J. Geogr. Sci. 2023, 33(6): 1185-1204
DOI: https://doi.org/10.1007/s11442-023-2125-7

Investigating merchandise trade structure in the RCEP region from the perspective of regional integration

CHEN Xiaoqiang[1,2], YUAN Lihua[1,2], *SONG Changqing[1,2]

1. Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China;
2. State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing 100875, China

Abstract: The Regional Comprehensive Economic Partnership (RCEP) was formally signed by the Association of Southeast Asian Nations (ASEAN) countries, along with China, Japan, South Korea, Australia, and New Zealand. This was a significant step towards regional integration in the Asia-Pacific region. Analysing the trade structure among member states is crucial in understanding the path to regional integration and policy implications of regional cooperation within the RCEP framework. Based on subdivided commodity data, this study reviews the evolution of merchandise trade in the RCEP region in the past two decades. It investigates the current trade structure of the RCEP, emphasising the relative importance of intra-regional versus extra-regional interdependence and the trade asymmetry of the regional members. The results of the study are as follows: First, the overall extent of regional trade integration in the RCEP region increased modestly from 2001 to 2018, indicating that the RCEP region was export-oriented and there was significant room for further expansion of regional trade. Second, most of the commodities traded in the RCEP region demonstrated much higher extra-regional interdependence than intra-regional in 2018, particularly labor-, capital-, and technology-intensive products such as television and radio apparatus. Third, the trade networks of the top five traded commodities were distinguished by large economic asymmetries, with China, Japan, and South Korea being the dominant regional powers. These findings have significant implications for understanding how to promote regional integration and cooperation. Besides expanding intra-regional trade, outward-oriented factors influenced by the regional powers—including consolidating the global advantages of manufacturing, stabilizing supply chains by including large resource countries, and attracting extra-regional investments—were also the main rationales for the conclusion of the RCEP.

Keywords: trade structure; regional integration; RCEP; subdivided commodity; trade network

Received: 2022-12-27 **Accepted:** 2023-03-20
Foundation: The Program of High-grade, Precision and Advanced Disciplines Constructions in Beijing Universities
Author: Chen Xiaoqiang (1996−), PhD Candidate, specialized in trade relationships and regional studies. E-mail: cxq@mail.bnu.edu.cn
***Corresponding author:** Song Changqing (1961−), Professor, specialized in geographical paradigms and regional integration. E-mail: songcq@bnu.edu.cn

1 Introduction

With increasing difficulties encountered in multilateral free trade negotiations at the World Trade Organization, the global free trade system has struggled, while regional trade integration has become increasingly vigorous (Sorgho, 2016). On November 15, 2020, the Association of Southeast Asian Nations (ASEAN) countries and China, Japan, South Korea, Australia, and New Zealand formally signed the Regional Comprehensive Economic Partnership (RCEP) after the fourth Leaders Meeting. The total population and economic and trade volume of RCEP's member countries accounted for about 30% of the global total in 2020, which means that about one-third of the world's economic volume had formed a large integrated market and the world's largest free trade agreement (FTA) was initiated. The formal signing of the RCEP was a major milestone in the course of regional integration in the Asia-Pacific region, which is even more important to the global economy in the context of the heightened sense of economic uncertainty, rising protectionism in the North Atlantic, and the global recession induced by the COVID-19 pandemic (Mahadevan and Nugroho, 2019; Drysdale and Armstrong, 2021; Wei and Yu, 2021). Against such a background, regional integration issues triggered by the negotiation and conclusion of the RCEP have been an area of focus for policymakers and scholars from multidisciplinary backgrounds, including geography (Chen *et al*., 2018).

The RCEP has received extensive attention from academia since its proposal. Some studies have qualitatively analyzed the motivations, prospects, and challenges of the RCEP (Li *et al*., 2016; Kimura, 2021b; Wei and Yu, 2021). The discussion of the motivation for and background of the RCEP is concentrated on easing the pressure of protectionism, making up for the failure of multilateralism, improving the business environment of Factory Asia, and promoting economic recovery from the COVID-19 pandemic. There are two extremes in the evaluation of the RCEP: one camp believes that it is the largest FTA worldwide and will be influential and promising (Fukunaga and Isono, 2013; Vines, 2018). The other claims that the RCEP will not make much of an impact because of its low quality (Rahman and Ara, 2015; Ratna and Huang, 2016). The challenges to the advancement of the RCEP arise from the extensive gaps in economic development and the degree of openness across member countries, some of which are conservative in terms of e-commerce and intellectual property (Li *et al*., 2016; Drysdale and Armstrong, 2021).

Several empirical studies have estimated the economic impact of trade liberalization on member countries under the RCEP framework. For example, Li and Moon (2018) adopted a Computable General Equilibrium (CGE) model to simulate the effect of the RCEP on China and South Korea's trade. Their results predicted that South Korea would experience a 0.9% trade increase, which would be less than the 1.5% increase in China, in an ambitious scenario for the RCEP. Other studies focused on the impact of reducing tariffs and non-tariff barriers in the RCEP on the ASEAN countries (Itakura, 2014; Plummer *et al*., 2014; Lee and Itakura, 2018). Lee and Itakura (2018) adopted a dynamic global trade analysis project (GTAP) model and found that the welfare gains of the ASEAN countries ranged from 1.6 to 3.7%. Comparing the RCEP with other ASEAN FTAs, such as the ASEAN+1 FTA and ASEAN+3 FTA, Itakura (2014) found that the RCEP would lead to the highest positive gain in the real GDP of ASEAN members. Plummer *et al*. (2014) indicated that the ASEAN countries would gain overall income growth of 18.4% at an aggregate level and varying de-

grees of increase in wage and employment from the RCEP. Some studies also examined the RCEP's impact on non-participating developing countries. Their results reported that the economic impact varies greatly across entities but generally supported the formation of the RCEP (Mishra, 2016; Palit, 2017; Wu, 2020).

As a typical mega-FTA, it is natural to compare the RCEP with other Asia-Pacific FTAs, such as the Trans-Pacific Partnership (TPP) and the Comprehensive and Progressive Trans-Pacific Partnership Agreement (CPTPP). Li and Li (2021) simulated and analyzed the trade effects of the RCEP and CPTPP under three different scenarios; they showed that becoming a joint member of the RCEP and CPTPP will result in greater benefits than only joining a single trade agreement or none. Cheong and Tongzon (2013) assessed the net economic impacts of the RCEP and TPP using a dynamic CGE model where the overlapping portions of FTAs are eliminated; they then analyzed the economic and political feasibility of both FTAs based on the quantitative assessment. Additionally, many studies have investigated the differences in the construction and potential impact and development between the RCEP and TPP or CPTPP and provide implications for economic integration in the Asia-Pacific region (Lee *et al*., 2009; Petri *et al*., 2012; Tang and Petri, 2014; Rosenbaum, 2018). As Wilson and Jeffrey (2015) argued, the TPP has a higher level of trade policy ambition than the RCEP to solve the quality issues in existing FTAs; meanwhile, the RCEP addresses the noodle bowl problem of overlapping FTAs in the Asia-Pacific region quickly at a low cost. Therefore, the TPP and RCEP compete to obtain regional governments' commitment. However, Kawasaki (2015) showed that the TPP and RCEP would complement each other rather than compete in establishing the Asia Pacific Free Trade Area, based on his estimation results of an updated CGE model.

Focusing on the economic outcomes of the regional integration institution, existing empirical research has simulated and estimated the RCEP's impact and prospects based on different scenarios of tariff or non-tariff barrier reduction, yielding interesting insights and significant policy implications for regional integration. However, limited studies empirically investigate the incentives for regional cooperation and the determinants of the path to regional integration in the RCEP region from the perspective of the causes of regional integration. According to regional integration theories, trade structure is an important determinant of the path to regional integration (Krapohl and Fink, 2013). Two factors, the relative importance of intra-regional versus extra-regional interdependence and the trade asymmetry of the regional member states, create diverse incentives for the behavior of member states, thereby generating different paths of regional integration.

In terms of the first factor, the economic rationale for integration in a region with high intra-regional economic interdependence is exploiting gains from increasing intra-regional trade, and there is a mutually reinforcing relationship between intra-regional trade and regional institution-building. However, the economic rationale for integration in a region with high extra-regional economic interdependence is attracting foreign investment and accessing extra-regional export markets. The success of regional integration would depend on the reaction of extra-regional actors.

In terms of the second factor, the asymmetries within the regional trade affect the distribution of benefits of regional integration. Especially for the region with high extra-regional interdependence, intra-regional competition between member states for extra-regional in-

vestment and export flows would obstruct regional integration and cooperation, which becomes even more problematic in the case of high asymmetries within a region. Regional integration can only proceed if the extra-regional interests of regional powers are met, while smaller member states have few options to influence regional power.

Moreover, the RCEP's trade creation and diversion effects deriving from the exploitation of comparative cost advantages and economies of scale also depend on the original trade structure in that region (Jiang and Yu, 2021). Analyzing these two structural characteristics in the RCEP region has theoretical and practical significance for promoting the RCEP. To the best of our knowledge, there is still a lack of research that investigates the trade structure of the RCEP region from the perspective of regional integration.

To address this research gap, we utilized subdivided commodity data at the Standard International Trade Classification (SITC) 4-digit code level to examine the trade's structural characteristics in the RCEP region. Our aim is two-fold: first, to provide insights into understanding the path to regional integration in the RCEP region; second, to identify comparative advantages and potential challenges for regional cooperation in the RCEP. Specifically, we examined the development of merchandise trade in the RCEP region over the past two decades. We then analyzed current intra-regional interdependence and extra-regional dependency at the subdivided commodity level based on two simple indicators, which can also reveal the detailed supply and demand status in the regional market. Furthermore, we used network visualization for the most important commodities to reveal the trade asymmetry of the RCEP members and analyzed the impact on the path to regional integration.

The remainder of this article is organized as follows. Section 2 describes the data source of the subdivided commodity trade, measures of regional integration at the subdivided commodity level, and the method of network visualization. Section 3 reviews the development of merchandise trade in the RCEP region and analyzes the current trade structure of the RCEP, including the relative importance of intra-regional versus extra-regional interdependence and the trade asymmetry of member states. Section 4 discusses the results and concludes the paper.

2 Materials and methods

2.1 Data

Our commodity data comes from the Atlas of Economic Complexity Dataverse hosted by the Growth Lab at Harvard University. It collects raw trade data from the United Nations Statistical Division (COMTRADE) and cleans it using the Bustos-Yildirim method, which cross-references the reported exports and imports of countries against each other to produce more reliable accounting. The Atlas of Economic Complexity provides a trade dataset containing trade flows classified via SITC Revision 2, categorizing approximately 700 commodities at the 4-digit detail level. We retrieved all SITC 4-digit code-level commodity flows traded by RCEP member countries in 2018 from the Atlas of Economic Complexity. We selected 2018 as our study period because it was the year when the merchandise trade of the RCEP region reached the highest level before the COVID-19 pandemic, which has impacted global and regional trade severely. The COVID-19 pandemic's impact is not the focus of this study, and data since 2019 was thus excluded.

According to the SITC one-digit code, all commodities have been classified into ten sections, including food and live animals (SITC0), beverages and tobacco (SITC1), crude materials excluding fuels (SITC2), mineral fuels (SITC3), animal and vegetable oils, fats, and waxes (SITC4), chemicals and related products (SITC5), manufactured goods (SITC6), machinery and transport equipment (SITC7), miscellaneous manufactured articles (SITC8), and unspecified commodities and transactions (SITC9). Conventionally, SITC0-4 commodities are classified as primary products, SITC6 and SITC8 as labor-intensive ones, and SITC5 and SITC7 as capital- and technology-intensive products. SITC9 is usually excluded from the classification.

2.2 Methods

2.2.1 Measures of intra- and extra-regional interdependence at the subdivided commodity level

Intra-regional trade share is the most commonly used indicator for measuring regional integration, which refers to the proportion of a region's total intra-regional trade to its global trade (O'loughlin, 1993; Kali and Reyes, 2007; Yuan *et al*., 2021). However, this measure has two limitations. First, it does not differentiate between imports and exports, which fails to provide a complete picture of the region's supply and demand situation. Second, it aggregates all trade flows of different commodities, which obscures details such as value chains and technology flows in the region's trade structures.

Therefore, we divided regional trade into intra-regional trade, extra-regional imports, and extra-regional exports. We calculated the intra-regional import share (IIS) and intra-regional export share (IES) for each traded commodity at the SITC 4-digit code level in the RCEP region to measure the relative importance of intra-regional versus extra-regional trade. In this study, each commodity's IIS is defined as the ratio of imports among RCEP members to the total imports of RCEP members globally, as expressed in Equation (1). Each commodity's IES is defined as the ratio of exports within RCEP members to the total exports from RCEP members to the world, as given by Equation (2).

$$IIS_k = \frac{\sum_i \sum_j m_{ij}^k}{\sum_i M_i^k} \times 100\% \tag{1}$$

$$IES_k = \frac{\sum_i \sum_j e_{ij}^k}{\sum_i E_i^k} \times 100\% \tag{2}$$

where i and j denote countries within the RCEP, m_{ij}^k is country i's import of commodity k from country j, M_i^k is country i's total import of commodity k from around the world, e_{ij}^k is country i's export of commodity k to country j, and E_i^k is country i's total export of commodity k to the world. The IIS and IES of hundreds of commodities were mapped onto a two-dimensional rectangular coordinate system with IIS on the X-axis and IES on the Y-axis as shown in Figure 1.

The position of each commodity on the rectangular coordinate indicates its supply and demand situation in the RCEP region, taking into account both import and export: (a) the

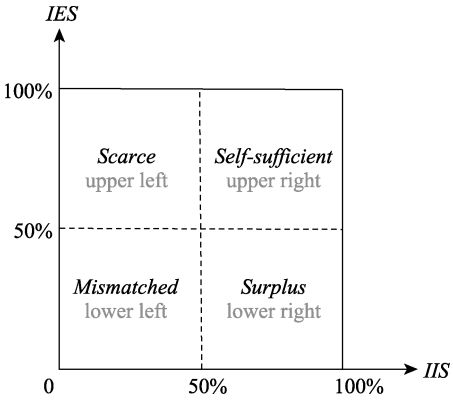

Figure 1 The two-dimensional rectangular coordinate system with IIS on the *X*-axis and IES on the *Y*-axis

upper right quadrant (IIS>50% and IES>50%) represents commodities that are self-sufficient in the RCEP region, with high regional trade integration; (b) the lower right quadrant (IIS>50% and IES<50%) shows a surplus situation where the commodity supply exceeds regional demand and over 50% of its trade volume is exported outside the region; (c) a commodity in the upper left quadrant (IIS<50% and IES>50%) is considered scarce because over half of its demand is met by extra-regional inputs, even though the share of extra-regional exports is relatively low; (d) if a commodity is located in the lower left quadrant (IIS<50% and IES<50%), it indicates that the supply chain for this commodity is not integrated within the region, and intra-regional trade is far less than the corresponding extra-regional imports and exports. It is important to note that only commodities in the self-sufficient quadrant have higher intra-regional interdependence than extra-regional interdependence, while for other commodities, extra-regional interdependence is higher.

2.2.2 Network construction of specific commodity trade in the RCEP

A trade network is a powerful means to investigate the characteristics and complex structure of trade flows between countries (De Benedictis and Tajoli, 2011; Lovric *et al*., 2018; Song *et al*., 2018; Chen *et al*., 2021). The structural properties of trade networks are assumed to be useful in explaining economic phenomena. Thus, trade networks have been applied when studying global and regional economic integration (Kali and Reyes, 2007; Krapohl and Fink, 2013; Yang *et al*., 2018; Zheng *et al*., 2021). Trade networks can help examine the extent of regional trade integration and identify countries contributing to it. To elucidate the asymmetries in the RCEP's regional trade structures, we constructed trade networks of specific commodities for RCEP member countries in 2018 and visualizated them as a Chord Diagram.

To present a clear main trade structure, we plotted each RCEP member's trade links to its three most important export and import partners, including extra-regional countries or regions. It is worth noting that the Hong Kong Special Administrative Region and Taiwan Province of China are also considered extra-regional partners. This reduction can be justified by looking at trade concentration measures; for nearly all RCEP members and the top five commodities, the top three import/export partners accounted for more than 40% of all imports/exports. Thus, the trade links shown in the networks reflect a significant share of trade. We set a threshold of USD 100 million to filter out unimportant ties considering the sizeable trade volumes of these commodities. Trade links between extra-regional partners were omitted because they did not pertain to our analysis. The configuration of nodes and links in this network allows for an analysis of the trade patterns of specific commodities and an assessment of the centrality of intra-regional and/or external actors in the RCEP region.

3 Results

3.1 Development of merchandise trade in the RCEP

To understand the overall characteristics of merchandise trade development in the RCEP region, we briefly analyzed the trends in trade volume and intra-regional share from 2001 to 2018. Despite the impact of the 2008 financial crisis, global merchandise trade experienced a long period of rapid expansion in the 2000s, with the total trade size tripling from USD 6125 billion in 2001 to USD 18044 billion in 2011 (Figure 2). However, the recent decade has witnessed a reduced growth momentum or even recession in world trade, with the volume stagnating at about USD 18000 billion. In the 2000s, the RCEP region's exports and imports grew from USD 1316 billion and 1003 billion in 2001 to USD 4830 billion and 3973 billion in 2011, respectively, roughly following the trend of global trade. While global trade increased by just 3.8% from 2011 to 2018, the RCEP's export and import rates of increase were 14.6% and 11.3%, respectively. Therefore, the RCEP's share in the global merchandise trade rose from 37% to 41% during this period. Additionally, we found that in the two years after the 2008 global financial crisis, the RCEP's share exhibited a leap of 5%, indicating that RCEP members were relatively more resilient to the decline in trade compared to the global average after the financial crisis. The RCEP region also showed impressive performance in trade development during the recent global economic downturn.

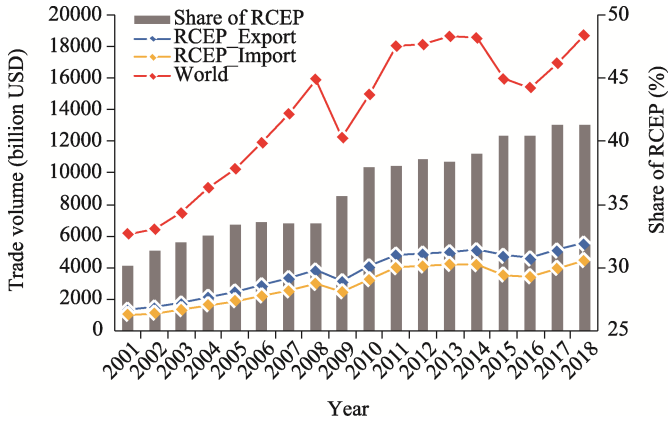

Figure 2 Merchandise trade of the RCEP and world from 2001 to 2018

Although trade in the RCEP region grew rapidly, the RCEP's intra-regional trade share showed a relatively slow growth trend and remained at a relatively low level. The annual RCEP intra-regional shares of exports, imports, and total trade from 2001 to 2018 are displayed in Figure 3. Overall, the intra-regional share of exports and imports depicted an upward trend, rising from 36% and 47% in 2001 to 40% and 51% in 2018, respectively. The intra-regional share of exports was much lower than that of imports, which implies that the RCEP region was export-oriented overall. The intra-regional share of total trade gradually increased from 25% to 29% during the period, demonstrating that the extent of integration of RCEP intra-regional trade moderately increased over this period. Nevertheless, there is plenty of scope for further trade cooperation among RCEP member economies, which is one of the direct rationales for signing the RCEP.

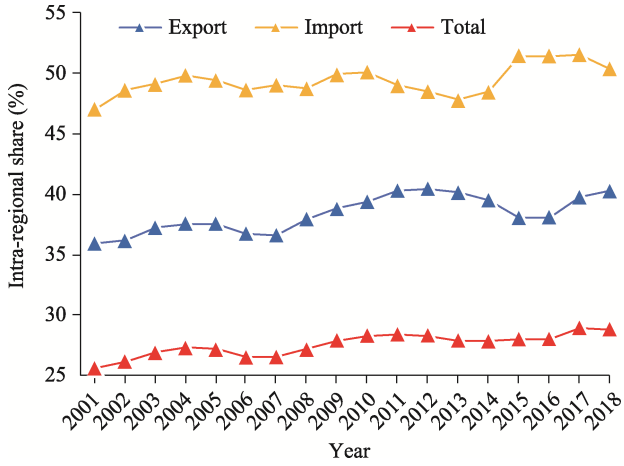

Figure 3 Intra-regional share of import, export, and total trade in the RCEP region from 2001 to 2018

3.2 Relative importance of intra-regional versus extra-regional interdependence

This section focuses on investigating the relative importance of intra-regional versus extra-regional interdependence at the subdivided commodity level in the RCEP region and reflecting the current supply and demand situation in the regional market. The previous section showed that the region was increasingly integrated at a macro level. Unfortunately, the COVID-19 pandemic induced a global economic recession and hindered trade development in the RCEP region. To gain a comprehensive and elaborate understanding of various commodities' characteristics, we investigate the IES and IIS of all 761 types of SITC 4-digit coded commodities (excluding five unspecified commodities in SITC9) traded by the RCEP in 2018, when the merchandise trade of the RCEP region reached the highest level before the COVID-19 pandemic.

Figure 4 presents the results. The IES and IIS, with the total trade volume of each commodity, are combined in Figure 4c. Each dot denotes one commodity. Its color indicates its category, and its size is proportional to the commodity's total trade volume by RCEP members. The position of each commodity in the rectangular coordinate indicates the supply and demand situation in the RCEP region, as described in Section 2.2.1. Furthermore, the density curves of IIS and IES for three categories of commodities were depicted in Figures 4a and 4d, respectively, based on the kernel density estimation method. The distribution of commodities' trade volume was depicted in Figure 4b as the rank-scale curve.

Several significant features are observed in the distribution of all commodities' IIS and IES. First, the number of commodities with higher intra-regional interdependence is far fewer than those with higher extra-regional interdependence. There are 155 types of commodities in a self-sufficient situation (IIS > 50% and IES > 50%) in the RCEP region, accounting for only 20.4% of the total (Table 1). While the remaining 79.6% of commodities show higher extra-regional dependence than intra-regional dependence. In terms of trade volume, the total trade volume of self-sufficient commodities is 1467.8 billion USD, accounting for only 19.7% of all commodities' volume. Second, most commodities with higher extra-regional dependence are densely distributed in the lower right area (IIS > 50% and IES < 50%), which indicates that these products were surplus in the RCEP region and thus ex

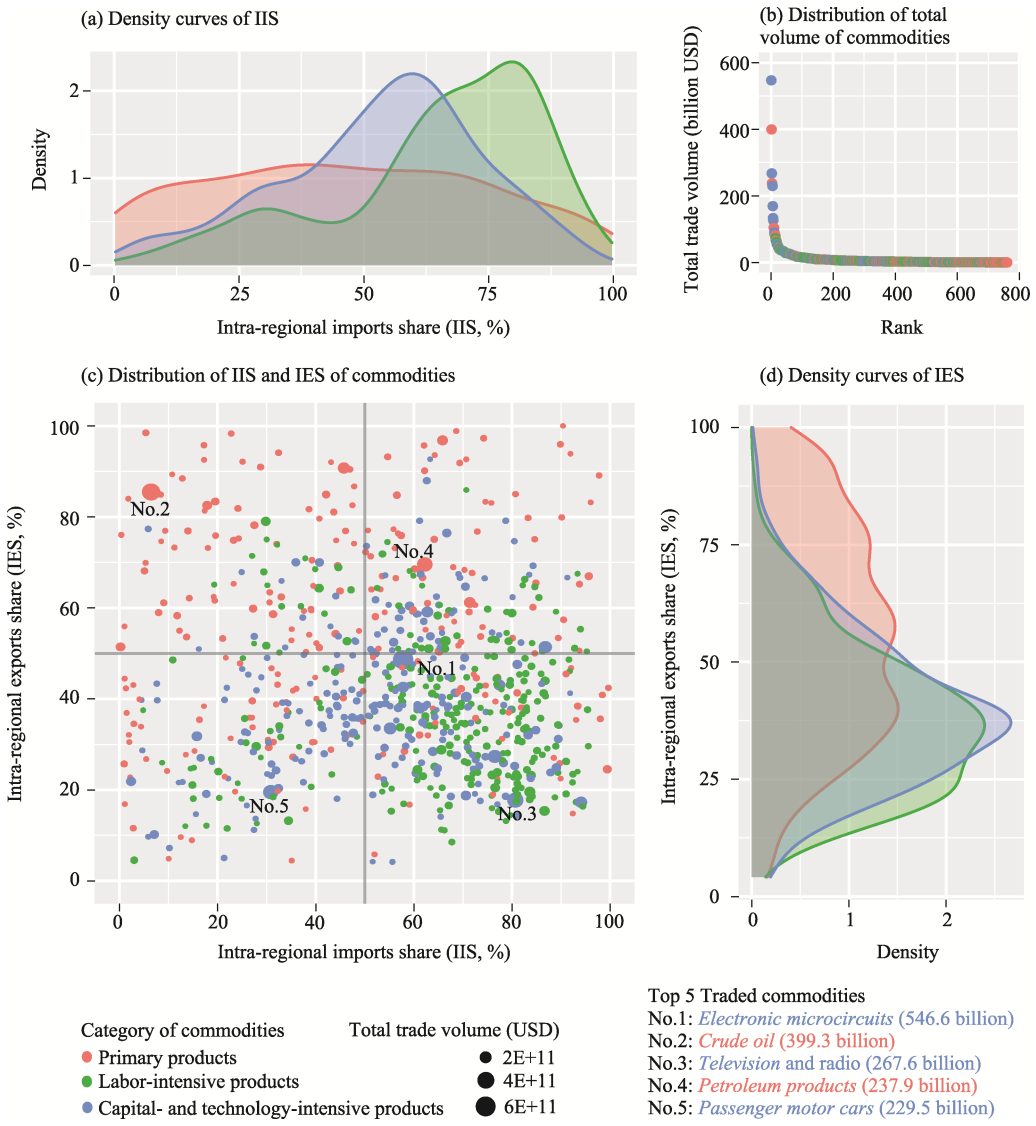

Figure 4 Distribution of IES, IIS and total trade volume of 761 types of SITC 4-digit coded commodities traded by the RCEP in 2018

Table 1 Number and total trade volume of commodities in different supply and demand situations

Situations	Primary products	Labor-intensive products	Capital- and technology-intensive products	Total
	Number of commodities			
Self-sufficient	66	40	49	155
Surplus	42	178	107	327
Scarce	73	19	14	106
Mismatched	56	37	80	173
	Total volume of trade (USD billion)			
Self-sufficient	592.7	293.7	581.4	1467.8
Surplus	125.6	1250.4	2461.1	3837.1
Scarce	860.6	153.9	84.1	1098.6
Mismatched	77.3	212.1	743.4	1032.8

ported mostly to extra-regional countries. The commodities in a surplus situation comprise 42 types of primary products, 178 types of labor-intensive products, and 107 types of capital- and technology-intensive products. Most notably, the number of commodities in a surplus situation is the largest for both labor-intensive products and capital- and technology-intensive products, accounting for 65.0% and 42.8% of the total number, respectively. This is also confirmed by the IIS (left-skewed distribution) and IES (right-skewed distribution) density curves of labor- and capital- and technology-intensive products in Figures 4a and 4d. The share of surplus commodities is even more overwhelming when considering trade volume. The total trade volume of labor-intensive and capital- and technology-intensive products in surplus reached 1250.4 and 2461.1 billion USD, respectively, far exceeding the volume of other commodities. Third, of all the commodities in a scarce situation, primary products account for the majority in both number and trade volume. There are 73 types of scarce primary products, and their total trade volume is 860.6 billion USD. By comparison, most mismatched commodities whose supply chains are not integrated into the RCEP region are capital- and technology-intensive products, the total trade of which reached 743.4 billion USD.

Furthermore, we have detailed the commodities in four extreme states, namely extremely self-sufficient (IIS>80% and IES>80%), extremely surplus (IIS>80% and IES<20%), extremely scarce (IIS<20% and IES<80%), and extremely mismatched (IIS<20% and IES<20%) in Figure 5. Some of these commodities may have been key industrial chain products in terms of trade volume or particular utility. Given their special position in regional trade, these commodities should be described in detail to facilitate the formulation of effective and efficient regional industrial development and cooperation policies (e.g., trade facilitation policies).

All the extremely self-sufficient commodities were primary products, as shown in Figure 5a. These included foods like bovine animals (0011), vegetable products (0548), bananas (0573), and palm nuts (2232); crude materials like sheep or lamb wool (2681); and mineral fuel including briquettes (3231) and lignite (3223). However, their trade volumes were not large. The most traded product was lignite, at USD 4.22 billion, followed by sheep or lamb wool at USD 2.92 billion, and vegetable products at USD 2.41 billion. With a relatively low value, these commodities are abundant in some countries in the region and are mainly traded between a few member states.

Most of the extremely surplus commodities in the RCEP region were labor-intensive products. Among them, footwear (8510), children's toys (8942), lighting fixtures (8124), and tyres (6252) had a trade volume of over USD 10 billion, with over 80% of them flowing out of the region. Although there were only three capital- and technology-intensive products, their trade sizes were staggering. RCEP members traded USD 268.81 billion and USD 104.35 billion worth of televisions (7643) and peripheral units (7525), respectively. Both ranking among the RCEP's top 10 traded commodities in 2018. These products were highly competitive in the international market, as they benefited greatly from the advantages of low-cost labor and specialized manufacturing in RCEP member states. Therefore, it is important to consolidate and expand the competitive advantages through regional industrial cooperation and coordination policies under the large regional trade agreement. In addition, we found that live sheep and goats (0012) were the only highly surplus primary products in

the RCEP despite the small volume of trade, likely from Australia and New Zealand, the two countries with developed animal husbandry. It indicates that the accession of these two resource-rich countries into the regional trade integration would improve the supply level of raw materials.

Some primary products faced severe shortages in the RCEP region. Crude oil (3330) had the largest gap between regional supply and demand, with nearly USD 400 billion of crude oil imported from extra-regional countries in 2018. There was also a large shortage of minerals and wood pulp, including copper ores (2871) and chemical wood pulp in dissolving grades (2517), whose total trade volumes were USD 43.74 billion and USD 18.76 billion, respectively. In addition to the above industrial raw materials, as one of the most important food and feed crops, the consumption of maize (0440) was also highly dependent on external

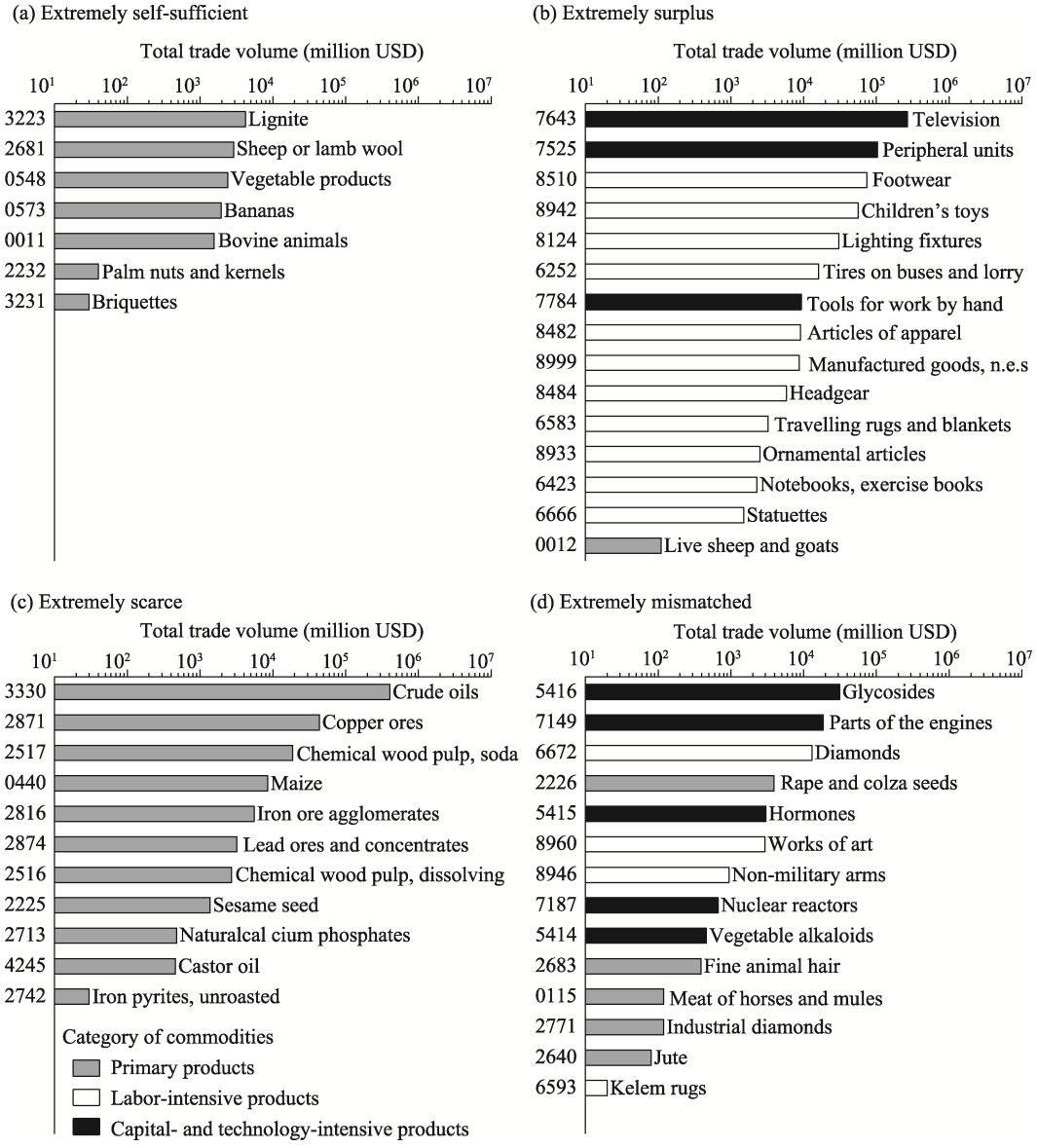

Figure 5 The commodities and their total trade volume in extreme states

supply. Compared to the aforementioned extremely self-sufficient primary products, these extremely scarce primary products seem to have a larger trade volume and higher industrial value. Thus, securing a stable supply of these raw materials will be a challenge in the process of promoting economic integration for RCEP members.

The extremely mismatched commodities existed in all three categories, as seen in Figure 5d. For these products, both extra-regional exports and imports accounted for nearly half of the total trade, indicating that their intra-regional trade was very narrow. The extremely mismatched commodities in the capital- and technology-intensive products had higher trade volumes, especially glycosides (5416) and engine parts (7149), whose total trade amounted to USD 31.42 billion and USD 18.62 billion, respectively. The extremely mismatched commodities with a relatively large trade volume in primary products included rape and colza seeds (2226), with a total volume of USD 3.94 billion. Among all four extremely mismatched labor-intensive products, diamonds (6672) had the largest trade volume of USD 13.02 billion. The mismatch may be due to differences in demand preferences, technological gaps, high tariff barriers among RCEP members, etc.

Overall, the results above indicate that the RCEP region seems to demonstrate much higher extra-regional interdependence than intra-regional, similar to a highly export-oriented economy consisting of many different components. Not only does the massive intra-regional manufacturing capacity need to be absorbed by the extra-regional markets of developed countries, but some key industrial raw materials and strategic resources highly depend on external suppliers. Intra-regional trade needs further expanded through various industry coordination mechanisms, tariff reduction policies, and trade facilitation measures. At the same time, increasing intra-regional trade is far from the only goal of the RCEP. Some outward-oriented factors, such as attracting extra-regional foreign direct investment, maintaining global competitiveness in manufacturing, and improving the ability to make international trade rules, are also the main rationales for regional integration efforts in the RCEP region. Additionally, the fact that crude oil is highly dependent on extra-regional imports makes energy security one of the priorities of regional cooperation.

3.3 Asymmetries in trade networks of the top five traded commodities

The asymmetries within the regional trade are an important structural characteristic that significantly influences the path of regional integration. While it is not possible to investigate the asymmetries in all trade networks of SITC 4-digit coded commodities, analyzing aggregated trade may be too rough and vague. Therefore, we have selected the trade networks of the top five traded commodities, namely electronic microcircuits, crude oil, television and radio apparatus, refined petroleum products, and passenger motor vehicles, to illustrate the main trade asymmetries of the regional member states. This is because (a) the top five traded commodities accounted for nearly 22% of the total trade volume, making their trade networks a rational sampling of the regional trade structure; (b) the top five traded commodities are key commodities for regional trade cooperation, and the roles of member states and extra-regional partners in these trade networks determine their interests in regional integration; and (c) each of the top five traded commodities exhibited distinct intra-regional interdependence and can represent the five different supply and demand scenarios as shown in Table 2. The trade networks for each of the five commodities are visualized in Figure 6 using

the method presented in Section 2.2.2. Furthermore, we have elucidated the trade networks with due emphasis on the trade patterns of different commodities and the asymmetric status of RCEP members.

Table 2 IIS, IES and total trade volume of top five commodities

	Top five commodities	Intra-regional import share (IIS)	Intra-regional export share (IES)	Total trade volume (billion USD)
1	Electronic microcircuits	57.8%	48.6%	546.6
2	Crude oil	6.4%	85.4%	399.3
3	Television and radio apparatus	80.7%	17.7%	267.6
4	Petroleum products	62.2%	69.5%	237.9
5	Passenger motor vehicles	30.8%	19.5%	229.5

The trade network of electronic microcircuits among RCEP members in 2018 is presented in Figure 6a. While the graph only comprises nine intra-regional and three external nodes, it covers USD 408.5 billion of electronic microcircuits trade, accounting for 75% of the total trade of electronic microcircuits in the RCEP region. The high added value and large consumption demand have resulted in a sizeable trade volume, and the high technical threshold of production and utilization has limited the involvement of only a few economies. In line with the results for the IES and IIS of electronic microcircuits in Table 2, extra-regional exports, extra-regional imports, and intra-regional circulation were roughly equivalent in terms of trade size. Specifically, intra-regional trade mainly comprises China's imports from South Korea, with a trade volume of USD 51.6 billion. Extra-regional imports were concentrated on imports of mainland of China from Taiwan Province, with a trade volume of USD 51.7 billion. Extra-regional exports included those from China, South Korea, and Singapore to Hong Kong, with a trade volume of USD 37.8 billion, 31.0 billion, and 25.6 billion, respectively. Overall, China had the greatest demand for electronic microcircuits, with a total import value of USD 148.6 billion. Although the United States had a low position in the trade network, its technological restrictions on China indirectly controlled the exports of South Korea and China's Taiwan province to the mainland of China. Thus, promoting regional cooperation in research and development (R&D) and breaking technical barriers from external countries needs to be included in RCEP's economic cooperation agenda.

The regional trade in crude oil was highly dominated by extra-regional imports in 2018, as indicated by the thick red ties in Figure 6b. Several salient features can be noted. First, almost all RCEP members were net importers, and extra-regional countries participated in regional trade as net exporters. In terms of import volume, China, Japan, and South Korea were the top three importers, with USD 87.9 billion, 45.9 billion, and 34.2 billion, respectively. Saudi Arabia, Russia, the United Arab Emirates, and Angola were major crude oil suppliers, with export volumes of USD 76.5 billion, 36.8 billion, 28.4 billion, and 25.3 billion, respectively. Second, as the largest crude oil consumers, the importing sources of crude oil in China, Japan, and South Korea were different. China's crude oil imports were mainly from Russia, Angola, and Saudi Arabia, whereas Japan's were mainly from Saudi Arabia, the United Arab Emirates, and Qatar, and South Korea's were mainly from Saudi Arabia, Iraq, and Kuwait. Given the strategic importance of crude oil, this is highly related to global geopolitical and security considerations (Yang, 2022). Third, Malaysia was the only

net exporter of oil, mainly to intra-regional countries such as China, Thailand, and Australia. However, crude oil exports from Malaysia were extremely small compared to the massive demand in the RCEP region. In order to improve the security of regional energy supply, on the one hand, it is necessary to further integrate the traditional energy supply chain and accelerate the construction of energy transportation capacity and energy infrastructure. On the other hand, technical cooperation in the field of renewable energy installations and renewable energy utilization should also be included in the agenda.

Extra-regional exports dominated the network of television and radio apparatus in 2018, as indicated by several thick yellow ties in Figure 6c. The network is also distinguished by large trade asymmetries, with China being the absolute dominant power in regional trade. Almost all RCEP member countries imported their television and radio apparatus from China. This was only a small part of its exports, despite exports to Japan and South Korea reaching USD 10.8 billion and USD 8.4 billion, respectively. Most of China's exports flowed into the external market. The US, Hong Kong, and the Netherlands were the top three destinations, with import volumes of USD 55.4 billion, 41.1 billion, and 11.1 billion, respectively. Vietnam was another major producer and exporter after China, and its main export partners were also extra-regional countries such as the United States and the United Arab Emirates. Both China and Vietnam's television industries benefited from low labor costs in the domestic market and the transfer of the electronics industry from Japan and South Korea in the last two decades. With the shift in production to lower labor-cost countries in Southeast Asia soon (Jin *et al*., 2021), lower value-added producers in China are likely to suffer. Thus, they are set to shift to more sophisticated manufacturing and higher value-added products. Against this background, the RCEP's cooperation framework is expected to create a better market environment for promoting regional industry transfer, and consolidating the advantages of the manufacturing industry.

As for the network of refined petroleum products, intra-regional trade ties dominated the graph, indicating that a densely connected internal market already exists in the RCEP region. In Figure 6d, we can see that Singapore was the main trading power, with the largest exports and imports of refined petroleum products, occupying a central role in the network. This is because it has made full use of its geographical advantages as a hub for offshore oil passages in the Strait of Malacca and has become one of the world's three major oil refining centres, as well as the largest re-export trade port in Asia. South Korea was another major exporter, with its petroleum refining industry developing rapidly and maturely since the 1990s. It has three world-class refineries, and refined petroleum products have become one of its main export products. Although some extra-regional trade (such as imports from India) was significant for some RCEP member states, the external trade partners occupied rather peripheral positions in the trade network. Overall, the network depicts a viable internal market for refined petroleum products driven by the utilization of economies of scale and comparative cost advantages through intra-regional trade. The signing of the regional trade agreement has the potential to catalyse the further expansion of the regional market and strengthen industrial cooperation.

In the network of passenger motor vehicles, as shown in Figure 6e, we found that the internal trade bloc (in blue) was somewhat thin compared with the external links (in red and yellow). Both extra-regional imports and exports of the RCEP region were sizeable, indicating a mismatch between the high regional consumer demand and strong production

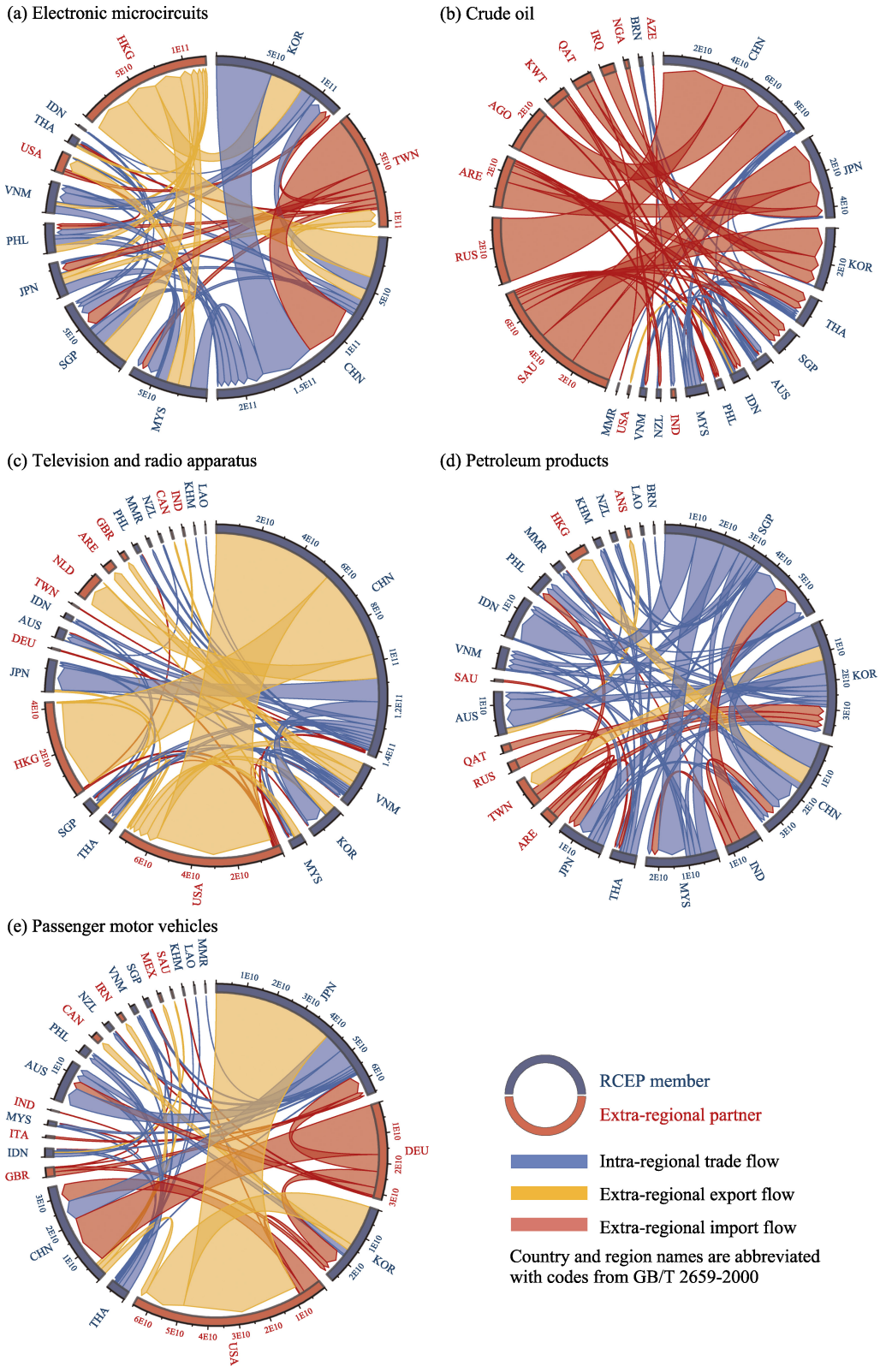

Figure 6 Networks of the top five traded commodities in the RCEP in 2018

supply. Specifically, Japan and South Korea were major exporters of passenger motor vehicles, while China and Australia were major importers. However, most of Japan and South Korea's production were exported to the US, with trade volumes of USD 41.1 billion and 14.0 billion, respectively. In contrast, China's largest sources of imports were Germany and the US, with trade volumes of USD 17.0 billion and 6.1 billion, respectively. Intra-regional trade, concentrated on Japan's exports to China and Australia, was relatively weak, likely due to differences in demand preferences and high tariff barriers. Therefore, the RCEP's promises of tariff relief and trade facilitation, especially among China, Japan, and South Korea, aim to improve this situation through trade creation and diversion effects.

In summary, the above network visualization results of the top five traded commodities provide crucial insights into regional economic asymmetries. The RCEP is distinguished by significant economic asymmetries, with China, Japan and South Korea being the dominant regional powers. Thus, the close economic cooperation between these three countries and the pursuit of common interests would be a significant premise and foundation to realize regional integration. Managing how to deal with the increasingly fierce competition among China, Japan and South Korea in high-end manufacturing and maintaining the stability of the industrial and supply chains have been key issues. For the first time, these three countries are connected by an FTA under the RCEP framework. As the largest economy in the region, China needs to leverage the existing complementary industrial comparative advantages with Japan and South Korea, actively explore new areas of cooperation, fully exploit the attractiveness of the mega market and improve the efficiency of the industrial chain synergy between China, Japan and Korea with the help of RCEP. In addition, the transfer of labor-intensive industries from China to Southeast Asian countries is also an important issue in the development of regional integration because the export-oriented characteristics of regional trade structure determine that consolidating the global advantage of the overall manufacturing industry is an important collective goal of regional integration. With the rising labor cost and the demand for industrial transformation in China, numerous labor-intensive industries are transferred to Southeast Asian countries with demographic dividends, which can improve the efficiency of regional resource allocation and the overall position in the global value chain. Especially in the current context of global trade protectionism, this is highly significant for maintaining the competitiveness of regional industries and merchandise trade.

4 Conclusions and discussion

4.1 Conclusions

Against the backdrop of heightened global economic uncertainty and rising trade protectionism, the formal signing and commencement of the RCEP will provide crucial support for regional integration and economic recovery in the Asia-Pacific region. Based on detailed and subdivided commodity trade data, this study investigated the trade structure of the RCEP through two clear regional trade indicators and network visualizations, intending to find a better way to further promote regional integration and economic cooperation under the RCEP framework. The results of the analysis are summarized as follows.

First, the overall extent of regional trade integration in the RCEP region increased mod-

estly from 2001 to 2018, whereas the intra-regional share of exports remained significantly lower than that of imports, indicating that the RCEP region was export-oriented overall. This suggests significant scope for further expansion of regional trade and economic cooperation among the RCEP member economies.

Second, the analysis revealed that most of the commodities traded in the RCEP region demonstrated considerably higher extra-regional interdependence than intra-regional. In 2018, over 40% of all commodities, primarily comprising labor-, capital-, and technology-intensive products, had a low share (below 50%) of intra-regional exports but a high share (above 50%) of intra-regional imports, respectively, highlighting the great comparative advantages in the manufacturing industry. Meanwhile, some key industrial raw materials and strategic resources, such as crude oil and copper minerals, were highly dependent on external suppliers.

Third, the network visualization results of the top five traded commodities indicated that the RCEP is distinguished by large economic asymmetries, with China, Japan, and South Korea being the dominant regional powers. Specifically, over 90% of the sizeable crude oil demand of China, Japan, and South Korea was met by extra-regional imports from the Middle East, Russia, and Angola in 2018. Singapore and South Korea dominated a densely connected internal trade bloc for refined petroleum products. China, followed by Vietnam, was the core producer and exporter of television sets, a larger portion of whose exports flowed into the external market and met most of the intra-regional demand. The high technical threshold of production led to only a few economies being involved in the regional trade network of electronic microcircuits. A mismatched supply and demand structure was found in the trade of passenger motor vehicles among China, Japan, and South Korea.

4.2 Discussion

Based on the findings of this study, we discuss the results and propose the potential impact of the RCEP on regional integration and policy implications for further regional cooperation in this section. We also present limitations and further extensions of this study at the end.

Our results show that the trade structure of the RCEP region is characterized by high extra-regional dependence and is much less integrated than other regions like the European Union, which is in line with comparative research on the degree of regional integration (Huh and Park, 2018). This results from the historical fact that economic integration in East Asia has been largely market-driven and lacks regional institutional arrangements (Soesastro, 2006). Multinational enterprises in the manufacturing sectors have become the main driving force of economic growth and regional cooperation (Kawasaki and Sato, 2021). Increasing intra-regional trade has mainly been achieved by expanding intra-industry trade based on production fragmentation. Meanwhile, the dependence on extra-regional developed consumer markets has also risen rapidly, which is the direct reason for the slow increase in the intra-regional trade share.

According to the results in Section 3.2, China and Japan were the dominant regional powers in terms of merchandise trade, and their interests would constrain regional cooperation. As Nguyen and Wu (2018) argued, it is difficult to predict the direction of institution-building for regional integration in East Asia because of the existence of China and Japan. Although most Southeast Asian countries have been in relatively peripheral positions in

the regional trade network, many studies emphasized the centrality of ASEAN in regional cooperation and institution-building (Drysdale and Armstrong, 2021; Shimizu, 2021). This is not only because ASEAN is the hub of connecting existing regional economic arrangements (including ASEAN+1 FTAs) but also because the high intra-ASEAN coherence strengthens its advantages in gaining access to resources and setting policy agendas (Mueller, 2019).

Furthermore, RCEP members have gained remarkable comparative advantages and scale economies in the manufacturing industry, which is consistent with the findings of previous studies on production networks in East Asia (Ando and Kimura, 2005; Baldwin, 2018; Kimura, 2021a). The economies in East Asia successfully built up "Factory Asia" by utilizing international production networks (IPNs) and the second unbundling since the 1990s, and multiple regional integration efforts in East Asia had provided a favorable economic environment for Factory Asia in terms of commodity trade and manufacturing FDI. However, Factory Asia faced several serious challenges in recent years, including the weakening of the rule-based trading regime, the intensification of Sino-US trade friction, and the global recession induced by the COVID-19 pandemic. The mega-FTA of the RCEP is expected to contribute toward maintaining a stable business environment and reduce global risks and uncertainties through liberalization and international rulemaking.

Based on our findings, some significant potential impacts of the RCEP on regional integration and economic cooperation need to be noted. First, within the RCEP framework, China–Japan and Japan–South Korea have been connected by an FTA for the first time. Tariff removal ratios for Japanese imports from China and South Korea were 86% and 81%, respectively, whereas those for Japanese exports were 86% and 83% in China and South Korea, respectively (Kimura, 2021b). The tariff reduction can hopefully further promote trade and investment cooperation among the three countries. For example, the large-scale reduction in auto parts tariffs will reduce the price of auto parts imported by Chinese auto companies from Japanese ones, thus reducing the manufacturing cost of complete vehicles, which may, to some extent, reduce China's high dependence on extra-regional imports from external countries like the US and Germany.

Second, RCEP's rules of origin (ROOs) would help consolidate the advantages of the manufacturing industry. The ROOs for preferential tariffs in the RCEP realize accumulation among the 15 member states, breaking the previous restrictions of accumulating across agreements. This significantly reduces the threshold for member states to enjoy zero tariffs on goods. It will promote the integration of industries and value chains, accelerate the flow of intermediate products, increase the flexibility and diversity of the layout of industrial and supply chains, and boost the formation of a complete transnational industrial division system in the region. Especially for surplus and self-sufficient industries like television and refined petroleum products, the RCEP is more conducive to forming industrial agglomeration and scale effects and achieving the optimal allocation of resources and efficiency improvements.

Third, the RCEP will also promote extensive cooperation for R&D and technological innovation and help break down the artificial technical barriers imposed by developed countries, such as restrictions on electronic microcircuits. However, the RCEP's impact on regional energy trade, such as crude oil, will be limited, and the volume of intra-regional trade is unlikely to increase significantly. This is mainly because member countries have implemented low- or even zero-tariff policies to varying degrees, and the RCEP has not made any enhancement in this respect. The share of major global crude oil suppliers, like Russia and

the Middle East, in the region's energy trade will not fundamentally change because of the signing of the RCEP.

Some limitations and further extensions need to be mentioned. The RCEP covers significant investment arrangements, and attracting extra-regional FDI is also an important motivation for regional integration. However, given the availability and richness of commodity data, our current study prioritised the analysis of the trade structure of the RCEP region at the subdivided commodity level. Thus, it is unfortunate that the study did not include an investment analysis in the RCEP member states. To enhance our understanding of the path to regional integration in East Asia, we will attempt to collect FDI data and investigate the investment structure in the RCEP region in a future study. Furthermore, this paper mainly focused on the regional trade structure in the most recent heyday of merchandise trade before the COVID-19 pandemic. The pandemic has had a profound impact on global and regional trade. We will explore how the COVID-19 pandemic reshapes the trade structure in the RCEP region in our ongoing study.

References

Ando M, Kimura F, 2005. The formation of international production and distribution networks in East Asia. *International Trade in East Asia*, 14: 177–216.

Baldwin, R, 2018. The Great Convergence: Information Technology and the New Globalization. Massachusetts: Harvard University Press.

Chen H H, He C F, Mao X Y, 2018. Review of regional integration: Scales, links and borders. *Tropical Geography*, 38(1): 1–12. (in Chinese)

Chen X Q, Yuan L H, Song C Q *et al*., 2022. Comparison on the trade development and influence of China and the U.S. in the surrounding areas of China. *Geographical Research*, 41(3): 663–680. (in Chinese)

Cheong I, Tongzon J, 2013. Comparing the economic impact of the trans-Pacific partnership and the Regional Comprehensive Economic Partnership. *Asian Economic Papers*, 12(2): 144–164.

De Benedictis L, Tajoli L, 2011. The world trade network. *World Economy*, 34(8): 1417–1454.

Drysdale P, Armstrong S, 2021. RCEP: A strategic opportunity for multilateralism. *China Economic Journal*, 14(2): 128–143.

Fukunaga Y, Isono I, 2013. Taking ASEAN+1 FTAs towards the RCEP: A mapping study. ERIA Discussion Paper Series No.201302.

Grossman G M, Helpman E, 2015. Globalization and growth. *American Economic Review*, 105(5): 100–104.

Huh H S, Park C Y, 2018. Asia-Pacific regional integration index: Construction, interpretation, and comparison. *Journal of Asian Economics*, 54: 22–38.

Itakura K, 2014. Impact of liberalization and improved connectivity and facilitation in ASEAN. *Journal of Asian Economics*, 35: 2–11.

Jiang H W, Yu M J, 2021. Understanding RCEP and CPTPP: From the perspective China's dual circulation economic strategy. *China Economic Journal*, 14(2): 144–161.

Jin F J, Yao Z L, Chen Z, 2021. Development characteristics and construction prospects for a multi-integrated economic zone in the South China Sea Region. *Journal of Geographical Sciences*, 31(3): 403–422.

Kali R, Reyes J, 2007. The architecture of globalization: A network approach to international economic integration. *Journal of International Business Studies*, 38(4): 595–620.

Kawasaki K, 2015. The relative significance of EPAs in Asia-Pacific. *Journal of Asian Economics*, 39: 19–30.

Kawasaki K, Sato K, 2021. A new assessment of economic integration in East Asia: Application of an industry-specific G-PPP model. *Japan and the World Economy*, 60: 101105.

Kimura F, 2021. The impact of COVID-19 and the US China confrontation on East Asian production networks. *Seoul Journal of Economics*, 34(1): 27–41.

Kimura F, 2021. RCEP from the middle powers' perspective. *China Economic Journal*, 14(2): 162–170.

Krapohl S, Fink S, 2013. Different paths of regional integration: Trade networks and regional institution-building in Europe, Southeast Asia and Southern Africa. *JCMS–Journal of Common Market Studies*, 51(3): 472–488.

Lee H, Itakura K, 2018. The welfare and sectoral adjustment effects of mega-regional trade agreements on ASEAN countries. *Journal of Asian Economics*, 55: 20–32.

Lee H, Owen R F, Van der Mensbrugghe D, 2009. Regional integration in Asia and its effects on the EU and North America. *Journal of Asian Economics*, 20(3): 240–254.

Li C, Li D, 2021. When Regional Comprehensive Economic Partnership Agreement (RCEP) meets Comprehensive and Progressive Trans-Pacific Partnership Agreement (CPTPP): Considering the "Spaghetti Bowl" effect. *Emerging Markets Finance and Trade*, 58(7): 1988–2003.

Li C, Wang J, Whalley J, 2016. Impact of mega trade deals on China: A computational general equilibrium analysis. *Economic Modelling*, 57: 13–25.

Li Q, Moon H C, 2018. The trade and income effects of RCEP: Implications for China and Korea. *Journal of Korea Trade*, 22(3): 306–318.

Lovric M, Da Re R, Vidale E *et al*., 2018. Social network analysis as a tool for the analysis of international trade of wood and non-wood forest products. *Forest Policy and Economics*, 86: 45–66.

Mahadevan R, Nugroho A, 2019. Can the Regional Comprehensive Economic Partnership minimise the harm from the United States–China trade war? *The World Economy*, 42(11): 3148–3167.

Mueller L M, 2019. ASEAN centrality under threat: The cases of RCEP and connectivity. *Journal of Contemporary East Asia Studies*, 8(2): 177–198.

Nguyen S T, Wu Y, 2021. Patterns of network trade: A comparison between East Asia and European union. *Asia and the Global Economy*, 1(2): 100011.

O'loughlin J, 1993. Geo-economic competition in the Pacific Rim: The political-geography of Japanese and United-States exports, 1966–1988. *Transactions of the Institute of British Geographers*, 18(4): 438–459.

Palit A, 2017. Mega-regional trade agreements and non-participating developing countries: Differential impacts, challenges and policy options. *Competition and Change*, 21(5): 417–434.

Petri P A, Plummer M G, Zhai F, 2012. The trans-Pacific partnership and Asia-pacific integration: A quantitative assessment. East-West Center Working Papers No.119.

Plummer M G, Petri P A, Zhai F, 2014. Assessing the impact of ASEAN economic integration on labour markets. ILO Asia-Pacific Working Paper Series, 2227–4405.

Rahman M M, Ara L A, 2015. TPP, TTIP and RCEP: Implications for South Asian economies. *South Asia Economic Journal*, 16(1): 27–45.

Ratna R S, Huang J, 2016. Regional comprehensive economic partnership (RCEP) FTA: Reducing trade cost through removal of non-tariff measures. *Korea and the World Economy*, 17(2): 213–242.

Rosenbaum C Y, 2018. RCEP or TPP? An empirical analysis based on global experience. *Asian Politics and Policy*, 10(3): 427–441.

Shimizu K, 2021. The ASEAN economic community and the RCEP in the world economy. *Journal of Contemporary East Asia Studies*, 10(1): 1–23.

Soesastro H, 2006. Regional integration in East Asia: Achievements and future prospects. *Asian Economic Policy Review*, 1(2): 215–234.

Song Z Y, Che S Y, Yang Y, 2018. The trade network of the Belt and Road Initiative and its topological relationship to the global trade network. *Journal of Geographical Sciences*, 28(9): 1249–1262.

Sorgho Z, 2016. RTAs' proliferation and trade-diversion effects: Evidence of the 'Spaghetti Bowl' phenomenon. *The World Economy*, 39(2): 285–300.

Tang G, Petri P A, 2014. New Directions in Asia-Pacific Economic Integration. Honolulu: East-West Center.

Vines D, 2018. The BRI and RCEP: Ensuring cooperation in the liberalization of trade in Asia. *Economic and Political Studies–EPS*, 6(3): 338–348.

Wei S J, Yu X, 2021. Semi-inclusive regional economic agreements in the pacific: A perspective from global value chains. *China Economic Journal*, 14(2): 171–186.

Wilson J D, 2015. Mega-regional trade deals in the Asia-Pacific: Choosing between the TPP and RCEP? *Journal of Contemporary Asia*, 45(2): 345–353.

Wu C H, 2020. ASEAN at the crossroads: Trap and track between CPTPP and RCEP. *Journal of International Economic Law*, 23(1): 97–117.

Yang W L, Du D B, Ma Y H *et al*., 2018. Network structure and proximity of the trade network in the Belt and Road region. *Geographical Research*, 2018, 37(11): 2218–2235. (in Chinese)

Yang Y, 2022. Energy globalization of China: Trade, investment, and embedded energy flows. *Journal of Geographical Sciences*, 32(3): 377–400.

Yuan L H, Chen X Q, Song C Q *et al*., 2021. Spatiotemporal evolution and determinant factors of the intra-regional trade community structures of the Indian Ocean Region. *ISPRS International Journal of Geo-Information*, 10(4): 214. doi: 0.3390/ijgi10040214.

Zheng Z, Chen W, Liang Y *et al*., 2021. Spatiotemporal evolution and driving factors of global production networks: An analysis based on the input-output technique. *Journal of Geographical Sciences*, 31(5): 641–663.