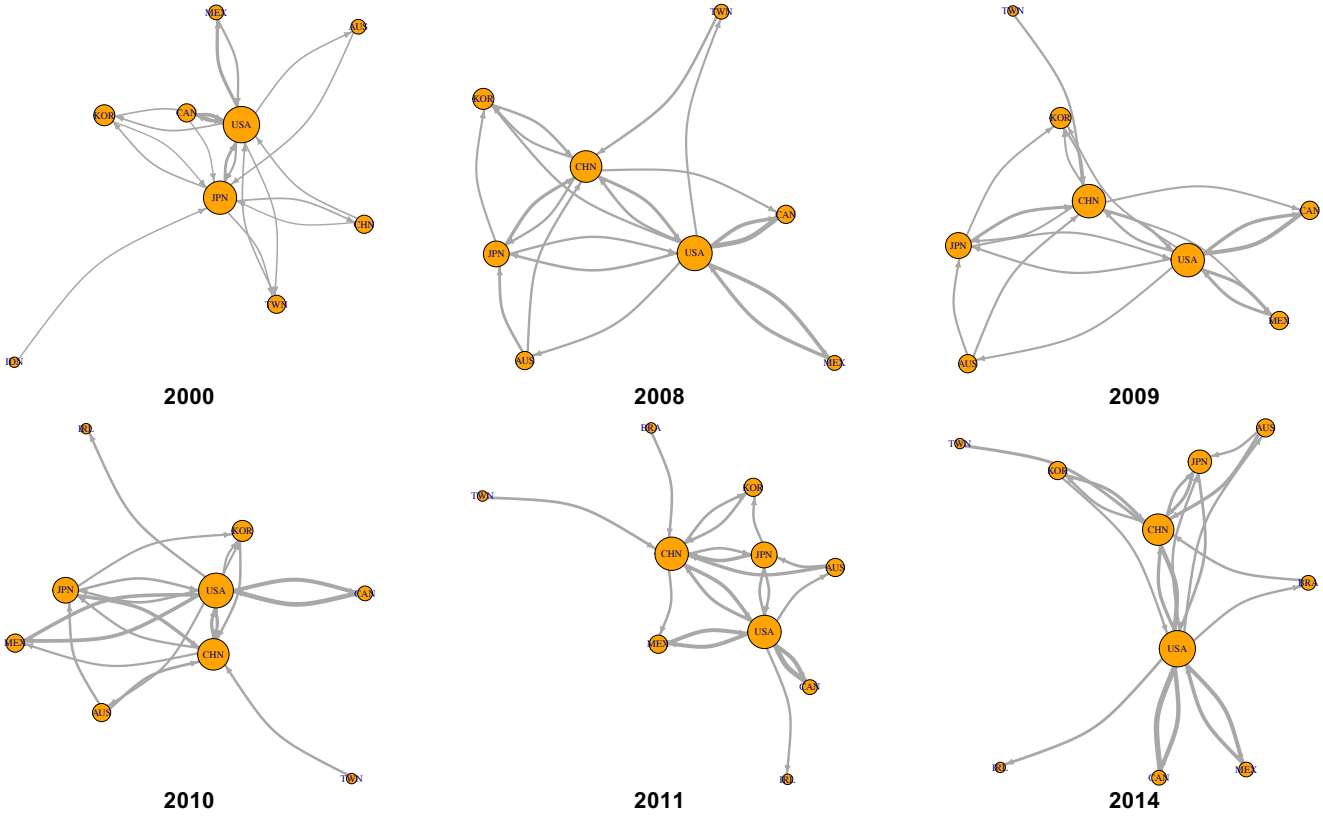


Fig. 3.16: International value-added circulation of the Pacific Rim community in 2000, 2008–2011, and 2014. These graphs illustrate the top 20 links. Their node sizes and link widths are in proportion to the square root of the degree and the amount of circular flow, respectively. Table 3.1 shows a detailed list of the sectors.

machinery manufacture, wholesale, financial services, and management services, which showed a large amount of the circular flow of IVAN. On the other hand, the economic integration in value-added index of the Pacific Rim was steady because the Pacific Rim community had stably included mining, manufacture (especially of motor vehicles and high-tech products), and construction which had high value-added circulation.

The obtained results suggest several topics for future research. The thresholds for detecting two regional communities by Infomap were significantly different before and after the economic crisis. What this means in terms of international trade requires further study. In addition, how to set appropriate thresholds for time-series community analysis of directed weighted networks such as IVANs also remains a research topic. Finally, it is also necessary to study whether the economic integration in value-added indices reflected the labor mobility in each regional community.

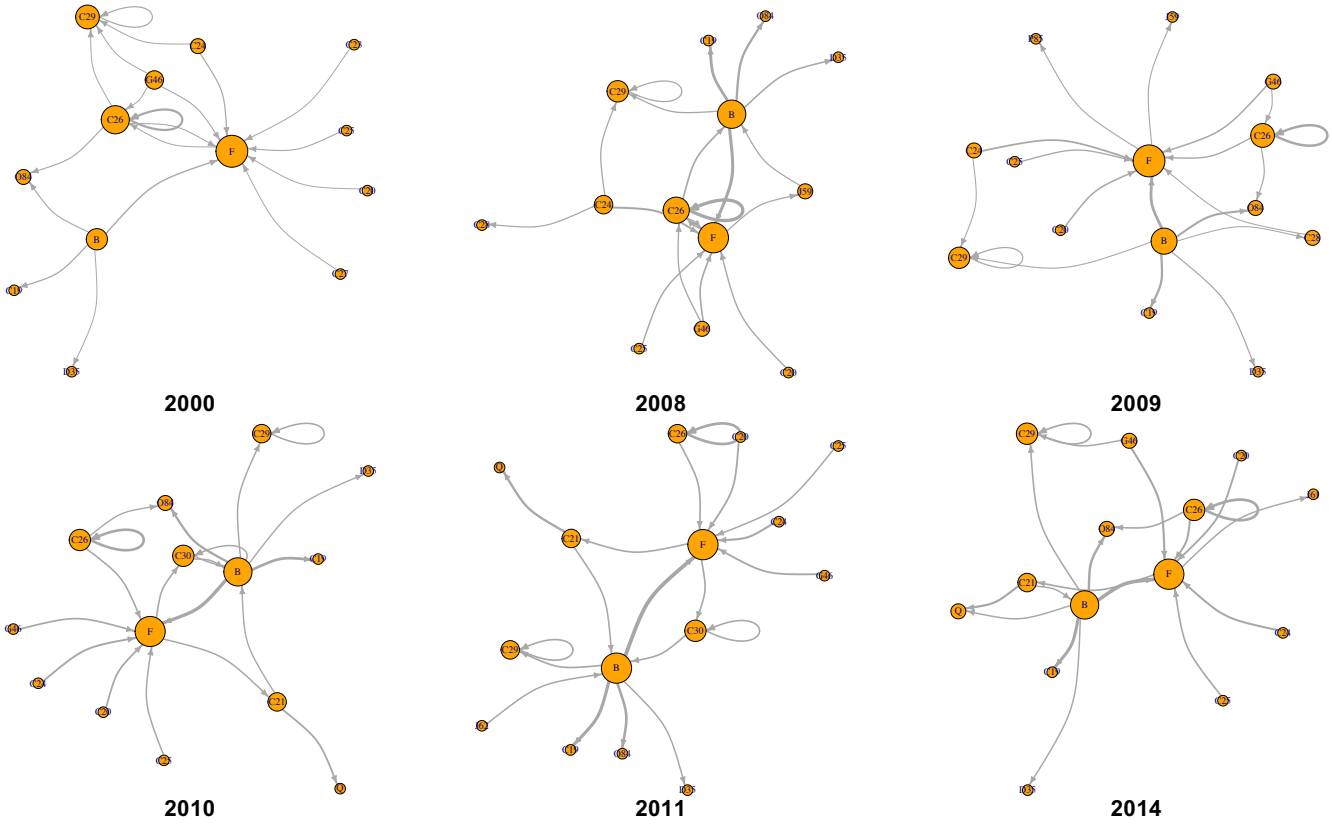


Fig. 3.17: Intersectoral value-added circulation of the Pacific Rim community in 2000, 2008–2011, and 2014. These graphs illustrate the top 20 links. Their node sizes and link widths are in proportion to the square root of the degree and the amount of circular flow, respectively. Table 3.2 shows a detailed list of the sectors.

Chapter 4

International Cooperation Analysis

In the previous chapter, we attempted to quantify economic integration based on the reality of international value-added relationships. However, the value of economic integration is merely the result of the respective economic activities of firms and other economic actors, and does not include the perspective of each country that intends to promote or not promote economic integration. Therefore, it is impossible to determine the contribution of each country to the progress of economic integration.

Therefore, the next step is to measure signs and country attitudes toward economic integration based on news coverage information that more directly reflects foreign policy. Can we capture the same trends as the economic integration indicator from the aggregate knowledge of news?[1]

In this study, we used event data to quantitatively analyze diplomatic relations in three ways. Fig. 4.1 shows the outline of the international cooperation analysis. It is a quantitative analysis of multilateral diplomacy based on international event data compiled from reports on the Internet.

Unlike economic relations, diplomatic relations do not involve objects to be traded, such as money or goods, and thus cannot rely as directly on data as the economy. However, the development of event data enabled quantitative analysis of diplomatic relations. By applying network science and physics methods to these data, we can reinforce our understanding of multilateral diplomacy, which until now has been discussed mainly qualitatively.

4.1 Event data

Databases for analyzing international relations have also been developed. Several data sets have been collected through automated classification of large amounts of text data (e.g. Global Data on Events, Location, and Tone (GDELT) [105], Integrated Crisis Early Warning System (ICEWS) [106], Armed Conflict Location & Event Data Project (ACLED) [107], Militarized Interstate Disputes (MID) [108],

[1]This study was conducted within an overseas internship in Economic Research Institute for ASEAN and East Asia. More detail is in Appendix B.

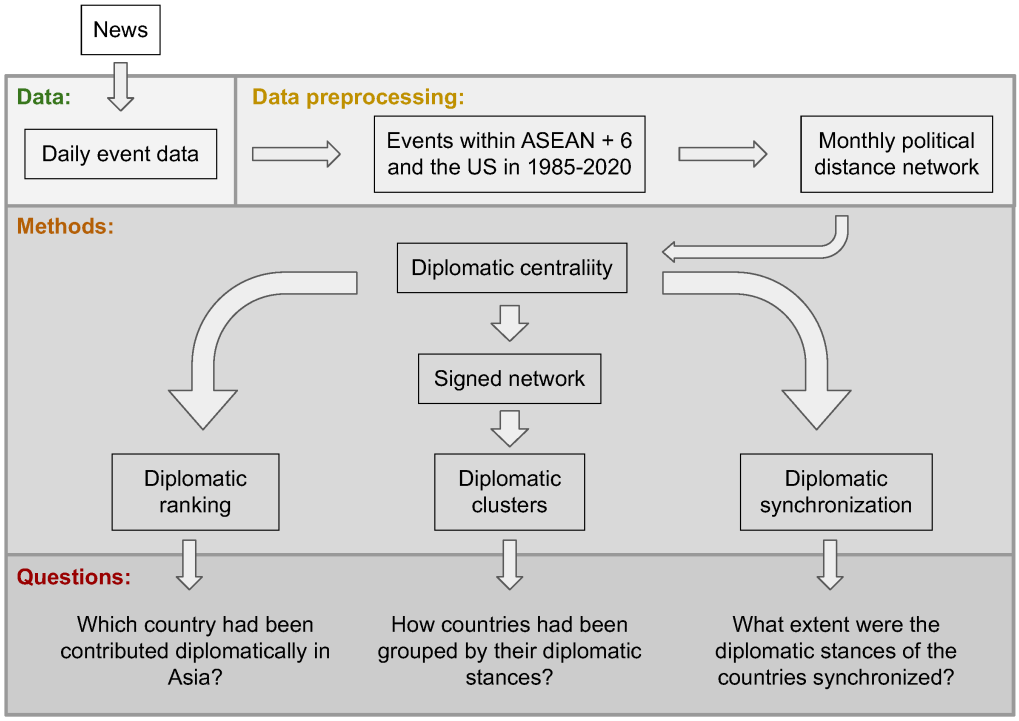


Fig. 4.1: Outline of the international cooperation analysis.

Virtual Research Associates (VRA)). These data were used to forecast economy [109], to estimate risks in investment [110], and to study peace [111], protests [112], and economic relations [113–117].

We used GDELT which records daily events involving up to two actors from 1979 to the present. Because it contains the longest period of events of the above data sets and has the largest number of events. In this study, we used the data with no missing country information for the two actors for the years 1985–2020 and selected events that involved 17 countries as actors. The countries are ASEAN plus 6 countries and the United States. Although the United States withdrew from the TPP after signing, it was included in this study because it was pursuing economic integration in the Asia-Pacific region through TPP negotiations. Table 4.1 displays each country's number of events in GDELT.

Each daily event data includes the Goldstein scale that rates cooperation-conflict at -10 to +10 for each type of event [118]. GDELT 1.0 used in this study records news reports in English, and Conflict and Mediation Event Observations (CAMEO) system classifies its events (Table 4.2) [119]. Each event data in GDELT contains information about its actors (up to two actors). We used data that included two actors and where at least one of the actors was in the country included in Table 4.1.

For the rationality of using GDELT for our study, we confirmed the FTA negotiations-related events[1] (hereafter, FTA events) recorded in GDELT are consistent with the events identified via the press releases by the Japanese government. Table 4.3 shows the ratio of the number of FTA events of the ASEAN+6

[1]FTA negotiations-related events include two kinds of the bilateral events: One was "engaging in negotiation" event for all meetings; the other was "signing formal agreement" event for the five meetings of/after the 3rd RCEP Summit.

Table 4.1: List of countries and the number of related events 1985–2020.

country	memberships	number of events
Brunei Darussalam	ASEAN, APEC, CPTPP	330,771
Cambodia	ASEAN	727,953
Indonesia	ASEAN, APEC	1,866,973
Lao PDR	ASEAN	268,595
Malaysia	ASEAN, APEC, CPTPP	1,971,216
Myanmar	ASEAN	844,573
Philippines	ASEAN, APEC	2,447,143
Singapore	ASEAN, APEC, CPTPP	1,069,453
Thailand	ASEAN, APEC	1,481,022
Vietnam	ASEAN, APEC, CPTPP	1,793,565
Australia	ASEAN+6, APEC, CPTPP	5,286,741
China	ASEAN+6, APEC	12,148,418
India	ASEAN+6	2,136,507
Japan	ASEAN+6, APEC, CPTPP	5,167,195
New Zealand	ASEAN+6, APEC, CPTPP	1,356,939
South Korea	ASEAN+6, APEC	3,000,660
United States of America	APEC, TPP	57,240,899

Table 4.2: List of event codes in GDELT. This lists only the highest class of the hierarchical event classification.

Code	Event category	Number of subcategories	Number of sub-subcategories
01	make public statement	10	0
02	appeal	9	18
03	express intent to cooperate	10	18
04	consult	7	0
05	engage in a diplomatic cooperation	8	0
06	engage in a material cooperation	5	0
07	provide aid	6	0
08	yield	8	17
09	investigate	5	0
10	demand	9	18
11	disapprove	7	5
12	reject	10	16
13	threaten	10	12
14	protest	6	20
15	exhibit force posture	6	0
16	reduce relations	7	6
17	coerce	7	6
18	assault	7	7
19	fight	7	2
20	use unconventional mass violence	5	2

countries recorded in GDELT in a given RCEP-related event (hereafter, RCEP event) month[2] identified via Japan's Ministry of Foreign Affairs (MOFA) website [120] to the average of the FTA events over the

[2]GDELT possibly records one specific event as multiple events because it regards the same event in two (or more) different date articles as two (or more) different events. It is natural that there were several different date articles regarding one RCEP event. Thus, we aggregate the events by month.

year. We can expect that the ratio will take a large value, typically more than one (the number of FTA events in a given month is larger than the yearly average of FTA events) if GDELT successfully detects RCEP events identified via public information. As seen in the table, almost all (26/30) the ratios of RCEP events were more than one. Moreover, the ratios in the months when important RCEP negotiations such as RCEP summits took place were close to or significantly above two. Therefore, using the chronology of the RCEP negotiations compiled by the MOFA of Japan, we confirmed that FTA events were recorded in a given month when RCEP negotiations took place more than in usual months.

Table 4.3: List of RCEP-related meetings and ratios of a daily average of the number of events in the month per daily average in the year in GDELT. Ratios $\geqq 1.0$ are colored light gray and ratios $\geqq 2.00$ are colored dark gray. The calculation before the 3rd RCEP Summit used the "engage in negotiation" event and of/after the 3rd RCEP Summit used the "engage in negotiation" and "sign formal agreement" events identified by CAMEO system [119] as codes 46 and 57, respectively. These 30 meetings were listed in the timeline summary by the Ministry of Foreign Affairs of Japan [120].

RCEP-related meeting	date	event ratio
6th East Asia Summit	19/11/2011	1.44
20th ASEAN Summit	03/04/2012	1.20
5th Trilateral Summit (CJK)	13/05/2012	2.63
1st AEM Plus FTA Partners	30/08/2012	1.04
21st ASEAN Summit	20/11/2012	3.12
1st RCEP Ministerial	19/08/2013	2.29
2nd RCEP Ministerial	27/08/2014	1.94
1st RCEP Intersessional Ministerial	10/07/2015	0.75
3rd RCEP Ministerial	21/08/2015	1.06
27th ASEAN Summit	22/11/2015	1.66
4th RCEP Ministerial	05/08/2016	1.25
29th ASEAN Summit	08/09/2016	1.84
2nd RCEP Intersessional Ministerial	01/11/2016	2.23
3rd RCEP Intersessional Ministerial	22/05/2017	1.26
5th RCEP Ministerial	10/09/2017	0.58
31st ASEAN Summit/ 1st RCEP Summit	14/11/2017	3.40
4th RCEP Intersessional Ministerial	03/03/2018	0.58
5th RCEP Intersessional Ministerial	01/07/2018	0.42
6th RCEP Ministerial	21/08/2018	1.12
6th RCEP Intersessional Ministerial	10/10/2018	1.12
33rd ASEAN Summit/ 2nd RCEP Summit	14/11/2018	2.46
7th RCEP Intersessional Ministerial	01/03/2019	1.45
8th RCEP Intersessional Ministerial	01/08/2019	2.96
7th RCEP Ministerial	03/09/2019	1.37
9th RCEP Intersessional Ministerial	11/10/2019	1.68
35th ASEAN Summit/ 3rd RCEP Summit	04/11/2019	2.64
10th RCEP Intersessional Ministerial	22/06/2020	2.23
8th RCEP Ministerial	25/08/2020	1.15
11th RCEP Intersessional Ministerial	13/10/2020	1.52
37th ASEAN Summit/ 4th RCEP Summit	15/11/2020	1.53

4.2 Methods

4.2.1 Political distance and diplomatic centrality

Political distance network

We calculated political distance using the Goldstein scale for events between the 10 ASEAN member states and the seven countries taken from GDELT. We redefined the political distance in Hardwick et al. [116] with a value greater than zero that can be used for network analysis.

Let the political distance P_M be 1 when the Goldstein scale is 0 or no events in a given month M, and let it be a value that is less than 1 when there are many cooperation events (i.e., the Goldstein scale is positive) and greater than 1 when there are many conflict events (i.e., the Goldstein scale is negative). Then the political distance P_{ijM} between country i and country j in a given month M can be expressed as

$$P_{ijM} = 1 - \frac{\sum_{t \in M} G_{ijt}}{E_{iM} + E_{jM} - E_{ijM}}, \tag{4.1}$$

where G and E are the Goldstein scale and the number of events, respectively.

In this study, the 10 ASEAN member states were grouped into one node, ASEAN-10, creating a network of eight nodes. Therefore, extending Eq. 4.1, we defined the political distance between ASEAN-10 and country i as follows

$$P_{i\mathrm{ASEAN10}M} = 1 - \frac{\sum_{j \in \mathrm{ASEAN10}} \sum_{t \in M} G_{ijt}}{E_{iM} + \sum_{j \in \mathrm{ASEAN10}} (E_{jM} - E_{ijM})}. \tag{4.2}$$

Here we note that ASEAN-10 means just the set of 10 ASEAN member states in 2022 and does not mean ASEAN member states of each month. We used this operation because the volume of the coverage was not enough to analyze in most of the states.

We constructed a monthly political distance network, a complete undirected graph, using the 6-month moving average of the above political distance $P^{(\mathrm{6ma})}$ as weights. The number of nodes is 8 for ASEAN-10 and the other seven countries, and the number of links is 28. The number of months was 426 months from April 1985 to September 2020 by taking a 6-month moving average.

As explained in Section 2.2.3 the number of ASEAN member states increased from 6 to 10 between 1995 and 1999. This study, however, analyzed the current 10 ASEAN member states collectively as ASEAN-10 throughout the 36-year period. One reason for grouping the 10 ASEAN member states together is the small number of events from ASEAN member states included in GDELT, especially before the 2000s. The second reason is to remove the effects of disputes among them (e.g., the Cambodian-Thai border dispute). If we create and analyze a political distance network of 17 countries, the political distances with ASEAN members would account for about 60% (56.25% for ASEAN members and 62.5%

for other countries) in the calculation of diplomatic centrality presented next. In short, we emphasized the relations between ASEAN member states and non-ASEAN states rather than among ASEAN states.

Diplomatic centrality

Diplomatic centrality is then defined using the average node strength of the political distance network. Let a set of ASEAN-10 and all countries be S, then diplomatic centrality D_{iM} of country i in a month M is

$$D_{iM} = \frac{1}{N} \sum_{j \in S} P_{ijM}^{(6\mathrm{ma})}. \tag{4.3}$$

The diplomatic centrality means the average of the political distances for the ASEAN-10 and the seven countries, with the smaller value being more cooperative and the larger value being more conflictual.

Assuming that the better the diplomatic relations are within the region, the smaller the diplomatic centrality, we used the inverse ranking of the diplomatic centrality as the diplomatic ranking. This ranking provides a relative indication of when and which countries have contributed to regional diplomatic relations.

4.2.2 Signed blockmodeling

Next, to determine how countries are divided by diplomatic stance, we created a signed network based on correlations of diplomatic centrality. Here, we assume that diplomatic stance can be detected by changes in diplomatic centrality and that countries that make the same change at the same time take the same stance. To discover countries with the same diplomatic stance, a network was created from positive and negative correlations between countries, and the nodes were clustered.

We only gave $+$ or $-$ sign information to the links in the signed network. In other words, the signed network was constructed as an undirected and unweighted network. We calculated the correlations of the diplomatic centrality between ASEAN-10 and the seven countries, and if the correlations were significant, the link of the sighed network is the sign of the correlation coefficient. To make it a monthly network, the correlation was first calculated for 6 months from April 1985, and then the starting month was shifted by one month thereafter to determine the sign for 426 months. When the p-value was less than 0.01, we considered the correlation significant.

Then, we used blockmodeling to divide a signed network into clusters. We followed Doreian and Mrvar's blockmodeing approach [121]. The clustering C_k into k clusters is determined by minimizing the following function:

$$G(\mathsf{C}_k) = \alpha \mathcal{N} + (1 - \alpha)\mathcal{P}, \tag{4.4}$$

where $\mathcal{N}$ and $\mathcal{P}$ are the total number of negative links within clusters and the total number of positive

links between clusters, respectively, and $0 \leq \alpha \leq 1$ is a trade-off parameter. When α is less than 0.5, the function $G(\mathsf{C}_k)$ prioritizes reducing the number of positive links among clusters; when α is greater than 0.5, it prioritizes reducing the number of negative links within clusters.

In this study, we performed blockmodeling with $k = 3$. This is because when $k = 2$, it is assumed that only two countries (e.g., Australia and New Zealand or Japan and South Korea) are frequently detected as clusters, and then another cluster is missed when it exists.

4.2.3 Diplomatic synchronization

When a region experiences, for example, progress in economic integration, events on economic cooperation are reported according to the importance of the event. Then, the diplomatic centrality within that region will be reduced in several countries at the same time. In other words, the more synchronized the diplomatic centrality is among countries within a region, the more internationally influential cooperation/conflict events are considered to be occurring in that region. Following this hypothesis, we compute the intra-regional synchronization of diplomatic centrality in order to detect and evaluate events that have developed/declined regional diplomatic relations.

The analysis of synchronization phenomena has been applied to economic phenomena outside the fields of engineering and physics; Ikeda et al. [122, 123] demonstrated the Japanese business cycle by calculating the synchronization of Indices of Industrial Production. Following their method, we estimated the phases for ASEAN-10 and seven other countries by analytic signal and calculated the order parameter.

In computing the analytic signal of country j, we used $x_j(m = 1, 2, \cdots, 425)$, which is the standardized log return of diplomatic centrality $D_j(m = 1, 2, \cdots, 426)$. Then, phase $\theta_j(m)$ of diplomatic centrality in country j is obtained by the analytic signal $z_j(m)$ and Euler's formula as

$$z_j(m) = x_j(m) + iy_j(m) = A_j(m)e^{i\theta_j(m)}, \tag{4.5}$$

where $i = \sqrt{-1}$ and $y_j(m) = H[x_j(m)]$, which is Hilbert transform of $x_j(m)$. Here, $y_j(m)$ can be calculated through discrete Fourier transform (DFT). First, we calculate $x(m) = F[X(m)]$ as

$$x_j(m) = \frac{1}{\sqrt{L}} \sum_{r=0}^{L-1} X_j(r) \left(\cos \frac{2\pi rm}{L} + i \sin \frac{2\pi rm}{L} \right), \tag{4.6}$$

where L is the length of $x(m)$, 425. Then, we applied Hilbert transform into Eq. 4.6 as

$$y_j(m) = H[x_j(m)] = \frac{1}{\sqrt{L}} \sum_{r=0}^{L-1} X_j(r) \left(H\left[\cos \frac{2\pi rm}{L}\right] + iH\left[\sin \frac{2\pi rm}{L}\right] \right) \tag{4.7}$$

$$= \frac{1}{\sqrt{L}} \sum_{r=0}^{L-1} X_j(r) \left(\sin \frac{2\pi rm}{L} - i \cos \frac{2\pi rm}{L} \right). \tag{4.8}$$

Because $H[\sin \omega t] = -\cos \omega t$ and $H[\cos \omega t] = \sin \omega t$.

Finally, we can obtain the order parameter for all countries and ASEAN as

$$q_S(t) = \frac{1}{N_S} \sum_{j=1 \in S} e^{i\theta_j(t)} = r_S(\cos(\phi_S) + i \sin(\phi_S)), \tag{4.9}$$

where $0 < r_S < 1$ and ϕ_S mean the extent of synchronization and phase of S.

4.3 Results

4.3.1 Networks and diplomatic centrality

Initially, we charted a rank-size plot to identify network and centrality features. Fig. 4.2 **A** and **B** show the left tail and right tail of the political distance distribution for four periods of 36 years divided by 9 years. The right tails change little, but the inclination of the left tails is steeper in more recent years. In other words, the difference in political distance between countries becomes smaller. The distribution of diplomatic centrality by country over the 36-year period results in Japan being the most central, followed by China (Fig. 4.2 **C** and **D**). Those farthest from the center are, in descending order, India, New Zealand, the United States, and Australia. The inclination of the distribution for South Korea and China was more gradual than for the other countries. In particular, South Korea shows almost smaller diplomatic centrality than ASEAN-10 in the left tail of Fig. 4.2 **C** and larger than ASEAN-10 in Fig. 4.2 **D**. China and South Korea are characterized by a wider range of diplomatic centrality values over 36 years than other countries.

Fig. 4.3 illustrates that there were four notable bottoms of the diplomatic centrality indexes from 1985 to 2020. The first bottom was in October 2003, when the diplomatic centralities of China, Japan, and South Korea (CJK) bottomed at the same time. Also, at this time, the diplomatic centralities declined for all countries and regions except India. The 9th ASEAN Summit and the 7th ASEAN+3 Summit were held the month. This is followed by the second-lowest bottom of CJK's diplomatic centrality around 2007. The CJK summit took place at this time. For the other countries, the U.S. is an exceptional country in the meaning that its diplomatic centrality also bottomed around 2007; Australia took even the local maximum. The third-lowest bottom of diplomatic centrality was China's in October 1997. At

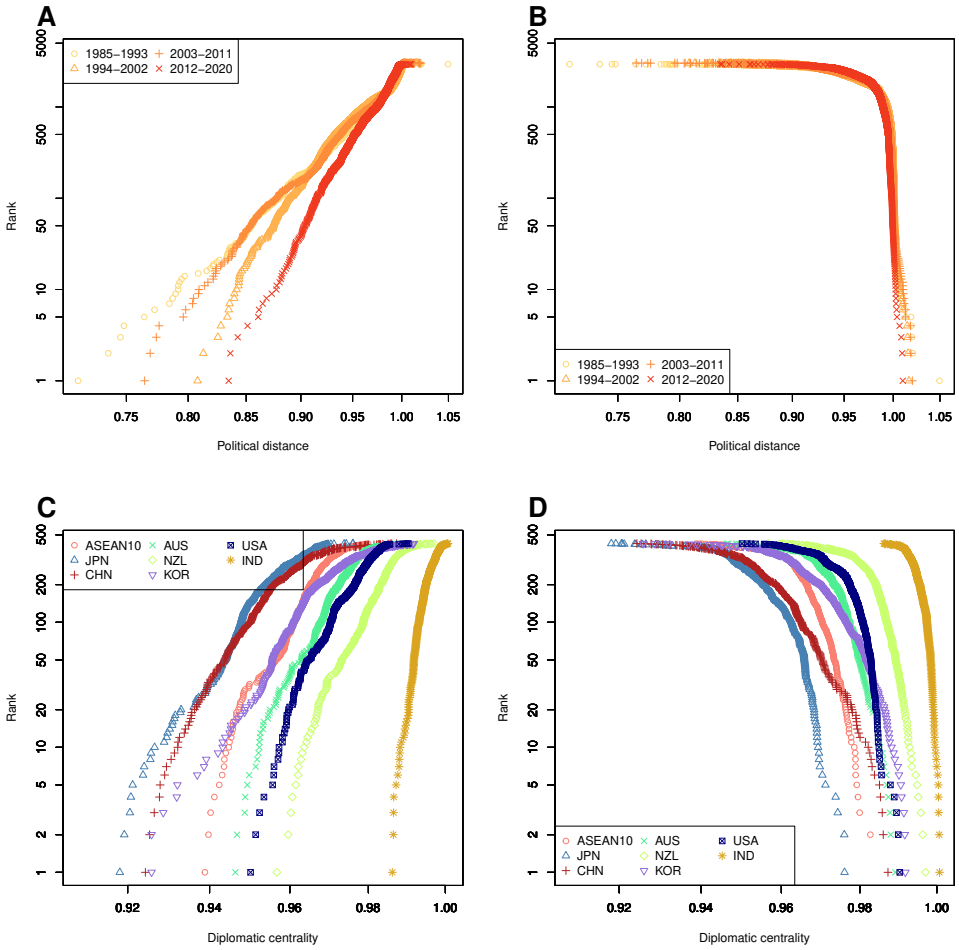


Fig. 4.2: Rank-size plots. **(A)** and **(B)** are plots of bilateral political distance. **(C)** and **(D)** are plots of diplomatic centrality of each country. Rank of **(B)** and **(D)** are ascending order of rank of **(A)** and **(C)**, respectively.

this time, the U.S. also bottomed, as Chinese President Jiang Zemin was invited by American President William Clinton to visit the U.S. and issued a China-US Joint Statement. The fourth-bottom of diplomatic centrality was Japan's in November 1989. The first APEC meeting was held in Canberra, Australia, in that month, which also marked the bottom of Australia's diplomatic centrality.

4.3.2 Diplomatic rankings

Diplomatic rankings in Fig. 4.4 show three major trends: 1985–1992, 1993–2011, and 2012–2020 throughout the entire period. Until 1992, Japan, ASEAN-10, and Australia were at the top of the list. Japan was almost always ranked first, but Australia was ranked first in 1987, and ASEAN-10 was frequently ranked first from 1990 to 1993. From 1994 to 2011, Japan and China occupied the top two or more positions, while the U.S. position gradually declined. From 2012 onward, in addition to Japan and China, ASEAN-10 was again in contention for the top position. South Korea and New Zealand were also affected by these trends. South Korea moved up from around 7th place at the beginning of 1993 to a

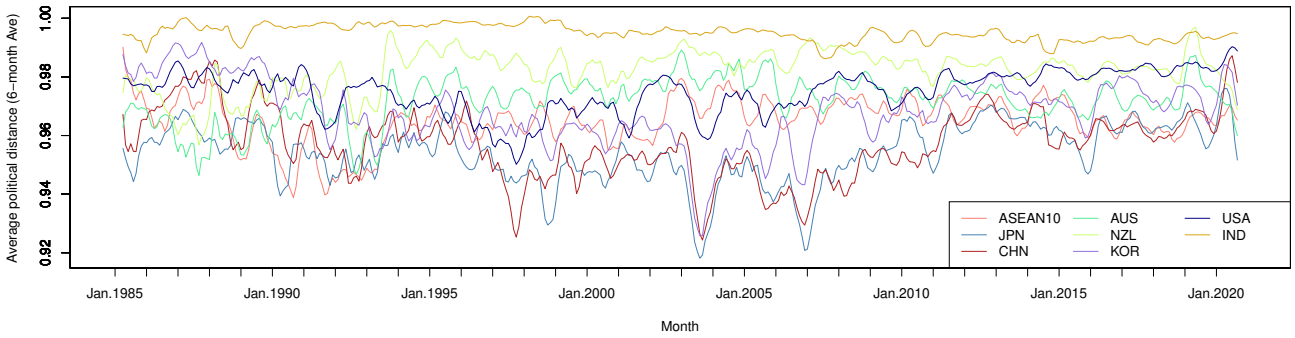


Fig. 4.3: Diplomatic centrality of ASEAN-10 and 7 countries. The smaller the diplomatic centrality, the more cooperative the country is in diplomacy among the 17 countries.

ranking between 3rd and 5th place. New Zealand followed the same trend as ASEAN-10 and Australia, falling to 7th around 1993 and continuing until around 2014, but in recent years it has competed with the U.S. and moved up in the rankings. It is also clear from Figs. 4.2 and 4.3 that India consistently remained at the bottom of the list.

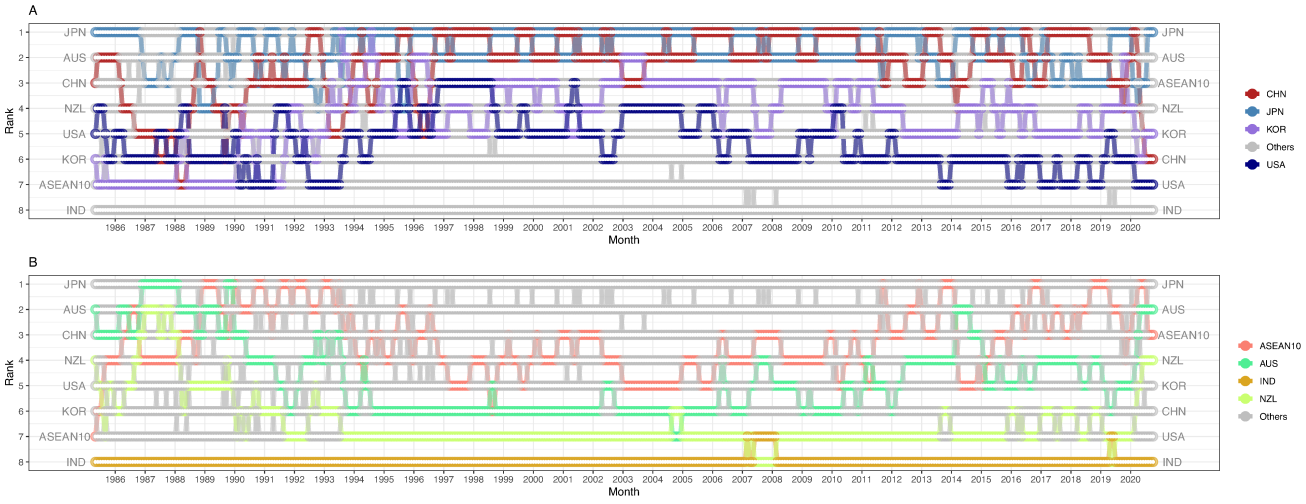


Fig. 4.4: Diplomatic rankings of ASEAN-10 and 7 countries. **(A)** is colored in China, Japan, South Korea, and the U.S., **(B)** is colored on ASEAN-10, Australia, New Zealand, India.

4.3.3 Diplomatic clusters

The links between two countries in the monthly signed network created from the diplomatic centrality correlations are shown in Fig. 4.5. Fig. 4.5 **A** shows the monthly sign of each link, and Fig. 4.5 **B** shows the number of positively, negatively, and not-significantly correlated links by month. It indicates that there were many months in which more than half of the links were not significant before 2001; however, after 2003, links of positive correlation accounted for more than half of the links, and the number of

positive correlation links increased.

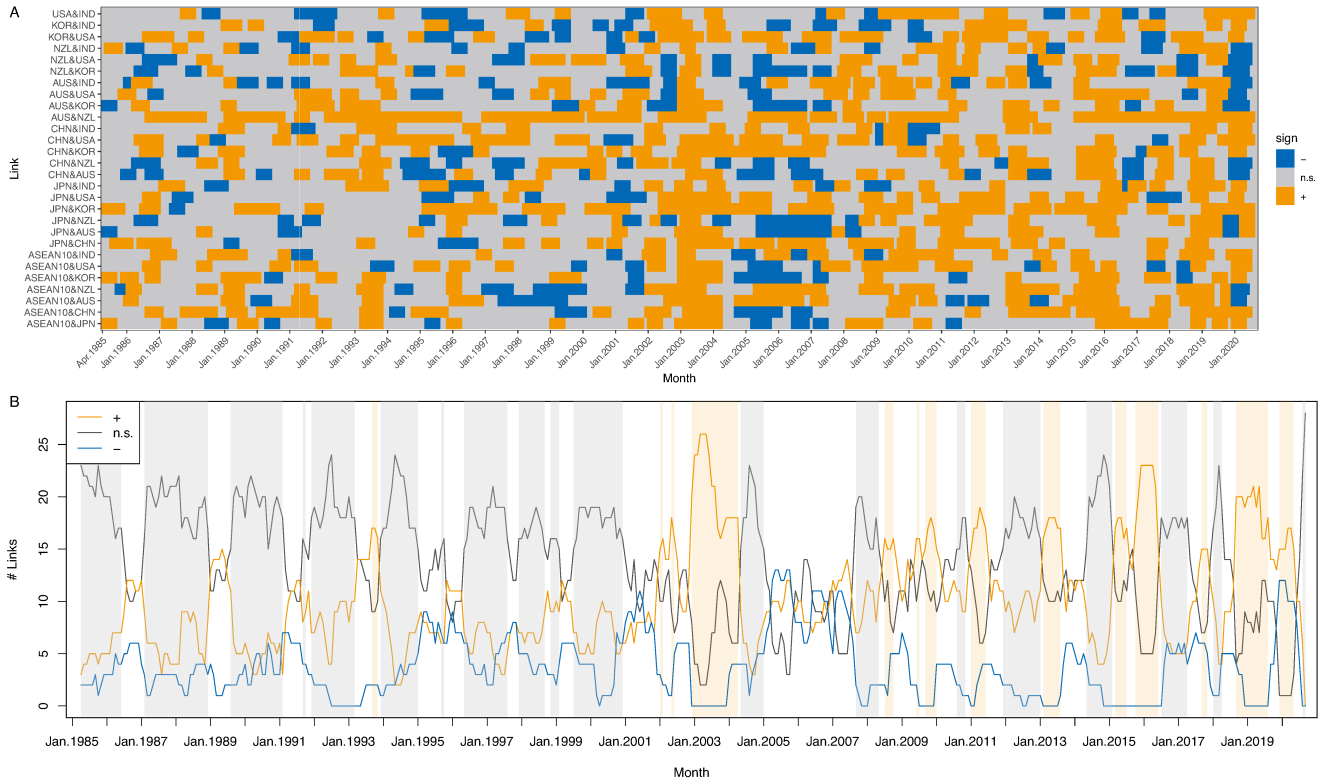


Fig. 4.5: Monthly signed network. **(A)** is signs of links and **(B)** is the number of links/non-links by sign. If the percentage of links of "+" and "n.s." in some months is more than 1/2, the background color of the terms in **(B)** are orange and gray, respectively. The percentage of links of "-" is less than 1/2 for all months.

In dividing the signed network as shown in Fig. 4.5 into clusters, we examined the dependence of α on blockmodeling (Fig. 4.6). Fig. 4.6 shows how many nodes comprise the largest, second-largest, and third-largest clusters in heat maps **A**, **B**, and **C**, respectively. As described in Section 4.2, the number of clusters was set to 3, but in some cases, only one cluster was detected, depending on α and month. In the periods that were orange in Fig. 4.5, there were often no multiple clusters. This is because, as shown in Eq. 4.4, reducing α prioritizes reducing the number of positive links between clusters, so that it is optimal not to split into clusters when positive links are in the majority. Since there tended to be more positive links than negative links over the 426-month period, the number of clusters increased as α was increased, and the size of the largest cluster (1st cluster) tended to be smaller. In particular, when α was less than 0.5, the probability of the number of clusters being 1 increased in some months (e.g., the first half of 2002 and 2007–2010). Fig. 4.6 shows that the number of clusters can be one when α is less than 0.5, and Fig. 4.6 **C** shows that a 3rd cluster can be detected when α is greater than 0.5. Therefore, $\alpha = 0.75$, which is greater than 0.5, was used for blockmodeling.

Blockmodeling results in Fig. 4.7 show that ASEAN-10 and the seven countries were divided into two clusters in 55.6% of all months, and 140 months out of 426 (32.9%) were divided into three clusters,

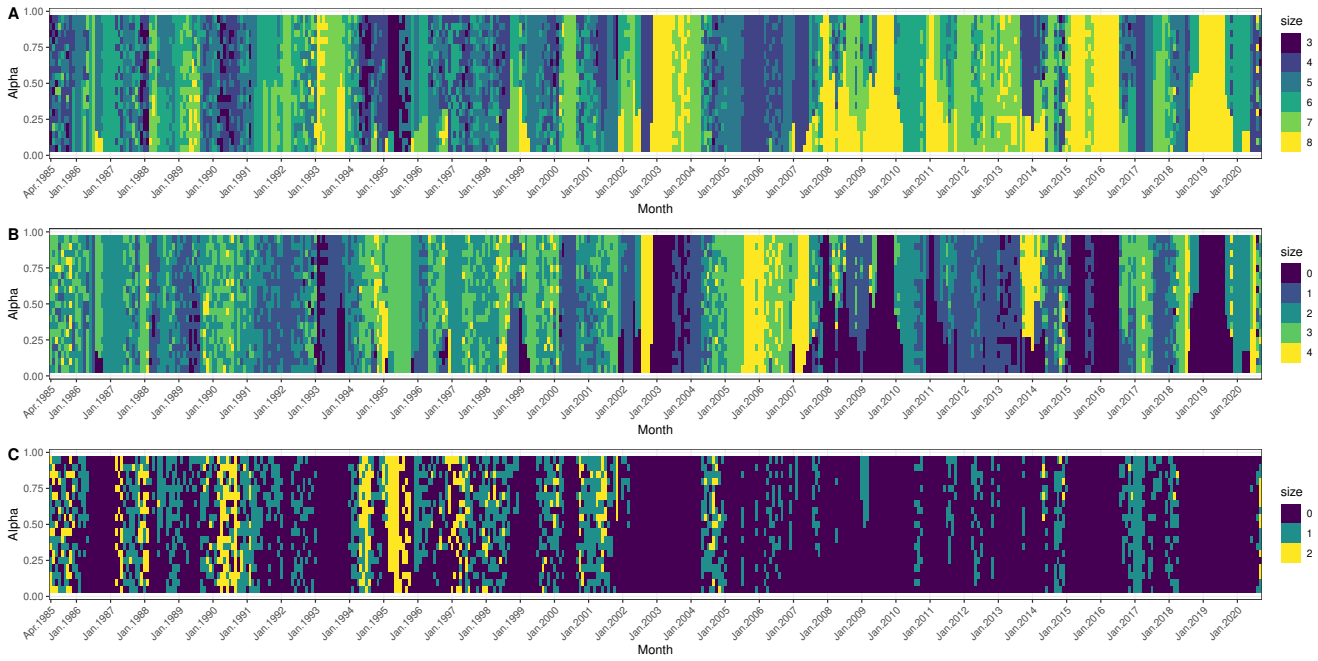


Fig. 4.6: Cluster sizes of signed blockmodeling by alpha. This figure shows the results of blockmodeling with alpha varying by 0.05 from $\alpha = 0.05$ to 0.95 for each month. Each cell represents the size of the cluster in color, with **(A)** representing the largest cluster, **(B)** the second largest cluster, and **(C)** the third largest cluster. If the second and third clusters do not exist, their size is zero.

of which 75.7%, or 106 months, had a cluster size of 1. There were also 49 months (11.5%) that were not divided into clusters. By numbering clusters 1–3 from the largest cluster to the third cluster, we can calculate the euclidean distance between countries. The complete linkage method, one of the methods of agglomerative hierarchical clustering, was used to calculate a dendrogram of the proximity between countries based on the cluster classification for the entire period. The closest pair in distance was then Australia and New Zealand, followed by Japan and South Korea. Thereafter, China, ASEAN-10, and the United States were in close proximity to Japan and South Korea, in that order, followed by the pair of Australia and New Zealand, and finally India.

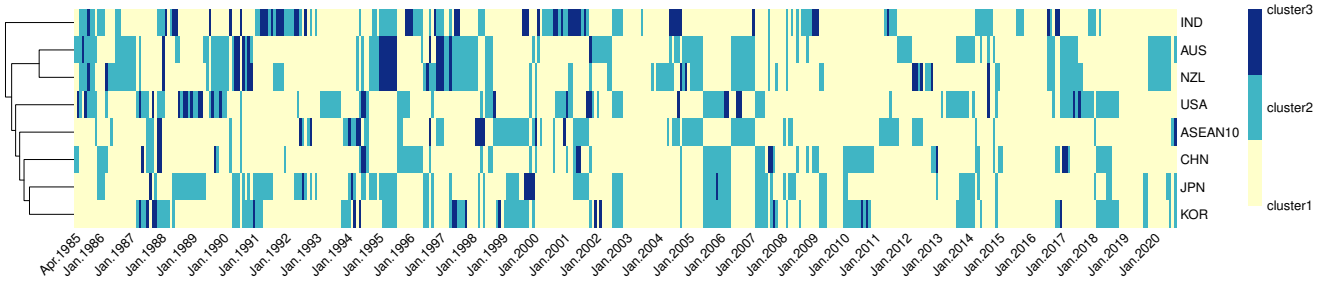


Fig. 4.7: Monthly results of signed blockmodeling. The cluster codes 1, 2, and 3 mean the largest, second, and smallest cluster in the month, respectively. The left dendrogram was by the complete linkage method.

4.3.4 Diplomatic synchronization

Finally, we present synchronization results. The diplomatic centrality of each country is represented in the complex plane by calculating the analytic signals of the diplomatic centrality in each country, as shown in Fig. 4.8. The order parameter is calculated from the phases of these countries according to Eq. 4.9, and Fig. 4.9 shows the degree of synchronization as a time series. Here, when the 6-month moving average is greater than 0.5, there is synchronization between these countries and ASEAN-10, and the period is shown in orange. It illustrates prior to 2002, seven periods were synchronized, but the synchronous periods averaged 6.125 months, while since late 2002, eight periods have been synchronized for an average of 13.78 months. Of the 273 months between April 1985 and December 2007, 27.4% were synchronized, while 62.1% of the 153 months between January 2008 and September 2020 were synchronized.

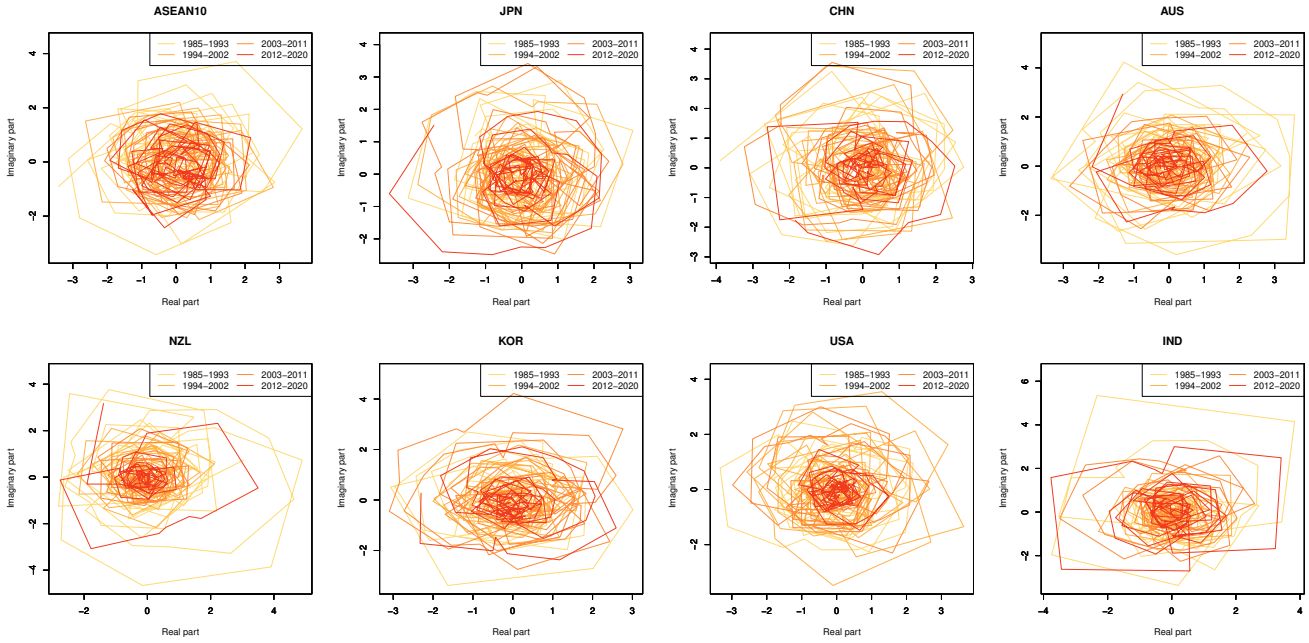


Fig. 4.8: Complex planes of the analytic signals of diplomatic centrality in ASEAN-10 and 7 countries.

The proportion of synchronous periods increased after the longest synchronous period, from September 2002 to October 2004, and the subsequent 35-month asynchronous period that lasted until September 2007. Fig. 4.10, a part of Fig. 4.7, shows diplomatic clusters in the 35-month asynchronous period. Although there are small variations in clustering, the division into two main groups, CJK and the U.S. and others, suggests that this 35-month period is asynchronous.

Table 4.4 summarizes synchronous periods with average ranks of ASEAN-10 and the countries. In the longest synchronous period (No.4 in Table 4.4), Japan's average diplomatic rank is 1.04, indicating that it is leading diplomatic relations in East Asia during this period. As Fig. 4.4 confirmed, this period

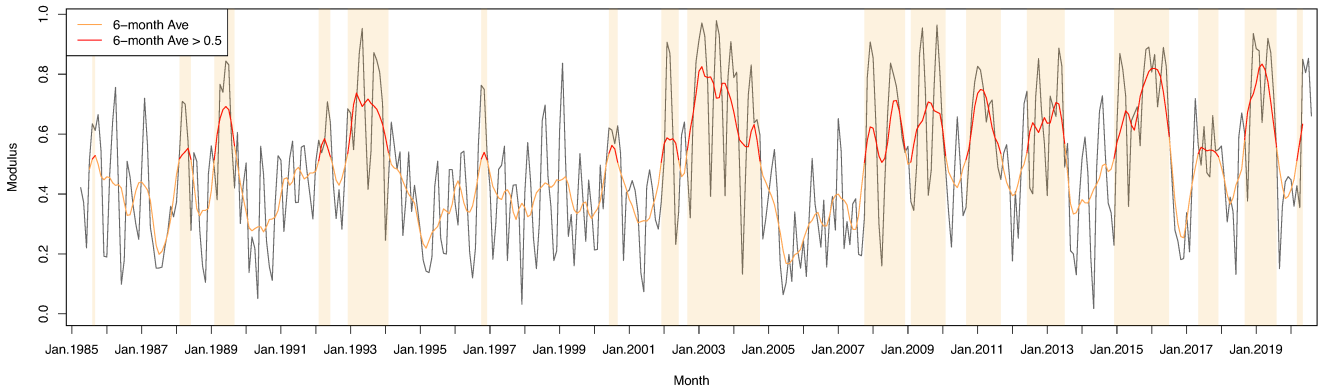


Fig. 4.9: Modulus of the order parameter of all countries. Orange-colored periods meant synchronous when the 6-month average of the order parameter was over 0.5.

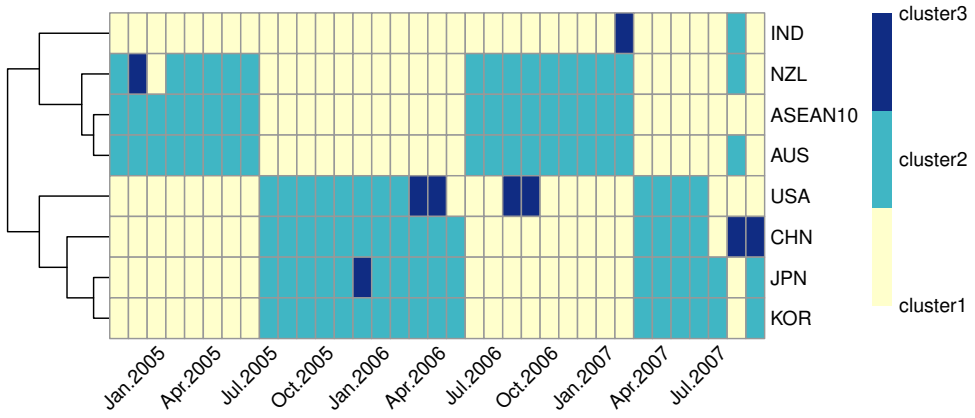


Fig. 4.10: Diplomatic clusters in an asynchronous period from November 2004 to September 2007. The cluster codes 1, 2, and 3 mean the largest, second, and smallest cluster of the month, respectively. The left dendrogram was by the complete linkage method.

included the year 2003, which had the smallest diplomatic centrality of the 36 years. It was also the period in which Asia Bond Market Initiative (ABMI) was established, the first Six-Party Talk, the 9th ASEAN Summit, and the 7th ASEAN+3 Summit were held. At the 9th ASEAN Summit, ASEAN declared to establish ASEAN Community. Meanwhile, CJK issued the Joint Declaration on the Promotion of Tripartite Cooperation after the 7th ASEAN+3 Summit, and ASEAN and Japan issued the ”Tokyo Declaration” which mentioned the East Asia Community. Japan also had the highest diplomatic ranking for the synchronous periods No.2, 3, and 7–9. In period No.2, the AFTA, which was declared at the 4th ASEAN Summit in January 1992, was implemented in 1993, and the first APEC Summit was held in the United States in November 1993. In period No.8, the first rounds of the negotiation on CJK FTA and the negotiation for RCEP were held; TPP was concluded and signed in period No.9.

China had the highest ranking for No.5, 6, and 10 periods. The first CJK trilateral summit was held at the end of the No.5 period. In addition, ASEAN-10 ranked the 1st in diplomatic ranking over Japan and China for the No.1 and No.11 synchronous periods. Overall, only Japan, China, and ASEAN-10

Table 4.4: Average ranks in synchronous periods longer than 6 months. The highest and second highest ranks in each period are colored dark and light gray, respectively.

No.	synchronous period			average rank							
	start	end	months	ASEAN10	JPN	CHN	AUS	NZL	KOR	USA	IND
1	Feb.1989	Sep.1989	8	1.45	2.82	3.73	2.27	4.91	7.00	5.82	8.00
2	Dec.1992	Feb.1994	15	2.13	1.47	3.80	4.60	6.53	3.40	6.07	8.00
3	Dec.2001	Jun.2002	7	3.43	1.29	1.71	5.57	7.00	3.57	5.43	8.00
4	Sep.2002	Oct.2004	26	4.88	1.08	2.27	6.12	6.88	2.65	4.12	8.00
5	Oct.2007	Dec.2008	15	3.60	1.80	1.20	5.00	7.27	3.53	5.87	7.73
6	Feb.2009	Feb.2010	13	3.77	1.69	1.31	5.92	7.00	3.38	4.92	8.00
7	Sep.2010	Sep.2011	13	3.38	1.46	1.85	4.92	7.00	3.54	5.85	8.00
8	Jun.2012	Jul.2013	14	2.36	1.57	2.07	4.00	7.00	5.00	6.00	8.00
9	Dec.2014	Jul.2016	20	3.15	1.40	1.85	4.65	6.75	3.95	6.25	8.00
10	May.2017	Dec.2017	8	2.50	2.50	1.00	4.00	6.25	5.00	6.75	8.00
11	Sep.2018	Aug.2019	12	1.42	2.17	2.42	4.92	6.83	4.33	6.08	7.83

were in the 1st position for 11 synchronous periods.

4.4 Discussion

4.4.1 Characteristics and limitations of the method

Section 4.1 insisted on the rationality of using GDELT for the political event study. Still, we have to mention that our analysis relied on press-reported event data, not an assessment of actual foreign policy effects. Political distances and diplomatic centrality were calculated based solely on the granularity of media coverage, i.e., information available to the general public. Diplomatic centrality does not indicate the extent to which they were central in the field of diplomacy, but rather the extent to which they were actively engaged in, or reportedly engaged in, diplomatic cooperation in the region.

As noted in Section 4.1, the data analyzed in this study (GDELT 1.0) is based on information reported in English and therefore has an English bias. In other words, Japan, which is closer to the position of the West, may be classified as more optimistic about events than China. In addition, the amount of information available had changed significantly over the past 36 years (especially with the development of the Internet), so the trends may be different before the early 2000s and after 2010.

We analyzed the political distance network of eight nodes, including 17 countries, with the 10 ASEAN member states as one node. As explained in Subsection 4.2.1, the reasons were the small number of events in the ASEAN member states and to remove the effects of disputes within them. Consequently, we discounted their diversity though they also uniquely concluded bilateral agreements without the auspices of ASEAN (e.g. US-Singapore FTA). However, our analysis included events of these agreements between an ASEAN member state and a non-ASEAN state as events between ASEAN-10 and the country. Any analysis that includes political distances within the ASEAN member states would need to gather

event information in the language of each country. In our case, the paucity of event data on the ASEAN member states was compensated for by considering all member states as one entity.

Moreover, there are limitations in analyzing individual measures for economic integration. While we cited RCEP and TPP as specific examples of economic integration, GDELT 1.0 does not distinguish between these agreements. Fig. 4.11 shows the evolution of the annual percentages of the four events related to economic integration as classified by CAMEO, which is the limit this study can identify. Analyzing RCEP and TPP negotiation events separately is not possible in GDELT 1.0; it is necessary to use texts and articles containing specific words (i.e., RCEP and TPP) rather than data classified by CAMEO. Therefore, this study analyzed all events converted to the Goldstein scales without distinguishing between measures to progress economic integration, and the scope of the study did not include an analysis of each agreement or policy.

Fig. 4.11: Annual event percentages of four types: (A) "make/host a visit," (B) "engage in negotiation," (C) "sign formal agreement," and (D) "cooperate economically." The event types were identified by CAMEO.

A major limitation of our study is the inability to elucidate the political mechanisms of diplomatic phenomena. However, by applying network science and physics methods to event data, our study provided a quantitative approach to observing multilateral relations. The analysis of complex relationships, such as multilateral relationships, could be unintentionally arbitrary. We augmented the findings of qualitative studies that answer the Why with data-driven research. The next Subsection discusses how the results of the diplomatic centrality analysis are similar to the leading position in regional integration as described in international relations theory, which has been discussed so far by collecting answers to the Why and How.

4.4.2 Implications from the analysis

The previous section showed the high diplomatic ranking of Japan, China, and ASEAN-10, diplomatic clusters representing similar diplomatic stance of Australia and New Zealand and unique diplomatic stance of India, and the potential for quantitative understanding of cooperative multilateral diplomacy through the observation of diplomatic synchronization. Therefore, this section discusses the results of this study, citing previous studies and specific examples.

Diplomatic centralities of Japan, China, and ASEAN-10

Our analysis quantitatively demonstrated that Japan's contribution to East Asian diplomatic relations was significant over a period of 36 years. Japan has been overtaken by China in GDP since 2010 and was about one-third of China's GDP in 2020 [124], but still competes with China for first place in East Asian diplomatic centrality. It is because Japan contributed to developing the regional production networks [125, 126] and promoted institutional building in Asia in the 21st Century [127].

On the one hand, China has been as influential in East Asia as Japan, especially since 1997, when it repeatedly ranked first in the diplomatic rankings. It is consistent with the growing Chinese role together with other East Asian countries after the Asian financial crisis in 1997 [128, 129]. On the other hand, other countries in East Asia did not align much during the period when China had the highest diplomatic ranking. For the percentage of times it ranked first in the region, it lagged far behind Japan in diplomatic ranking during the synchronous period. This result may suggest that from a security standpoint Japan can be aligned when its diplomatic rank is high, but not with China.

ASEAN-10 had increased its diplomatic ranks from 1989–93 and after 2012; in addition, ASEAN-10 was the center of East Asian diplomacy in two synchronous periods, tying with China in the number of times, whereas in most periods it had a lower diplomatic ranking than China. During the 1989–1993 period, ASEAN was central to the development of APEC [130] and declared the formation of the AFTA in 1992 [55]. 1993 was also the year of the publication of the World Bank report that called the rapid economic growth of East Asia between 1965 and 1990 the East Asian Miracle [131]. The period after 2012, when ASEAN's diplomatic ranking rose, coincided with the period when the establishment of the ASEAN Community [132] made East Asian regional integration a reality and when ASEAN centrality drove the negotiation and conclusion of the RCEP [133, 134].

Similarity and uniqueness of diplomacy

Diplomatic clustering showed that Australia and New Zealand have the closest diplomatic stance in the Asia-Pacific. Both countries are located in Oceania and are independent of British colonial rule. Furthermore, publicly, Australia describes the bilateral relationship as "natural allies with a strong trans-

Tasman sense of family" [135], while New Zealand describes Australia as "no better friend and no closer ally" [136]. This mutually recognized proximity was also clearly demonstrated by the political clustering. Indeed, the two countries are noted to have four shared commitments to preserving and promoting the international rule-based order, crisis management, Pacific regionalism, and regional trade liberalization [137].

On the other hand, India, which engaged in non-aligned diplomacy during the Cold War, was regarded as having the most unique diplomacy in the Asia-Pacific region. Even today, India has not joined either the CPTPP or RCEP and conducts its unique diplomacy. Such a diplomatic stance is reflected in the results of the diplomatic clustering.

One finding is that two countries with friendly relations are actually detected as close, while countries with unique diplomatic stances are observed as distant from any country. Diplomatic clustering shows that CJK, ASEAN-10, and the U.S. do not have as unique a diplomatic strategy as India and show a diplomatic stance more distant than Australia and New Zealand.

Synchronized cooperative diplomacy

In the 36 years since 1985, East Asian diplomacy was most synchronized in 2003. 2003 was a year of significant progress in cooperation among ASEAN, ASEAN+3, and CJK. First, in May 2003, the ABMI was agreed upon at the ASEAN+3 Finance Ministers Meeting, one of the important ongoing forums of the ministerial level [138]. Efforts to foster the local bond market in the Asian region in reflection of the Asian financial crisis contributed to institutionalizing the ASEAN+3 framework and bringing these countries together in a way that excluded the United States [139]. Second, in August 2003, the Six-Party Talks were held on the North Korean nuclear issue. At that time, China assumed the chairmanship of the Six-Party Talks and fulfilled its responsibility for the security of East Asia. China became the second non-ASEAN member of the Treaty of Amity and Cooperation in Southeast Asia (TAC) with India. Through the ASEAN Regional Forum (ARF) and ASEAN+3, China seemed to support the ASEAN-driven multilateral security community [140, 141]. In October, the 9th ASEAN Summit was held in Bali, Indonesia, and the Declaration of ASEAN Concord Ⅱ (Bali Concord Ⅱ) was issued, which called for the creation of an ASEAN Community by 2020 [142]. It was a symbolic moment that ASEAN promoted the integration itself and strengthened the relationship with its external partners [143]. In December, the Tokyo Declaration was issued at the ASEAN-Japan Commemorative Summit Meeting [144], which called for deepening cooperation in East Asia to create the East Asian Community. Japan also declared its intention to negotiate accession to the TAC at the meeting.

The recent trend toward regional economic partnerships such as TPP and RCEP may be reflected in the lengthening of the synchronous period. Interestingly, the trend began during the Global Financial

Crisis of 2008–2009. During the crisis, China and other emerging countries increased their international presence through international forums (such as the G20 and BRICS (Brazil, Russia, India, and China) summit, International Monetary Fund (IMF), and World Bank) [145]. This is consistent with the ranking of China in Table 4.4. During that period, the United States announced its participation in the Trans-Pacific Strategic Economic Partnership Agreement (TPSEP), the original agreement of the TPP which is the piece of US rebalancing to the Asia-Pacific [146], and the U.S. joined the TAC in 2009 and East Asia Summit (EAS) in 2011. In 2012, ASEAN began negotiations for the RCEP with original EAS member countries (ASEAN+6), which has each bilateral FTA with ASEAN. RCEP participating countries have agreed that RCEP will affirm the principle of “ASEAN centrality” in Asian regionalism [147]. The ASEAN-centered institutional building has been promoted, such as the ASEAN Defense Ministers' Meeting Plus in 2010, the Chiang Mai Initiative Multilateralization (CMIM) and the establishment of the ASEAN Plus Three Macroeconomic Research Office (AMRO) in 2011, and the establishment of ASEAN Plus Three Emergency Rice Reserve (APTERR) in 2011, in line with the ASEAN Community Building.

As described above, the period during which our analysis identified diplomatic synchronization was a period when cooperative multilateral diplomacy was gaining momentum in East Asia. Thus, the negotiations and formations of the ASEAN Community, a manifestation of regionalism, may be observed as a synchronous phenomenon of diplomatic centrality.

Furthermore, the years in which economic integration in Asia-Pacific was more advanced than in Europe were 2010 and 2013–2014 [68], the years after 2008, when the synchronization became more active. While economic integration was more than in Europe because of the decline in the extent of European economic integration after the crisis, the Asia-Pacific was steadily increasing its economic integration. Earlier studies also pointed out that while Europe faced serious problems such as the debt and euro crises, the ASEAN and East Asian regions recovered more quickly than Europe after the Global Financial Crisis and advanced economic integration [132, 148]. While economic integration has deepened in East Asia after the Global Financial Crisis, there has also been competition between Japan and China in infrastructure development in the region [149, 150]. The results of this study supported that regionalism in East Asia has been evident, especially since 2008.

4.4.3 Significance and applicability of the study

We have shown that it is possible to analyze not only bilateral relations by calculating political distances from event data, but also multilateral international relations. Diplomatic centrality made it possible to compare diplomatic cooperation stances in the region over time or internationally. We showed that diplomatic clustering divided countries into groups based on their time-series correlations and that changes in

the centrality can be viewed as an analytic signal and the degree of synchronization can be calculated to capture regional diplomatic movements.

GDELT and other event data are freely available, and anyone can apply the methodology of this study to any combination of countries such as APEC, European Union (EU), and North American Free Trade Agreement (NAFTA) members. The content of the data handled in this study was limited due to the long period of time covered by the analysis, but if we focus on more recent years, non-English languages will be included, and we can analyze with less bias. We can also compare how we perceive diplomacy in different reporting languages and media by, for example, analyzing political distance and diplomatic centrality in different languages and media.

Finally, we discuss what our study can contribute. The ability to quantitatively measure multilateral diplomatic relations is helpful in reviewing diplomatic events that have occurred in the region. Events that can be interpreted in multiple ways over various histories occur daily, and it is difficult to understand even bilateral relations alone without being biased toward one point of view. Therefore, it is important to have an objective way to assess the state of diplomatic relations. Having quantitatively stated criteria allows us to begin the discussion from those criteria.

4.5 Summary

We created a political distance network consisting of the ASEAN+6 and the United States for the period 1985–2020 using GDELT, which classifies and records events around the world from the news. We defined diplomatic centrality from the network and analyzed it from three perspectives: rankings, clustering, and synchronization.

Diplomatic rankings showed that Japan had contributed significantly to East Asian multilateral diplomacy over the entire period, China had contributed alongside Japan since 1997, and ASEAN-10 had contributed alongside Japan and China in 1989–1993, from late 2011 to early 2014, and from 2016. Diplomatic clusters illustrated that the diplomatic stances of New Zealand and Australia were closest in any period, and in about 36 years, the diplomatic stances of CJK, ASEAN-10, and the U.S. were close in that order. Diplomatic synchronization quantified East Asian regionalism which has appeared frequently since 2008. Negotiations and formations of ASEAN Community and Mega-regional FTAs (e.g. TPP and RCEP), a manifestation of regionalism, may be observed as a synchronous phenomenon of diplomatic centrality.

The results of our analysis are consistent with various previous studies and political facts, and demonstrate the progress of East Asian economic integration in recent years. Our research proposes a data-based method of analyzing multilateral diplomacy by applying network science and physics. It allows case studies to be augmented with quantitative evidence, making complex international relations more

accessible to a wider audience.

Chapter 5

Role of the Japan's Energy Sector in Asian Economic Integration

5.1 Introduction

The previous chapters of this thesis have provided data supporting the progress of economic integration in the Asia-Pacific region, both in value-added and diplomatic relations. Diplomatically, Japan has made a significant contribution over the long term. Therefore, this chapter focuses on the Japanese sector and discusses its role in Asian economic integration.

In considering which sectors to focus on, we briefly review the suggestions from Chapter 3. Study in the chapter identified that the extent of economic integration in Europe hinges on Russia as a country abundant in resources [68]. On the other hand, the Pacific Rim community kept developing the extent of economic integration because it includes natural resources and some important manufacturing sectors: high-tech and motor vehicles sectors. Therefore, we intended to focus on one of these sectors, but they have been analyzed in considerable detail by experts as GVCs studies [31, 32].

Hence, we focus on the energy sector, a sector in which all of these sectors are deeply involved. The high-tech and automotive sectors use significant electricity in the process of their manufacturing, and electricity generation requires natural resources such as fossil fuels.

The energy sector is significant to treat as a research subject in three ways. First, electricity supply is essential for both manufacturing and service industries, and is therefore important for the development of domestic companies as well as for inviting foreign companies to the country. Second, Japan has been supporting international cooperation in Asia through projects for development of power and power transmission and distribution, which is consistent with the theme of this chapter. Third, the recent climate crisis has led to calls for the introduction of renewable energy sources and the accompanying strengthening of power grids, so there is much room for the energy sectors of developed countries to continue to

contribute in the future.

Moreover, Russia's incursion into Ukraine that commenced in 2022 has brought into sharp focus on the predicament of dependence on Russia for energy resources. This incident further revealed the problem of resource dependence on Russia. The adoption of decarbonization policies worldwide could reshape the magnitude and extent of economic integration.

In the both energy and economic integration contexts, the ASEAN Power Grid (APG) and Greater Mekong Subregion (GMS) projects is underway in the ASEAN region [151–153]. Energy transition and international interconnections are progressing with deepening the extent of and reshaping the sphere of Asian economic integration.

With the background above, this chapter discusses the role of the Japanese energy sector in Asian economic integration. In Chapters 3 and 4, we observed the state of economic integration from a bird's eye (macroscopic) view, but the results alone will lead us away from the practice. Therefore, we intend to connect the quantitative research we have been engaged in and the practices of economic actors through a discussion from the worm's eye (microscopic) viewpoint of Japan's energy sector.

In this study, we referred to the action research method that involves the active involvement of the research subject. Due to research constraints, the author conducted action research, which should have been conducted over a longer period, through a short-term project. While action research is often conducted with the goal of changing the subject of the research, this study is only an exploration of the role of the sector, so a shorter period is sufficient.

The next section introduces the action research methodology and describes the research approach to further focus the project on one electric power company. Section 5.3 presents the results generated during the project and the findings throughout the project. Section 5.4 discusses the role of the Japanese energy sector based on the results of Section 5.3. Section 5.5 summarizes the contents of this chapter.

5.2 Methods

5.2.1 Action research and a project

Action research was first established by Kurt Lewin [154] and has since been used in research dealing with change in a variety of social subjects, including nursing [155], education [156], and organizational development [157]. In action research, the researcher obtains new knowledge through actions taken with the subjects of the research. This study adopts action research and aims to identify the role of the author's involvement in the energy sector in Asian economic integration.

Although there are various approaches to action research, this study follows the action research cycle by Coghlan & Brannick [158] (Fig. 5.1). Before starting the cycle, we first examine an external context

namely, the need for the project the author planed, as a pre-step. Subsequently, we work on an action research cycle consisting of four main steps: constructing, planning action, taking action, and evaluating action. In the first step, issues to be addressed as actions are constructed through communication with project stakeholders. In the second step, actions are planned based on the external context and the issues constructed in the first step, and then implemented in the third step. In the fourth step, the results of the actions are evaluated from the perspective of whether the constructing and actions were appropriate and what can be applied to the next cycle.

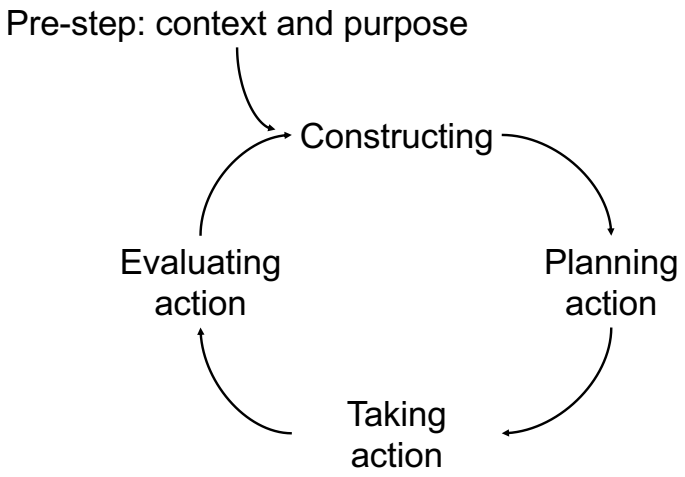


Fig. 5.1: The action research cycle. The author made this figure based on Coghlan & Brannick [158].

In this chapter, the pre-step corresponds to the introduction of this chapter, based on the results and discussions in Chapters 3 and 4. Following this, we move on to the constructing step, where we face the difficulty of putting the energy sector into concrete actions due to the size and ambiguity of the target. Therefore, in the next section, as a part of the pre-step, we focus on a company in the energy sector. In other words, this chapter selects a representative company from among the companies in the energy sector that meets the research question of this thesis, and discusses the role of the sector through actions taken with that company.

Overall, the author conducted the action research cycle as Fig. 5.2. In the constructing step, the author interviewed the company's managers about their awareness of the issues and problems they were facing about the company's overseas expansion, and planned a project in the next step, planning action. Due to time constraints, the author discussed with the managers to determine possible projects within the time frame. By planning and carrying out a project with the managers to address the issues they were facing, the author learned what kind of thinking and strategies the company had gone through to reach its current state, and how it was considering future initiatives. In the taking action step, the project is executed according to the plan, and Subsection 5.2.3 describes the project. The results of the project and the discoveries obtained through the project are described in Section 5.3, and its evaluating action step is

described in Section 5.4.

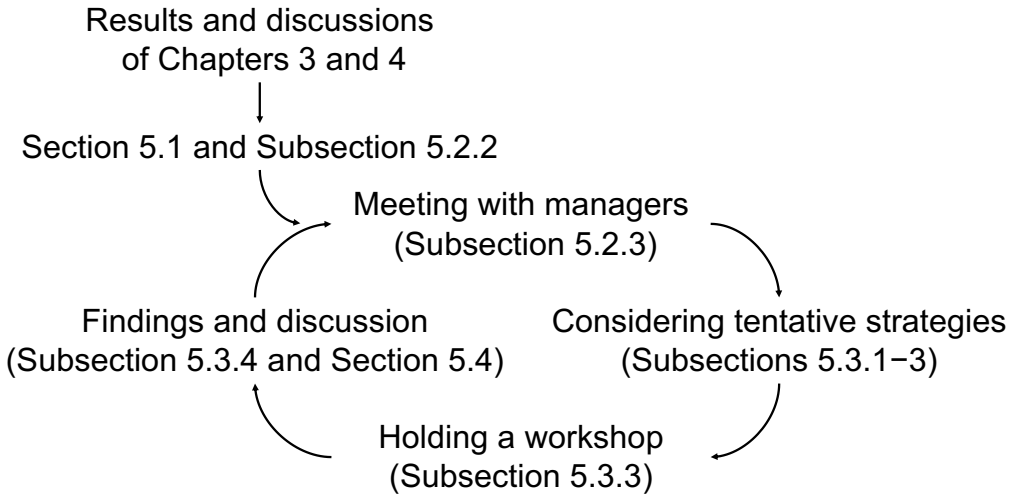


Fig. 5.2: The action research cycle in Chapter 5.

5.2.2 Specialization from the energy sector to a company

Since the energy sector is a broad and ambiguous subject for action research, the author focused on a single company that constitutes the sector. This chapter discusses the role of the energy sector by conducting action research on a single company. For two reasons, this study focuses on Kansai Electric Power Company, Inc. (KEPCO) as a subject of this action research.

In the Japanese energy sector, the most powerful entity is the electric power company which held a regional monopoly until 2016. Among the ten major electric power companies in Japan, KEPCO was the earliest to engage in overseas power generation and international interconnection projects. Therefore, analyzing the case of KEPCO, the company that has taken the most initiative in overseas business in the Japanese energy sector, could provide insights into the role of Japan's energy sector under the economic integration of Asia.

Besides its initiative, the company has made an informal offer to hire the author, and the author will be able to conduct action research as both a researcher and a future employee. In other words, while a conflict of interest exists in this subject, the author is in the best position to study a conservative company, an electric power company.

5.2.3 Project setting and overview

In this study, the author plans a short-term project that adopts their considered approach to an organizational issue as perceived by the organization's managers and conduct an action research project to implement it as an outsider. This subsection outlines the project.

In the meeting held as the constructing step, the General Manager of the R&D Center, who encouraged the author to join KEPCO, the Deputy General Manager of the R&D Center, and the General Manager of the Innovation Lab gathered. All of them were members who felt that there were major organizational issues that needed to be overcome in order for the company to grow. Since there were two managers who had already established a trusting relationship with the author at the meeting, it was an environment in which the author could hear their honest opinions about the issues. During the meeting, it was shared that the conservative culture of the electric power company is holding back KEPCO's internationalization and that the international projects already underway are being undertaken in an ad hoc manner without a strategy.

Furthermore, the Managers raised the question of what was the difference between Enel and KEPCO, a company that used to be similar to KEPCO but now has a global presence. Although the environment of the Italian state-owned company, which is a member of the EU, and KEPCO, which monopolized a region in Japan, is very different, it was decided to proceed with the project with Enel as the comparator because there may be points that can be learned in Japan, where the deregulation of electricity market and unbundling of electricity generation and transmission, following the policies in EU, were implemented.

The point here is to take some action, considered together with them, aimed at solving organizational issues that come from the managers of the organization. Through that project, this study observes the reactions that occur within the organization.

Ultimately, it was decided to conduct a project to survey the success factors of Enel and the status of international business within KEPCO and conduct a workshop to propose a tentative strategy for international expansion at the International Business and Cooperation Division. In conducting this project, the author will take into account the facts identified in the previous chapter. In the previous chapter, Japan's contribution to international cooperation in Asia was made clear, and KEPCO had also undertaken Japanese international cooperation projects. This project attempts to clarify the relationship between such Japanese contributions in Asia and the international business of a company in the Japanese energy sector.

During the project, the author analyzed the international activities of KEPCO by proposing overseas expansion strategies to the International Business and Cooperation Division of KEPCO. The proposal was assessed by the division's managers, who indicated a difference in strategies between Japanese and European energy corporations.

Purpose and goal of the project

The purpose of the project is to examine 1) how Japan's international cooperation has led to overseas operations of electric power companies, 2) how these companies perceive their international role in

energy transition, economic development, and integration, and 3) how the liberalization of the domestic electricity market has facilitated the overseas expansion of companies. Based on these examinations, the author discussed the potential for Japanese electric power companies to contribute to the deepening of the economic integration of energy in Asia.

To achieve these objectives, the author established a specific goal for the project: to propose overseas expansion strategies to a division responsible for international business strategies in the electric power company in Japan. These strategies are not the author's conclusions of the project but rather tentative proposals to electric power companies. Through the project, the author surveyed a case study, conducted interviews, and obtained feedback from the companies.

Plan and achievements

The author carried out the project from August 22nd to November 21st, 2022, in collaboration with KEPCO. At a preliminary meeting, employees gave the example of Enel S.p.A., a former electric power company like KEPCO that had successfully expanded overseas and become a multinational energy company, so the author devised a plan to propose a further international expansion of KEPCO using Enel's international expansion as a comparison. The plan involved conducting interviews about KEPCO's international business to develop strategies while exploring the factors behind Enel's successful multinational expansion and proposing them in a workshop. The author also aimed to collect cases that led to international projects in the Asia-Pacific region from Japan's international cooperation through the interviews. The entire structure of the action research is illustrated in Fig. 5.3.

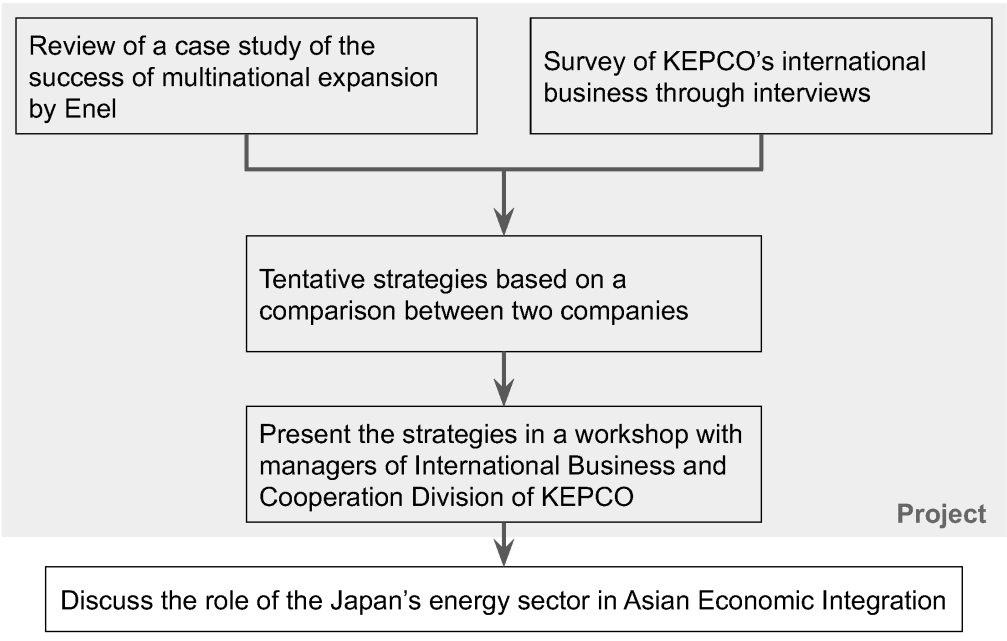


Fig. 5.3: Structure of the action research.

During the project, the author accomplished the following tasks:

1. Summarized the success factors outlined in the book, "National Monopoly to Successful Multinational: The Case of Enel," which analyzed Enel's international expansion by researchers [159].

2. Conducted interviews about international business with the manager of the International Business and Cooperation Division through meetings and e-mails [160, 161].

3. Examined ways to expand internationally and investigated the electricity situation in Asia and the potential for renewable energy deployment based on the content of the hearings.

4. Conducted a workshop at KEPCO's head office for four KEPCO employees, including the chief manager and manager of the International Business and Cooperation Division. During the workshop, the author presented Enel's success factors and ASEAN electricity trends, proposed three strategies for international deployment, received feedback, and discussed the proposals with managers [162].

5. Based on the information obtained through the project, the author discussed the potential for Japanese power companies to contribute to the promotion of economic integration in the energy sector in Asia.

The author communicated with KEPCO employees via email and meetings. Dr. Iwata, the General Manager of the R&D Department, coordinated contact with the International Business and Cooperation Division. The project's goal of proposing a strategy for international expansion to KEPCO's International Business and Cooperation Division was achieved. All of these process in the project are the method of this action research.

5.3 Results

5.3.1 Multinational expansion of Enel

Enel was established in 1962 as a state-owned enterprise in Italy and has now evolved into a multinational corporation with over 1,000 subsidiaries in 47 countries [163]. The company's global expansion started in 1999, following the Bersani decree, with the divestment of domestic power generation assets amounting to 15 million kilowatts. Enel subsequently broadened its horizons to Eastern Europe and South America [159][1].

In brief, the critical determinants of Enel's global expansion through foreign company acquisitions involved: 1) a clearly-defined strategy, 2) the decision to divest assets to generate funds for the acquisition

[1]The more detail of the success of Enel's international expansion is summarized in Appendix C.

process, and 3) thorough preparation before procuring a major entity. Enel's clear strategy was exemplified by the careful selection of regions exhibiting high and anticipated market receptivity, a predisposition towards early investment in renewable energy, and the track record indicating it as a premium investment destination based on relevant indices. In addition to its strategy, Enel made crucial decisions such as divesting its domestic telecommunications business that had grown in value, acquiring foreign energy entities, and making sound judgments regarding the timing and location for selling acquired overseas assets. Furthermore, Enel's preparations for a large-scale acquisition were aligned with its clear strategy. Following a previously successful acquisition, the management team respected the pre-acquisition management framework, leading to another fruitful procurement. For a major acquisition, Enel conducted negotiations with both home and partner countries' governments and prime ministers, securing a partner firm in the target country. Furthermore, one of the most critical preparations involved having assets that would be advantageous during the negotiation process.

5.3.2 History and current states of international business of KEPCO

KEPCO operates internationally in 11 countries across North America, Europe, and Asia [164]. In 1998, KEPCO made history by becoming the first Japanese electric power company to acquire a stake in San Roque Power Corporation of the Philippines, establishing its position as an overseas Independent Power Producer (IPP) business. This investment was prompted by the decline in Japan's domestic power development needs and the progress of electricity deregulation. KEPCO effectively demonstrated its technological prowess in construction management, operation, and maintenance, and generated stable earnings from long-term power sales contracts.

Between 2000 and 2005, KEPCO participated in thermal IPPs in the U.S., Taiwan, and Thailand, as well as in hydropower in Taiwan. In the 17 years leading up to 2015, 11 thermal and hydropower projects were carried out, and in the six years following full liberalization in 2016, 20 new international projects were undertaken [160]. The scope of these projects expanded to include wind power and transmission and distribution. Of the 20 projects, seven were wind IPPs, and one was the first international interconnection line project in which a Japanese power company participated.

KEPCO has engaged in numerous international cooperative efforts, spanning regions such as Bhutan, Myanmar, Indonesia, and Pacific Island nations. KEPCO entered into a consulting agreement with Myanma Electric Power Enterprise in 2001, which proved instrumental in facilitating a hydropower project in 2015, while in Indonesia, KEPCO's consulting led to a feasibility study for the Rajamandala Hydroelectric Power Project, which was financed by the Japan Bank for International Cooperation (JBIC) in 2003. The author heard about a case in which the connections made during the consulting business later led to an IPP project contract through the interview [160].

In general, although KEPCO was expanding into a variety of countries, it was one-off and ad hoc. From the interview, it appeared that most of KEPCO's overseas projects are projects brought in by other companies or other external parties and that the company does not have much of a strategy. On the other hand, as regions, KEPCO is focusing on Asia and North America, and in Asia in particular, the company said it would continue to do so even if it withdrew from North America.

The author also summarizes insights obtained through interviews with employees stationed in Southeast Asia regarding Japan's presence, noting a notable decline in Japan's presence, which corresponded with an increase in Korea's presence [161]. The emergence of Korean versions of public relations magazines, and increased advertisement of Korean apartments and restaurants, were some of the indicators. Furthermore, signs at construction sites were only available in Chinese, underscoring a dominant Chinese presence. In contrast, China and South Korea were observed to continue developing in the electric power sector, while the efforts of Japanese companies in the region remained largely unheard of.

5.3.3 Tentative proposals and a workshop

Tentative proposals to accelerate international business

Based on Enel's expansion case study and Southeast Asian energy trends, the author has put forward three tentative strategies in the workshop. Firstly, to establish a policy of investing exclusively in renewable energy and next-generation technologies at the earliest opportunity. Enel began its investment plan in renewable energy early, which increased the company's market value. From 2015 to 2019, it significantly reduced its holdings in thermal and nuclear energy. In its investments, it shifted its strategy to invest in assets that would increase in value over the long term, rather than seeking immediate gains in earnings. To demonstrate the company's brand power and stance, it will make it clear that it will not invest in thermal power, including high-efficiency ones, in the future, and will focus on investments in renewable energy and hydrogen. In parallel, the company will also promote the sale of thermal power assets before their value declines.

Secondly, KEPCO should strive for power stability across the Asian region by promoting international interconnection and the integration of Asia. International transmission interconnection projects such as APG and GMS are currently underway, and these interconnections are expected to stabilize supply and increase the efficiency of electricity in Southeast Asia. Going beyond the current concept of its international project, "contribution to the partner country," KEPCO should expand its concept to "contributing to a peaceful region and improving lives by promoting Southeast Asian integration" as the company's mission. Before KEPCO releases its mission for international expansion, it is necessary to have a prospect of winning project bids. By setting up this mission and demonstrating its stance on the Asia-Pacific region, it could increase the possibility of winning bids for international interconnection

line projects and entering the domestic market in Southeast Asia. However, since the State Grid has significant power, KEPCO should seek and explore the possibility of participating in the Global Energy Interconnection Development and Cooperation Organization (GEIDCO)[1] and joint projects. It is highly likely that working with the State Grid[2] and negotiating with the partner country may be effective in maintaining ASEAN centrality because currently, China has an overwhelming presence in the energy field of Asia.

The third strategy is to establish a cyclical system of selling off internal non-power businesses and promoting investment in overseas energy industries. Overseas expansion is primarily an acquisition strategy for foreign local companies, so it is important to have funds available for this through the sale of the company's businesses. KEPCO has been working to nurture internal entrepreneurs, so the author proposes setting the sale of the company's businesses as its goal. Thus, KEPCO should create a cycle of creating new businesses within the company, increasing their value, and aiming to sell them to obtain funds for acquisitions. In non-electric power businesses, KEPCO should consider more actively transferring its business not expected to grow in the future within a company or that could be made more valuable by selling them.

A workshop at KEPCO

The author presented a comparison of international business between Enel and KEPCO and tentative strategies in the workshop. The author curated meeting materials to collect feedback from attendees, while the managers of the International Business and Cooperation Division freely commented on the proposals in the workshop.

Overall, the proposal direction was generally consistent with KEPCO's strategy. However, the proposal to establish an international vision, clarify initiatives, and link domestic assets with overseas development was not accepted. The primary reasons for this decision were that KEPCO's core business is still in Japan, particularly in the Kansai region, where many of its employees have a strong desire to contribute. KEPCO's strategy, considering the deregulation of electricity, is to expand the supply of electricity outside the Kansai region within Japan, as well as develop various lifestyle-related services.

During the workshop, managers provided feedback on each of the tentative strategies. Concerning the first strategy, KEPCO already has a 2050 zero-carbon vision. The author's proposal is close to the 2050 vision, and KEPCO intends to follow its plan to achieve zero-carbon emissions by 2050. As KEPCO's international business is an investment project, focusing on low-profit renewable energy projects at present

[1]GEIDCO is a non-profit international organization dedicated to promoting the sustainable development of energy worldwide [165].

[2]State Grid is state-owned enterprise crucial to China's energy security and economic lifeline, founded on Dec. 29, 2002. State Grid supplies power to over 1.1 billion population in 26 provinces, autonomous regions and municipalities, covering 88% of Chinese national territory [166].

is not feasible. Furthermore, selling thermal power assets is challenging as they are long-term contracts that require consent from buyers, banks, and shareholders. Additionally, the managers consider it does not make sense to sell thermal assets in terms of decarbonization since their emissions will continue even if they are sold. KEPCO sold the gas-fired power plant in Thailand in July 2021. In the future, there is potential for thermal power generation to be used for hydrogen and ammonia combustion.

Regarding the second strategy, KEPCO is currently working on the interconnected line project as an independent project, much like the British-German interconnected line project. Hence, the policy is similar to this proposal. However, private companies face a significant challenge in achieving multilateral coordination. Thus, the hurdle is high for employees who wish to contribute to domestic shareholders and the Kansai region. Additionally, the managers commented that KEPCO has no intention of participating in international company communities such as GEIDCO since these companies will eventually compete with them. KEPCO works on acquiring projects gradually, relying on their technological capabilities.

Concerning the third strategy, the proposal and KEPCO's policy are similar in that K4 Ventures GK, a KEPCO subsidiary, partially implements the proposal. KEPCO has been nurturing internal entrepreneurs, but the number of such entrepreneurs is still small. Most of the employees lack experience in other companies and setting up their businesses or businesses outside of the electric power business. While they recognize the importance of divesting businesses, they currently do not divest large assets or businesses, only companies that have a low affinity with KEPCO. KEPCO does not intend to narrow its business field and aims to diversify its business.

5.3.4 Main findings through the projects

Comparing KEPCO to Enel, a successful overseas expansion by a European liberalized power company, the author proposed international expansion to KEPCO, a liberalized Japanese electric power company. The following findings were obtained from interviews conducted during the project period and reactions to the proposal:

1. Following liberalization, KEPCO prioritized international projects, which were more profitable through stock acquisitions.

2. KEPCO's international cooperation in Myanmar and Indonesia contributed to the acquisition of hydropower projects by increasing recognition of KEPCO.

3. KEPCO's existing international interconnection in Europe and its policy of focusing on Asia for overseas expansion suggest a potential contribution to future Asian integration.

4. However, KEPCO's strong desire to contribute to the Kansai region and its strategy of diversifying domestic business make full-scale overseas expansion like Enel's unlikely at this time.

5. KEPCO currently lacks a vision for building international relationships and has little interest in multilateral economic integration. As a result, KEPCO has distanced itself from the corporate community's vision of an international transmission grid and is deploying technology and existing connections.

6. Japan's presence in Asia is declining while China and Korea are gaining prominence.

5.4 Discussion

5.4.1 Generalization from a company to the sector

This project had three objectives. Firstly, to identify instances in which Japan's international cooperation has led to subsequent business ventures for companies. The author confirmed that KEPCO had such cases in Indonesia and Myanmar that resulted in hydropower projects. In addition to KEPCO, a diverse range of Japanese companies have been entrusted with international cooperation projects implemented by Japan, suggesting that Japan's emphasis on high-level diplomacy has or may have a positive impact on business development in the Asia-Pacific region.

However, unlike Enel, Japanese electric power companies have not swiftly shifted their business strategies toward overseas markets even after domestic deregulation. This may be because Japan's deregulation did not compel Japanese power companies to expand overseas as extensively as Enel since they have retained their domestic assets and still have room to expand domestically. Without divesting some domestic assets, as Enel has done, it will be difficult to secure the necessary funds to acquire companies abroad.

Furthermore, interviews with former KEPCO expatriates revealed Japan's declining presence and the growing presence of China and South Korea. Among electric power companies, the State Grid and Korea Electric Power Company are conducting more overseas business ventures than their Japanese counterparts. The fact that Japanese power companies are not state-run and are divided into regions appears to have influenced their lack of aggressive overseas expansion.

In addition, KEPCO did not aim for energy integration in collaboration with other companies but instead took its path. Since KEPCO does not have an international vision to promote economic integration and is pursuing its overseas business based on referrals from connections gained through its own experience, its future contribution to economic integration in the Asia-Pacific region is expected to be limited.

In the field of energy, Japan's low energy self-sufficiency rate [167] hinders its international influence; however, Japan's contribution to the energy sector in Asian countries as bilateral cooperation can be observed in the long term. In fact, for most of the past 20 years, Japan has provided the highest amount

of Official Development Assistance (ODA) to East and Southeast Asian countries among Development Assistance Committee (DAC) countries [168–173]. Japan has also provided international cooperation in the energy sector through ODA to East Asian countries. Energy-related international cooperation has been carried out with eight ASEAN member countries, excluding Singapore and Brunei, and nearly 40 projects have been implemented in Vietnam and Indonesia. In addition to ASEAN member countries, Japan has implemented approximately 60 projects in India and 30 projects in China [174]. Japan's international cooperation activities in the energy sector have been confirmed among the ASEAN+6 countries. Furthermore, technicians from Japanese companies are also dispatched for these activities, which may lead to further business opportunities.

This action research obtained examples that contributed to subsequent projects in Myanmar and Indonesia. Therefore, there is a possibility that Japan's international cooperation in the energy sector can be utilized for business expansion in Asia. However, in the case of KEPCO, the overseas business expansion was not strategically planned but rather happened by chance as a result of relationships formed during activities such as technical cooperation. It is believed that if companies have a desire and strategy for expanding into Asia, they can obtain even more opportunities for overseas business. For overseas expansion, it is necessary to strategically select target regions for expansion and to own and operate power assets and transmission and distribution systems in those regions, as demonstrated in Enel's case. However, most Japanese power companies are still in the stage of deploying single projects in various locations and do not seem to view overseas expansion as an extension of their domestic business. While economic integration is progressing in the Asia-Pacific region, the energy sector in Japan is not advancing toward integration. Although there are risks involved, it is hoped that efforts will be made to promote participation in international interconnected lines that connect Asia, taking a long-term perspective beyond single projects, and leveraging Japan's track record of international cooperation in Asia.

5.4.2 Role of the Japan's energy sector in Asian economic integration

The role of Japan's energy sector is to enable the promotion of East Asian economic integration in balance with China by actively contributing to energy transformation and increased electricity supply in the ASEAN region. This is because Japan needs to engage in economic activities to regain its presence in the ASEAN member states, which it is losing, while ASEAN needs to maintain its ASEAN centrality without becoming too dependent on China, and to further develop its economy with decarbonization.

Because of differences in the form of economic integration between Europe and East Asia, there are also differences in the role played by the energy sector as a regulated industry. Enel expanded in Europe by finding commercial opportunities in Eastern Europe and later expanded into South America. This expansion abroad was facilitated by member states' policies in response to EU directives. On the other

hand, the situation is quite different in East Asia, where *de facto* economic integration, rather than *de jure* economic integration as in the EU, is underway. In the electric power sector, where national regulations are heavily involved, there are difficulties in expanding in the Asian region, where policies for electricity liberalization and the unbundling of electricity generation and transmission have not been unified.

Even in such a different environment, Japan's energy sector has contributed to the development of the energy sector in Asia through international cooperation in the form of technical assistance. International contributions in various fields have resulted in the highest Japanese contribution in the Asia-Pacific region [175] and Japan being ranked as the most trusted country by ASEAN, above the US, EU, and China [176]. The percentage of respondents in ASEAM member states who trusted Japan was more than twice that of those who distrusted it. This trust provides considerable scope for Japanese companies to advance the energy transition and power supply development in East Asia in the energy sector where security is concerned.

Unlike in Europe, China, the world's second-largest economy, exerts a strong influence in East Asia, and while ASEAN member states approve of China's economic influence in Southeast Asia, trust in China is low, with those who distrust China far exceeding those who trust it. In addition, more than 60% of respondents in ASEAN member states worried about China's growing regional economic influence [176]. In other words, they are forced to depend on China despite their concerns and key area where excessive dependence threatens national security is energy.

Japan should contribute to economic integration not only through diplomacy but also economically, so that ASEAN member states do not become deeply dependent on China and the economies of East Asia as a whole are not influenced by Chinese policies. In particular, Japan should not only create jobs by relocating or opening factories for automobiles and high-tech products but also contribute to overall economic activities in the region by building infrastructure. A framework of public-private partnerships (PPP), in which the public and private sectors contract with each other, has been developed for the implementation of infrastructure projects in Asia. This is intended to enable the public sector to reduce financial expenditures and efficiently operate high-value-added projects [177].

For Japan's energy sector to become a leader in promoting economic integration in East Asia, Japan's PPP policy needs to take a more strategic perspective that will enable the Japanese sector to develop its business in East Asia over the long term. In parallel with the action research that led to these suggestions, Japan's national strategy for development cooperation, the Development Cooperation Charter, was revised. The revised version was approved by the Cabinet in June 2023, at the time of writing this manuscript, and it clearly states that one of the priority policies for a further effective and strategic use of development cooperation is to strengthen efforts in the area of high-quality infrastructure, including power and energy infrastructure [178, 179].

As this action research has revealed, although there were cases where international cooperation projects were one factor that led to the implementation of overseas projects, it was by chance and not strategically aimed [161]. Originally, until deregulation, electric power companies were favored as regional monopolies and were able to make profits without risk by adjusting electricity prices, and they wanted to invest the profits they earned in improving their services and returning them to customers in those regions rather than expanding their businesses [162]. In other words, they believed that going out of their way to expand overseas and take risks was contrary to their corporate philosophy. If the sector continues to operate overseas as a side business even now that deregulation has been implemented, it is unlikely that the sector's economic activities will contribute to economic integration in Asia. Japan will not be able to utilize the trust it has built up through international cooperation in East Asia in its own economic activities, and the sector will miss out on access to the growing Asian market by remaining in a declining domestic market. To reduce this double loss, and to fulfill its role in promoting both the security of energy supply, which supports economic growth, and climate crisis countermeasures in the context of East Asian economic integration, a coordinated strategic effort by the government and the sector is desirable.

Japan's strategic international cooperation mentioned above will be provided for East Asian economic integration and energy infrastructure through contributions to ERIA and feasibility studies. The budget for FY2023 shows that through ERIA, the government will create a blueprint for East Asian economic integration, contribute to the stable supply of energy, promote the use of energy conservation and renewable energy, and establish an organization for cross-regional coordination of transmission operators in ASEAN (1.63 billion yen in total) [180–182]. The budget for the Feasibility Study for Overseas Development of High-Quality Energy Infrastructure is 850 million yen [183].

The effectiveness of these measures in the domestic energy sector, especially for electric power companies, will be judged by whether they can make these companies more conscious of and willing to expand overseas. Japan's deregulation policy in the electric power sector has been exposed as not functioning properly due to cartels among electric power companies, and the separation of power transmission and distribution has not been properly implemented due to the power companies' access to customer information held by power transmission and distribution companies. This is one result of the attempt to stay and continue business in Japan without taking risks based on an approach that has not changed from the management policies of the past. If companies that have been operating as regional monopolies begin to engage in overseas power generation and grid operations not as investment projects but as power businesses, Japan's strategic international cooperation measures in the energy sector will be evaluated as a success.

In the case of Italy's Enel, the Bersani Law, which followed an EU directive, created an environment

in which the company was forced to expand overseas through the forced sale of domestic assets. Conversely, without such a drastic policy, regulated companies would not suddenly aim to expand overseas. Japanese electric power companies were not required to sell their facilities as Enel did, and they were able to continue to operate primarily domestically. The government should encourage the energy sector to do business strategically, noting that it is in the process of changing from an organization optimized for the operation of domestically regulated businesses in the past.

Energy companies should incorporate ERIA's research findings including a blueprint for East Asian economic integration into their business strategies, and strategically expand overseas with a vision for the business to be conducted in East Asia, where economic integration has advanced. This will naturally lead them to actively engage in overseas business, which they have been passively entrusted with in the past. In particular, the energy sector can utilize Japan's accumulated contributions to East Asia in its economic activities by conducting sustainable business in East Asia, where the sector has also contributed through technical cooperation and consulting.

5.5 Summary

This chapter considers the role of the Japan's energy sector in Asian economic integration through the author's three works: previous research on economic integration, international cooperation analysis during the overseas internship, and an action research. Previous research suggested the considerable impact of Russian natural resources on the extent of regional economic integration and stable development of Asian economic integration compared to Europe's one. The international cooperation analysis supports the latter result and demonstrated Japan's high contribution to Asia, thus, the author focused on the Japanese energy sector. As the action research on the international business strategy of Japan's leading electric power company, KEPCO, the author conducted a project aimed to propose tentative strategy for its international business in a workshop with its managers with three purposes: to examine 1) how Japan's international cooperation has led to overseas operations of electric power companies, 2) how these companies perceive their international role in energy transition, economic development, and integration, and 3) how the liberalization of the domestic electricity market has facilitated the overseas expansion of companies. Finally, the author discussed the role of the Japanese energy sector in enabling the promotion of East Asian economic integration in balance with China by actively contributing to energy transformation and increased electricity supply in the ASEAN region. In order to fulfill the role, it is necessary to resolve the issues that the Japanese government's strategy for the international expansion of the sector and the outlook for regional economic integration by international organizations are not being utilized in the business strategies of the sector.

Chapter 6

Conclusion

This study was conducted to develop an instrument for citizen-driven assessment of the state of international relations, independent of experts and authorities. The development of the Internet and computers has created an environment in which it is possible to manage a society relying on information technology. This thesis applies network science, a field that has developed in recent years, to develop a simple method for grasping the state of complex international relations in practice. We have shown that it is possible to quantitatively express the state of regional economic integration, a topic that is difficult to grasp but is also a policy issue, in the same way, that stock prices and exchange rates are quantitatively expressed. Furthermore, based on the facts obtained from the indicators, it was concluded that strategic support is necessary to enable Japan's energy sector to sustainably develop its business in Asia in order to promote stable Asian economic integration.

Individual findings and suggestions obtained through this study are as follows. In Chapter 3, a community analysis of the value-added network confirmed the regional nature of the network. This is a result not confirmed in previous studies. While the trade network was divided into communities by industry, we were unable to observe any communities in the value-added network. The present results show that by ignoring small value-added relationships and by choosing an appropriate community analysis method, the European and Pacific Rim regions can emerge from the value-added relationships alone, even without including distance. This fact has two significant implications. The first is that when analyzing a network of international economic relations, a completely different feature is extracted than when creating a network by trade value. The value-added network confirms strong intra-regional value-added relationships, which are broadly reduced to different industries within the region rather than they are divided among the world as a whole in homogeneous industries. In other words, the value-added network is characterized by the influence of distance and the extent of economic integration rather than by ties within homogeneous industries. The second is that some industries have a stronger influence on the other region than on the other region they are located in. This is due to how people divide communities based

purely on value-added relationships, rather than on geographic, historical, or institutional perspectives. Thus, communities by industry are revealed without preconceptions, so that, for example, in our analysis results, whether or not the Russian mining industry was included in the European community affected the economic integration index of the European community.

Chapter 3 then defines the level of economic integration in value-added as the percentage of value-added circulating within a region. Comparing the economic integration in value-added indices between the detected European communities and Pacific Rim communities, it is suggested that economic integration in value-added has been more advanced in the Pacific Rim than in Europe since 2009. This is due to the fact that the European communities were affected by the economic crisis of 2009, which led to a decline and destabilization of the value-added circulation rate within the communities. On the other hand, the Pacific Rim communities were not significantly affected by the economic crisis, and their share of value-added circulation in the region remained stable and increased after 2009. The sectoral economic integration indices and each structure of the value-added circulation networks of countries and sectors revealed that the Russian mining sector and the high-tech sector in the European community were the two main sources of disturbance in the European value-added index. Conversely, the dependence on Russian resources led to a high level of economic integration in the value-added of European communities. Based on those results and the definition of the indices, the mining sector and the automotive, electrical, and electronics sectors can stabilize the amount of value-added circulation in the region by increasing intra-regional international trade, especially with different sectors.

Overall, in Chapter 3, we were able to represent the degree of economic integration in value-added within economic blocs and their areas in a simplified manner by using data from the publicly available international input-output table. On the other hand, we would like to understand not only the economic blocs identified as a result of international economic activities but also the movement toward the formation of future economic blocs. Therefore, in Chapter 4, we developed a method to observe the state of international relations, including the development of an environment for economic integration, by using event data reported on the Internet.

Specifically, we constructed a political distance network in East Asia based on event data involving multiple countries and used the values of the centrality index to measure international relations using three approaches: diplomatic ranking, clusters, and synchronization. The diplomatic ranking explained three main points: Japan's long-term contribution to international cooperation in the region, China's strong influence in international relations comparable to that of Japan, and the period when ASEAN contributed more than Japan and China. Until now, the influence of a country has been implicitly assumed based on its level of economic development and other economic factors, but this method allows for a clear calculation of the influence of a country's international cooperation in the region based on actual

diplomatic events.

The diplomatic clusters identified similarities between Australia and New Zealand and the unique diplomatic stance of India. In short, this approach allows us to determine, on a period-by-period basis, which countries in the region have similar political positions and which countries in the region have unique diplomatic strategies.

From diplomatic synchronization, we can confirm that the attitude of trying to shorten or distance oneself politically is a synchronization phenomenon in the region. According to the results, East Asia has shown an almost continuous regional cooperative stance since 2008. In the entire period analyzed, the longest period of synchronization was around 2003, when cooperation among ASEAN, ASEAN+3, and CJK made significant progress. These results show that even if one is not familiar with politics, one can learn about important periods in international relations simply by identifying synchronization phenomena based on news. Furthermore, by reviewing the diplomatic rankings for the period, it is possible to determine the countries that have contributed to international cooperation in the region. Of the 11 periods of diplomatic synchronization longer than six months, Japan had the highest ranking for six periods, followed by China with the highest ranking for three periods, and the ASEAN-10 with the highest ranking for two periods. The results show that Japan has made important contributions to intra-regional cooperation and that ASEAN members were showing greater contributions than China and Japan in intra-regional cooperation in the second half of 2018 for the first time in nearly 30 years.

In Chapter 3, it was shown that economic integration in value-added in the Pacific Rim is progressing compared to Europe and that relationships with countries with abundant energy resources, such as mining, have a significant impact on the value-added cycle in the region. In Chapter 4, it is shown that Japan has been contributing through international cooperation in East Asia, where substantial economic integration is progressing. In Chapter 5, we focus on Japan, which has contributed greatly to international cooperation in East Asia as a Pacific Rim country where economic integration in terms of value-added is advancing, and examine the role of the energy sector in Asian economic integration, which has a significant impact on economic integration in value-added. Japan's energy sector has basically remained a domestic regional monopoly and has not expanded overseas in earnest. On the other hand, the situation surrounding the sector is currently undergoing major changes due to the deregulation of the electric power companies, the legal separation of power transmission and distribution, and the need for a global energy transition. From these two points of view, it is worth considering what role Japan's energy sector will play in future Asian economic integration.

The author conducted action research at KEPCO, which was one of the earliest companies in the Japanese energy sector to conduct overseas business. The author examined and proposed a strategy for overseas business expansion from the perspective of the differences between KEPCO and Enel, a com-

pany that has been promoting international expansion, which was raised in a preliminary meeting with KEPCO managers. Based on the feedback on the proposal, we considered the possibility of contributing to Asian economic integration from KEPCO's perspective.

The responses to the research questions posed in Section 2.3 are summarized in three outcomes. The first is the establishment of a method to calculate the degree of international economic integration on an industry-by-industry basis, making comparisons possible between Europe and the Pacific Rim. This has revealed that economic integration in Europe was shaky in terms of value added during the economic crisis of 2009, and that even excluding financial services, which triggered the economic crisis, Russia, the natural resources sector, and the automotive sector were far removed from the economic cycle within Europe. On the other hand, the Pacific Rim showed solid progress in the level of economic integration (value-added circulation per unit of GDP), suggesting that, in real terms, economic integration has progressed more than in Europe.

The second result is that it was possible to quantitatively calculate regional trends in cooperative diplomatic stance and country-by-country comparisons by calculating the political distance between the two countries based on event data collected from news reports, and then calculating diplomatic centrality from that network. The results indicate that Japan and China have been leading cooperative diplomacy in the Asia-Pacific region, and that contributions by ASEAN member states have been prominent in recent years. In addition, the length and frequency of synchronous periods of diplomatic centrality visualized that cooperative diplomatic posture has been conspicuous in the region as a whole since 2008.

The third distinctive outcome of this thesis is clarifying the role of the Japanese energy sector under Asian economic integration, derived from the results of previous quantitative research and a project conducted for KEPCO's International Business and Cooperation Division. Using the action research method, the author conducted a workshop to propose tentative strategies for the international expansion of KEPCO based on the manager's awareness of the problem. This short-term project, whose goal was to conduct a workshop, allowed us to understand the relationship between Japan's international cooperation and the electric power company's business in Asia, and the positioning of international expansion for the company. It was suggested that Japan's international cooperation is one of the causes leading to KEPCO's overseas projects. From the perspective of returning Japan's presence in ASEAN member states and guaranteeing ASEAN-centrality in the energy sector, Chapter 5 concluded that the role of Japan's energy sector is to actively contribute to energy transformation and increased electricity supply in the ASEAN region, thereby enabling the promotion of East Asian economic integration without overdependence on China. However, the energy sector is not strategic enough in its Asian expansion, thus support for the sector through international organizations such as ERIA is important for them to fulfill their role in the future.

This study did not aim to analyze a specific country or sector but focused on a simplified understanding of the complex global situation through the lens of information technology. Ultimately, the project focused on the Japanese energy sector in order to incorporate the perspective of economic actors for which quantification studies alone are insufficient, but could, of course, be applied to other sectors and countries. Therefore, it is possible to freely apply the methodology of this study to any country or region of interest. In addition, although many countries were included in the analysis, it was not possible in this study to carefully verify the quantified results by arguing for the significance of the events that took place based on the history and institutions of all the countries involved. This means that there is still room for analysis and critique from all perspectives. It is hoped that this research will be used in the future to compare economic integration at the regional level between Europe and the Asia-Pacific and to understand the relationship between specific countries and sectors and the international economy.

Appendix A

Communities of International Trade Network

Table A.1 shows the results of the Infomap analysis [92] of the international trade network excluding domestic transactions as well as IVAN. The hierarchy of the results of Infomap was two levels and these communities are the first layer. The data is from WIOD [25, 26]. IVAN detected only one huge community, while international trade netwok (ITN) detected many communities even without setting any threshold. In the table, only communities with more than 10 nodes are counted, and the number of nodes for each is shown in order of increasing size. Looking at the size, one community is relatively large every year. The smallest maximum community size was in 2011, and the largest is in 2005. The maximum communities include service sectors and the second and subsequent communities are sectors of manufactures or food industries. In other words, the same type of industry has been detected as the ITN community. Detailed results of the community analysis are summarized in Figs A.1–A.3. Each cell of a community map in a figure means node of ITN and the row and column of the heat maps are countries and sectors. The legend shows ID of communities, which means colors represent communities ' ID. We obtained IDs to communities whose size is more than 10 nodes and the gray cells are nodes belonging to communities which are smaller than 10.

Table A.1: Number of communities of international trade networks.

Year	Number of communities	Sizes of communities
2000	10	1713, 123, 94, 93, 52, 52, 46, 43, 26, 18
2001	8	1881, 116, 58, 55, 44, 40, 37, 23
2002	9	1657, 153, 120, 101, 60, 55, 44, 44, 23
2003	13	1494, 114, 110, 100, 87, 66, 53, 52, 51, 47, 39, 22, 14
2004	15	1509, 111, 90, 89, 67, 59 56, 50, 47, 44, 38, 24, 23, 20, 14
2005	9	1891, 110, 51, 50, 43, 40, 35, 22, 12
2006	10	1798, 119, 64, 53, 47, 45, 44, 38, 29, 14
2007	13	1482, 144, 116, 93, 71, 66, 52, 52, 51, 44, 34, 29, 14
2008	14	1350, 165, 146, 105, 93, 86, 70, 52, 44, 43, 36, 35, 21, 12
2009	9	1880, 113, 67, 57, 43, 37, 24, 15, 14
2010	10	1712, 111, 109, 71, 64, 55, 43, 36, 36, 10
2011	13	979, 561, 111, 109, 101, 70, 65, 59, 47, 44, 37, 33, 13
2012	14	1421, 116, 112, 101, 91, 64, 63, 58, 55, 44, 43, 31, 22, 21
2013	12	1581, 179, 155, 68, 55, 52, 47, 45, 26, 16, 11, 10
2014	15	1238, 220, 158, 122, 116, 65, 55, 55, 46, 41, 36, 33, 28, 24, 10

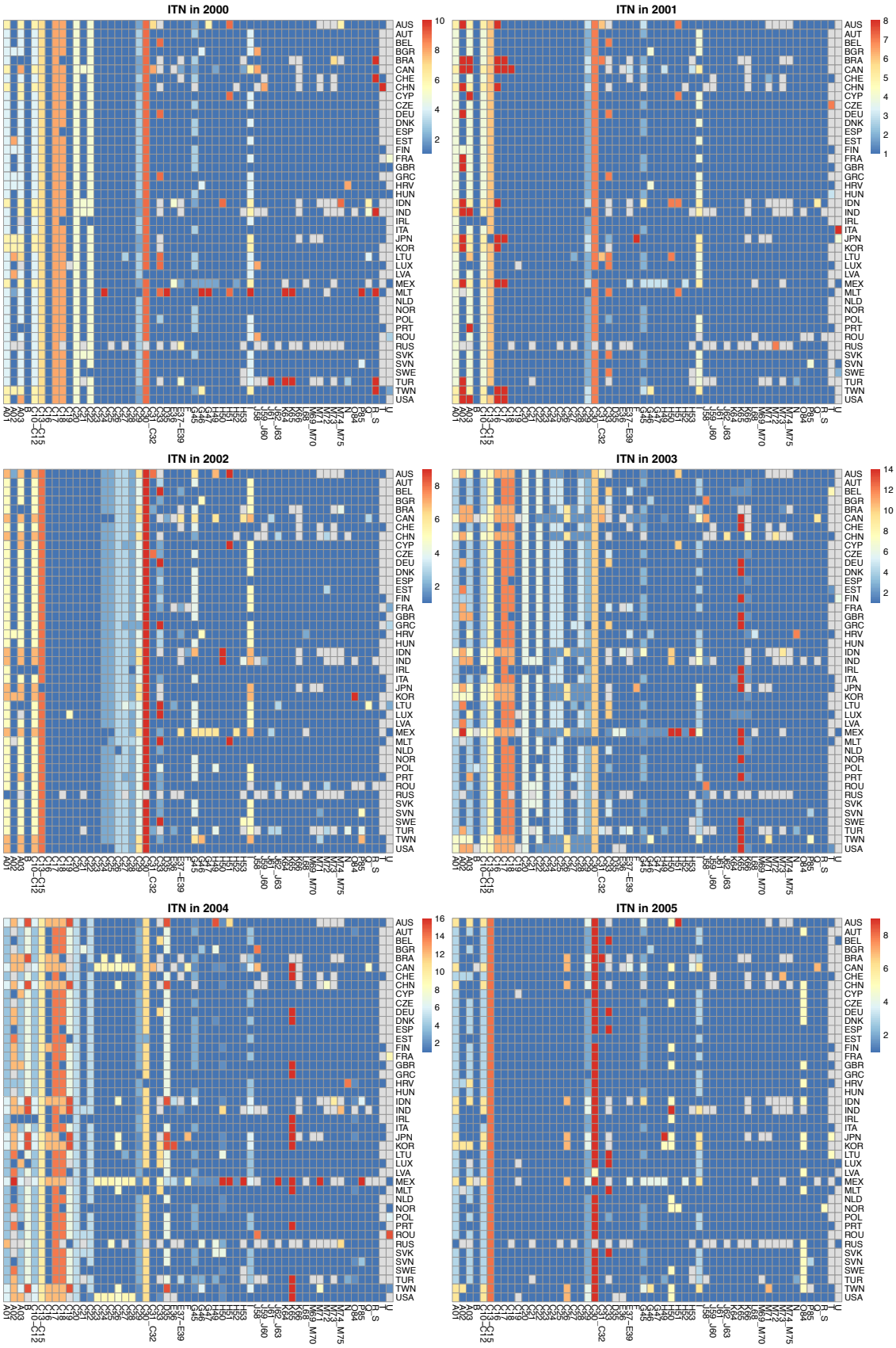


Fig. A.1: Community maps of international trade networks 2000–2005.

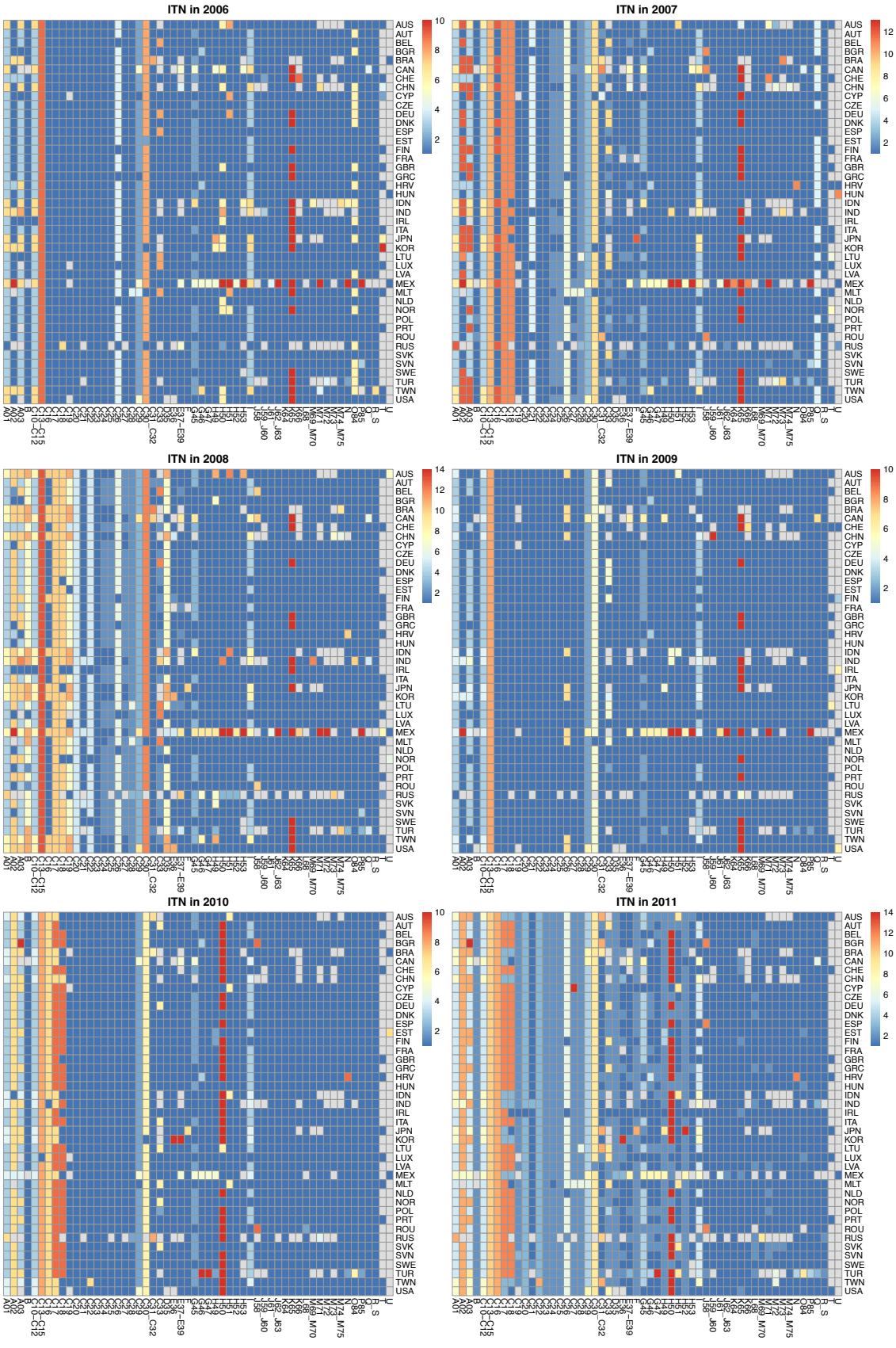


Fig. A.2: Community maps of international trade networks 2006–2011.

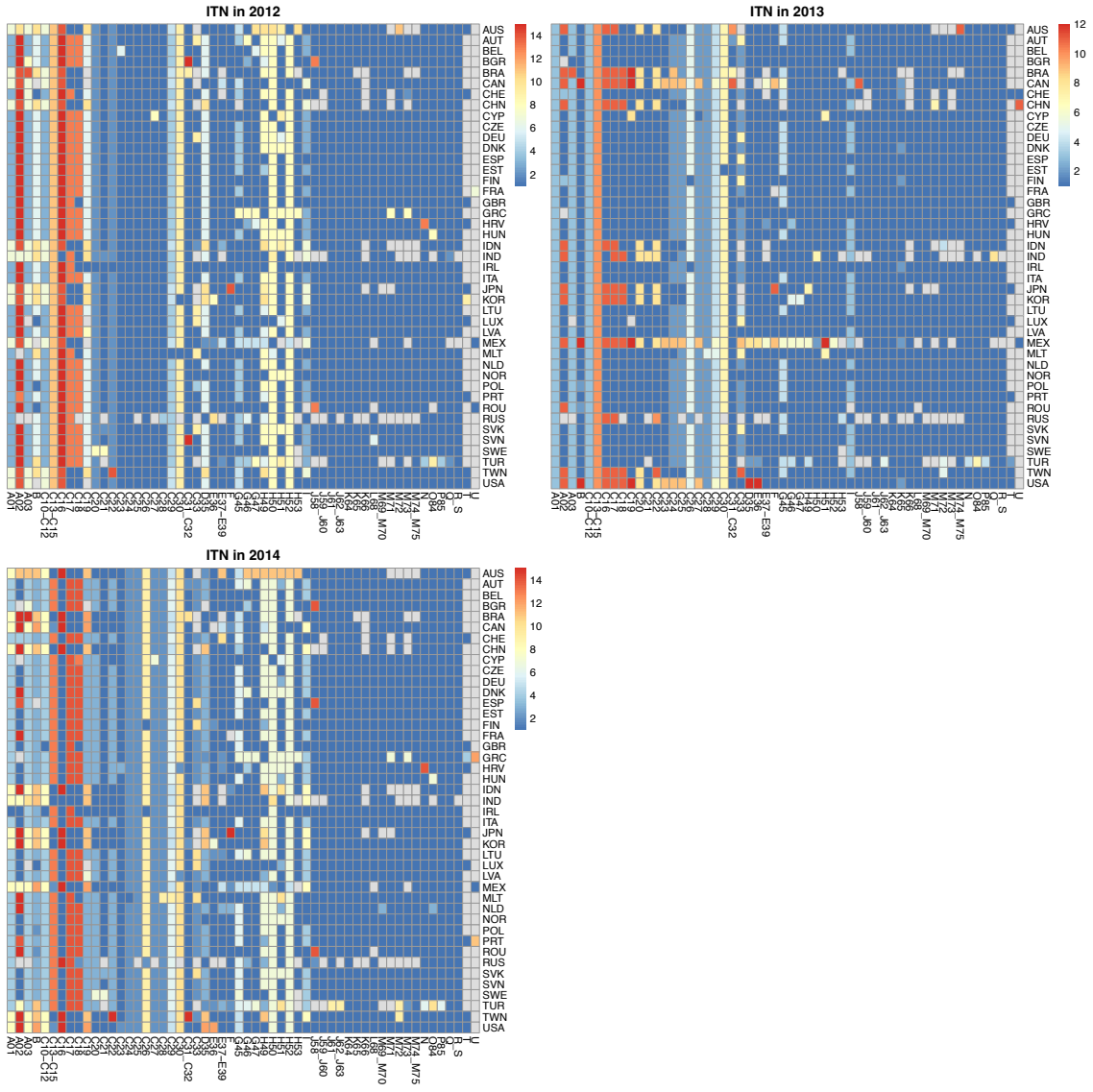


Fig. A.3: Community maps of international trade networks 2012–2014.

Appendix B

Overseas Internship

During the period spanning from February 22nd to August 21st in the year 2022, the author completed an overseas internship program at the Economic Research Institute for ASEAN and East Asia (ERIA) as an Analyst in the Research Department. The main focus of the internship was conducting an international cooperation analysis, which was published in the Interdisciplinary Physics section of a journal, as the Research Topic of Interdisciplinary Approaches Towards the Evolution of Socio-economic Systems Under Selective Trend Pressures [175].

ERIA and the author's position

ERIA, which was proposed in 2006 by Mr. Toshihiro Nikai, Japan's Minister of Economy, Trade and Industry, was established as an East Asia version of the Organisation for Economic Co-operation and Development (OECD) and was formally agreed upon during the third East Asia Summit in Singapore on November 21, 2007 [184]. Currently, ERIA is an international organization conducting research in three key areas that focus on issues related to economic integration, narrowing development gaps and reducing poverty, and achieving sustainable development [184]. These areas, or "pillars," are supported by the four departments, with the Research Department being the main department that comprises six Units (Fig. B.1). In 2016, the Policy Design Department was established to propose actionable policy recommendations for each member state [185]. Today, ERIA ranks ninth out of the top 85 International Economic Policy Think Tanks and fifth in the category of Top Think Tanks in Southeast Asia and the Pacific [186].

Objective and goals

The author's objective in interning at ERIA was to deepen their previous global research perspective to a regional level by analyzing GDELT to understand the deepening Asian economic integration. The

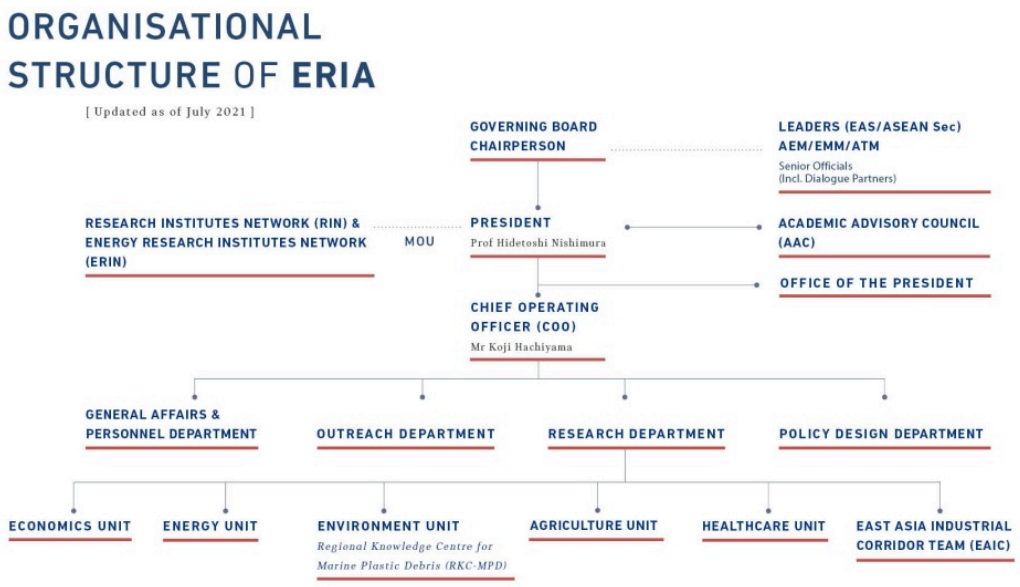


Fig. B.1: Organization structure of ERIA.
Source: https://www.eria.org/about-us/organisational-structure

author and colleagues' goals during the internship were to conduct research on economic integration in Asia-Pacific with a diplomatic perspective, resulting in the submission of a discussion paper or an article.

Plan

Originally, the author planned an analysis using the economic integration index which the author proposed in the author's latest paper [68] at that time. In meetings, however, before the internship, the author understood we could not use the index because ERIA could not access international input–output tables within ASEAN countries. Therefore, the author changed to the analysis using GDELT [105].

To achieve the goal, the author first planned a schedule as Fig. B.2. However, after the second plan of review, we should not use tone value in GDELT. Thus, we calculated political distance which had been used in a previous study, using the Goldstein scale [118] in GDELT.

Tasks

In the internship, the author worked mainly on six tasks: (1) studied and summarized networks from the perspective of political science through a book, (2) participated in a workshop on RCEP organized by ERIA, (3) reviewed previous studies, (4) confirmed the contents of GDELT data and investigate the other data sets, (5) analyzed the data and discussed the results, (6) wrote and submitted a paper.

Plan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Study “Networked Politics”							
Review international politics paper related to GDELT							
Plot monthly tone of dyad events by ASEAN countries							
Collect critical events for concluding TPP or RCEP							
Plot & analyze the tone							
Write 1st draft of discussion paper							
Discuss, revise the draft, and write 2nd draft							
Write the final draft and submit							

Fig. B.2: Plan of the internship. Grayed cells mean the planned months of implementation.

Achievements

As a result, the author and colleagues published a paper on international cooperation analysis that defined the diplomatic centrality measure and revealed the diplomatic ranking, clusters, and synchronization of the ten ASEAN countries and seven countries (Australia, China, India, Japan, the Republic of Korea, New Zealand, and the United States) for 36 years [175].

This study made significant contributions, starting with the definition of diplomatic centrality that enabled quantitative observation of diplomatic relations within the region. The results showed that Japan, China, and ASEAN remarkably contributed to diplomatic relations in East Asia for all 36 years (1985–2020), for 23 years (1997–2020), and within three terms (1989–1993, 2012–2014, and 2016–2020), respectively. Second, the correlation of diplomatic centrality allowed us to divide countries by their diplomatic stance within the region. The results confirmed that New Zealand and Australia were close in their stances, as well as Japan and South Korea, China, ASEAN, and the United States, in that order. Finally, the extent of synchronization was calculated based on the phase of diplomatic centrality to identify when diplomatic stances were aligned in the East Asian region. The results showed that diplomatic stances were most aligned in 2003 when the 9th ASEAN Summit and the 7th ASEAN+3 Summit were held in October 2003.

Appendix C

Summary of Enel's Success in Multinational Expansion

This appendix presents an overview of Enel's triumphs based on a case study [159].

Enel was primarily an engineering firm characterized by a technical culture, expertise, and proficient bureaucratic mechanisms (such as hierarchy, regulations, and organizational procedures) before its international expansion. Operational and business processes were also governed by technical standards and criteria. Additionally, its ethos emphasized user service rather than customer service, with a focus on fairness and validity over satisfaction. Enel was also able to determine fees commensurate with costs owing to the legal monopoly regime, which had no economic restrictions.

Nevertheless, Enel rapidly transformed into a multinational corporation with more foreign employees than those in Italy within approximately five years by implementing a series of major top-down organizational changes. Enel abolished dual signatures and bureaucratic promotions, boosted mobility, and recruited workers with management skills from other companies. Furthermore, it improved customer satisfaction, became more environmentally conscious, and achieved global business expansion through daring divestitures and acquisitions to enhance its corporate worth.

In tandem with the liberalization of the electricity market between 1996 and 2002, Enel executed an organizational culture overhaul. During the initial half of the period, 1996–1999, Enel underwent a structural transformation through divisional and personnel reforms, such as retirement benefits and hiring retirees, as well as a decrease in executive numbers from 1,369 to 652 over four years. Conversely, Enel recruited 82 individuals with management expertise from external firms. Furthermore, Enel eliminated employee titles and job classifications.

In the second half of the period, 1999–2002, Enel endeavored to diversify its business by adopting a resource-based view (RBV) management approach. It expanded into unrelated businesses (such as the telecommunications business) in addition to the power generation sector. At the time, it owned

the largest private telecommunications network in Italy and gained a competitive advantage owing to its unique management resources. It also adopted a multi-divisional structure in the form of a holding company with 36 group firms and units in each division, known as an M-form strategy. By granting each company its management, human resources, and specific operational and governance structure, the firm made strides in transforming its organizational culture and fostering professionals. However, dividend yields decreased by about 10% over four years. Finally, in 2000, Enel commenced its international expansion with the acquisition of CHI Energy, which promotes renewable energy in North America, and Viesgo, a Spanish power company, in 2001. At the same time, Enel commenced the construction of a 1,278-kilometer high-voltage transmission line in Brazil, with 2% of all employees participating in international business at the end of 2001.

From 2002 to 2006, Enel reverted to its core operations and executed a comprehensive global expansion plan. In 2002, the divestment of power generation assets based on a government mandate was accomplished, and a new Chief Executive Officer with an MBA degree and extensive international experience was appointed. Subsequently, Enel abandoned the M-form and restructured it into four divisions: 1) Power Generation and Energy Management; 2) Markets, Infrastructure, and Networks; 3) Telecommunications; and 4) Company Services and Diversified Businesses, shifting towards a Cost Leadership strategy. In 2004, Enel divested itself of Real Estate Holdings and Enel Hydro and penetrated Eastern Europe by procuring firms in Russia and Romania. At that time, Enel was enlisted in the Ethical Code, FTSE4Good Global 100, FTSE4Good Europe 50, and the Dow Jones sustainability index. In 2005, Enel established an international unit and sold 60% of Wind, which had been in the telecommunications industry, while reducing its holdings in Italian transmission firms from 36.14% to 5%. Meanwhile, Enel declared its intention to invest over 40 billion euros in research on renewable energy and carbon emission management, among other areas, and acquired 66% of Slovakia's main electricity provider, which operates nuclear power plants. Consequently, the company secured a prominent position in the heart of Europe. In 2006, Enel concentrated its global expansion strategy on Latin America and Eastern Europe, procuring energy firms in Brazil and Bulgaria. Later, in 2007, together with Acciona, Enel obtained Endesa, Spain's biggest electricity generation firm.

Enel succeeded in acquiring Endesa by using its experience from one failed acquisition. Originally, Enel's CEO believed that Enel needed a major M&A to become a global energy company. With firm determination, he endeavored to acquire Suez in France after reaching an agreement with Veolia in early 2006. However, the French government responded very unfavorably and shielded Suez from a takeover by merging it with Gaz de France, triggering a dispute between France and Italy, including with the EU. Enel promptly abandoned the Suez acquisition and awaited the next opportunity, which it obtained with the acquisition of Endesa in Spain, competing with Germany's E.On for the acquisition. The process was

executed to the mutual satisfaction of Germany, Spain, and Italy, where each firm is based, and with the prime ministers of the three countries, with transparent procedures and adherence to market regulations. After an 18-month legal battle, Enel consented to transfer its assets in Italy, Turkey, France, and Poland, as well as its thermal power plants in Spain, to E.On, and enter into a contract to supply nuclear power for ten years.

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