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Original Paper

Quantitative Analysis of Economic Complexity and Industrial Competitiveness of Asian Countries

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Abstract

This paper mainly quantifies the economic development situation and industrial competitiveness of Asian countries by measuring the Generalized Economic Complexity Index (GECI) and statistical indicators. The measurement results reveal that it can reflect the real and effective national economic industrial competitiveness more accurately than traditional macro-economic indicators promptly. Another new finding is the GECI of economies, which shows clear geographical differences, with relatively the highest in the East Asia. Besides, we compare the potential of industrial upgrading and conclude that China, Turkey and India have stronger industrial upgrading, while Qatar and Kuwait are obviously weaker.

Keywords

bipartite network, the Generalized Economic Complexity Index (GECI), industrial upgrading, industrial competitiveness

1. Introduction

Economic globalization makes international trade increasingly competitive, and both developed and developing countries try to gain a larger market share and maximize economic benefits by improving their competitiveness in global trade. Under the background of the recent complex international economic environment, strengthening independent innovation, optimizing industrial chains, subsequently promoting transformation and upgrading of industrial structure, and changing the position in the international division of labor system have become the key to enhance the international

competitiveness of industries. As such, how to objectively analyze and measure the industrial structure of different countries, the differences in economic development and the potential of national economic development have given rise to an important topic of interest for economists.

Understanding the substantial differences in economic growth among different countries, which is of great guiding significance for how to promote national growth. Half a century ago, scholars usually used Purchasing Power Parity (PPP) or Gross Domestic Product (GDP) to measure the economic development status of a country, but the statistics and calculation of these two indicators require consuming an abundant resources and time cost actually, so neither of them could reflect the real and valid national economic development promptly (Liu, 2016). Balassa proposed the index of Revealed Comparative Advantage (RCA) to measure the relative advantage of a country's exports of a certain product with the global average export level of the product, as a reflection of the country's competitiveness in that product (Balassa, 1965). Hausmann et al. proposed the Product Space and the theory of evolution of comparative advantage based on Romer's endogenous growth theory in 2006 and 2007, respectively, where they argued that products reflect a country's productive capacity, and the degree of similarity between products determines how easily a country can "leap" from one product to another new product. That is, when the product is at the core of the product similarity network, it is easy to upgrade or transform into another product. That means countries with such products are more likely to transform and upgrade their industrial structure. In addition, for them, the diversity of national export products and the ubiquity of products reflect a country's industrial competitiveness from different aspects (Hausmann, 2006, 2007).

The study of economic complexity began in the 1960s, which has far-reaching influence and significance for an in-depth analysis of the law of economic system development. The Economic Complexity Index (ECI), proposed by Hidalgo and Hausmann in 2009, is a new indicator to measure the economic strength and productive capacity of a country using network science. Specifically, the method of reflections, based on the RCA index of a country's exported products, is used to measure economic complexity using a combination of two indicators: the diversity index and the ubiquity index of each country's products exported (Hidalgo, 2009). Tacchella et al. found that the measurement of the ECI based on the method of reflections did not take into account the situation that "a country exports a few products, most of which are high-end products", and developed a nonlinear fitness-complexity method, which made up for the shortcomings of the method of reflections but deviated from the essence of economic complexity theory (Tacchella, 2013). Later on, Sciarra et al. proposed the Generalised Economic Complexity Index (GECI) by combining the advantages of the first two methods and reconciling the method of reflections and the nonlinear fitness-complexity method to reflect the economic structure of the country more comprehensively, which has a high interpretability and can better reflect the economic strength of the country, and has raised widespread attention and recognition from scholars (Sciarra, 2020).

There are a lot of documents that based on the method of reflections and the nonlinear fitness-complexity method to study the nexus between economic complexity and economic growth performance, and some important results have been achieved. Hidalgo and Hausmann with Simoes generally concluded that economic complexity has a significant and persistent positive impact on the growth of economic levels (Hidalgo, 2009, 2021). Ferrarini and Scaramozzino found that the complexity of productive capacity has a potential impact on national income (Ferrarini, 2016). Hartmann et al. studied 150 countries over the period 1963-2008 and discovered that countries with high economic complexity were less likely to experience income inequality (Hartmann, 2016). Gao and Zhou analyzed data from 31 Chinese provinces for the period 1990-2015 and concluded a significant negative correlation between economic complexity and relative income differences (Gao, 2017). Sweet and Eterovic studied a sample of 70 countries around the world for the period 1965-2009 and found that a significant positive impact of economic complexity on productivity in each country (Sweet 2018). Lee conducted a study on economic complexity and national income levels using cross-country panel data and the results reconfirmed the findings of Hartmann, which suggest that higher economic complexity helps to improve national income inequality when education levels, government spending and trade openness reach certain thresholds (Lee, 2020). Sephrdoust stated that the rapid development of Foreign Direct Investment (FDI) inflows, free trade, and capital investments have increased the economic complexity of developing countries in the Middle East, which in turn has led to a rapid increase in the level of national economies (Sephrdoust, 2019).

Most of the existing studies on economic complexity are based on the method of reflections and the fitness-complexity method to analyze the world trade network, with individual-level complexity analysis of countries or industries, such as China (Gao, 2018), the United States and the United Kingdom (Mealy, 2019), Mexico (Chvez, 2017), Italy (Basile, 2019). Moreover, the studies mainly focus on the study of export complexity index in developed countries or industries, and there are few studies that examine the relationship between the economic complexity of a country and its industrial competitiveness using the GECI. Accordingly, the study object of this paper is 36 Asian countries. Using a combination of network science and statistical analysis method, we empirically analyze the correlation between the economic complexity and industrial competitiveness of these Asian countries. Firstly, we establish a country product bipartite network based on global economic trade data, and then calculate the diversity index of national products exported based on the RCA index, measure the GECI of countries and its rankings, analyze its evolutionary characteristics, and combine the GECI of countries with the complexity outlook index to reveal the characteristics and development trend of international competitiveness of Asian countries' industries.

The structure of the paper is as follows. In Section 1, we present a review of the relevant literature on theoretical research and empirical analysis of economic complexity. In Section 2, the metrics used in this study will be described as a way to provide the theoretical basis. Section 3 mainly measure the GECI and empirically investigate the evolution of industrial competitiveness. In Section 4, we examine

the correlation between the GECI and economic growth performance by statistical method. Section 5 compares the industrial upgrading potential across countries based on the theory of product space. Finally, the conclusions and further discussion of this work are given in Section 6.

2. Data and Methodology

2.1 Sample Selection and Data Pre-processing

The paper focuses on the economic development of Asian countries. Due to the different statistical standards for domestic products in each country, products exported are subject to rigorous testing in the global market compared to domestic products, and products exported are considered to be more competitive globally. Our primary source of export data is the Atlas database from Hausmann (2014), these data are drawn from the UN COMTRADE database. This paper selects the trade data at the HS 4-digit level of desegregation (1440 products) in 2010, 2015, 2019, and 2020.

To more accurately measure the economic development of countries, this paper selects a population size of 1 million and an average annual transaction value of 1 billion as the lower threshold, and then screens out 36 countries in Asia that meet both the population size and a certain level of economic development (Table 1), making it easy to identify the differences between countries.

Table 1. The Regional Distribution of 36 Asian Countries

Distribution area	Country
East Asian countries	Japan, South Korea, China
South Asian countries	Bangladesh, India, Pakistan, Sri Lanka
Central Asian countries	Kyrgyzstan, Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, Mongolia
West Asian countries	Jordan, Iran, Israel, Saudi Arabia, Bahrain, Qatar, Kuwait, Oman, Yemen, Georgia, Turkey, Cyprus, Armenian, Lebanon, Azerbaijan
Southeast Asian countries	Philippines, Cambodia, Myanmar, Thailand, Malaysia, Singapore, Indonesia, Vietnam

According to the classification standards commonly used in international trade statistics, this classification selects the international convention for Harmonized commodity description and coding System (HS). Different from other classification standards, the HS code was originally compiled for the convenience of customs import and export management, taxation and customs statistics. It also pays attention to the natural characteristics and performance uses of commodities, and the classification is more detailed. Therefore, it is widely used in international trade statistics and customs management. Table 2 presents the 1140 products (types) exported in this paper, which are composed of 9 sectors, including textiles, agriculture and stone.

Table 2. The Classification and Quantity of Products Exported

Classification	Quantity	Classification	Quantity	Classification	Quantity
Textiles	174	Agriculture	247	Stone	64
Minerals	64	Metals	142	Chemicals	204
Vehicles	37	Machinery	161	Electronics	47

2.2 Revealed Comparative Advantage (RCA) Index

The Revealed Comparative Advantage (RCA) index, a measure of whether a country is an exporter of a product, based on the comparative advantage or disadvantage a country has as an exporter of a certain product. We use Balassa's definition, given by

$$RCA_{cp} = \frac{X_{cp} / \sum_p X_{cp}}{\sum_c X_{cp} / \sum_c \sum_p X_{cp}} \quad (1)$$

Where RCA_{cp} denote the index of revealed comparative advantage of product p exported by country c , and X_{cp} is the return in dollars of a country c exports through the product p. It is generally believed in the academic community that if RCA_{cp} greater than or equal to 1, which says that the product has revealed comparative advantage, and the larger the value of RCA_{cp}, the greater the competitiveness of the product in the world; otherwise, it is not.

2.3 The Bipartite Network

A bipartite network model of country-product based on the RCA index was built to calculate the GECI. The bipartite network is a special kind of network (Watts, 1998), which is mainly used to portray and study the network model of the relationship between two sets. In this paper, the two vertex sets of the country-product bipartite network are composed of 36 Asian countries and 1440 exported products, and the connected edges represent the corresponding export relationship between countries and products, and such a relationship actually implies that the country has the knowledge and capacity to produce, which is specifically reflected in whether the country has a revealed comparative advantage for the exported products. As shown in Figure 1, there is a connected edge between the country and the product, which indicates that the country has a comparative advantage for the product exported.

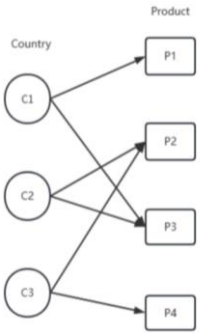


Figure 1. Schematic Diagram of the Country-product Bipartite Network

The country-product bipartite network is represented as the adjacency matrix $M = (M_{cp})$, where rows represent countries and columns represent products. The element M_{cp} of the matrix M represents whether country c has a comparative advantage over product p. Furthermore, the matrix $M = (M_{cp})$ is mapped to the index of RCA_{cp}, where $M_{cp} = 1$ if $RCA_{cp} \geq 1$, and $M_{cp} = 0$ otherwise. The above expression is a binary matrix $M = (M_{cp})$ representing the existence of country-product relationships.

$$M_{cp} = \begin{cases} 1, & RCA_{cp} \geq 1 \\ 0, & RCA_{cp} < 1 \end{cases} \tag{2}$$

2.4 The GECI

The GECI of each country is calculated on the basis of the above country-product bipartite network, the specific methods are as follows: by first calculating the diversity index and the ubiquity index, which reflect information on the diversity of the country's economy and the ubiquity of the product, respectively.

Summing the rows of matrix $M = (M_{cp})$ yields the diversity index K_c of country c's exports, that is, the number of products with comparative advantage of country c:

$$\mathrm{K_c} = \sum_{\mathrm{p}} \mathrm{M_{cp}} \tag{3}$$

The columns of matrix $M = (M_{cp})$ are summed to obtain the ubiquity index of product p, that is, the number of countries with export advantages in product p:

$$K_p = \sum_{c} M_{cp} \tag{4}$$

Based on the two indices above, K_p' is the transposed matrix of K_p, the matrix $W = (W_{cp})$ represents a weighted incidence matrix of an undirected bipartite network uniquely describes the relationships between countries and products exported:

$$W_{cp} = \frac{M_{cp}}{K_c K_p'} \tag{5}$$

Equally, $(W_{cp})'$ is the transposed matrix of $W = (W_{cp})$. According to the idea of spectral clustering by Mealy, the symmetric matrix $N = (N_{cc*})$ is noted as the proximity matrix for countries (the more common products exported by two countries the more similar they are), and it describes the similarity in the export baskets between countries c and c*, and the matrix expression is:

$$N_{cc*} = \begin{cases} \sum_{p} W_{cp} (W_{cp})' = \sum_{p} \frac{M_{cp} M_{c*p}}{K_c K_{c*} (K_p')^2}, & if c \neq c* \\ 0, & if c = c* \end{cases} \tag{6}$$

The GECI for countries is defined as follows:

$$GECI = (\sum_{i=1}^{2} \lambda_i x_{ci})^2 + 2 \sum_{i=1}^{2} {\lambda_i}^2 {x_{ci}}^2 \tag{7}$$

Where x_{c1} and x_{c2} are the eigenvectors corresponding to the first two largest eigenvalues λ_1 and λ_2 of the proximity matrix $N = (N_{cc*})$ respectively.

3. Empirical Analysis of the GECI

This section mainly measures the quantities of products with revealed comparative advantage and the GECI for each Asian country, which can analyze the industrial competitiveness and economic strength of these countries. Significantly, the products exported in the empirical data are limited to manufacture (regional service trade data are not included due to non-standard statistics).

3.1 Measurement of the RCA Index

The number of revealed comparative advantage products for each country calculated from equation (3) is shown in Table 3 (for example, in 2020). Due to the limitation of space, only the measurement results of some countries are listed in Table 3.

Table 3. Quantities and Sectors of Products with Revealed Comparative Advantage in Asian Countries in 2020

	Textiles	Agriculture	Stone	Minerals	Metals	Chemicals	Vehicles	Machinery	electronics
China	141	59	33	13	68	69	12	90	37
Japan	20	10	27	7	54	80	14	90	31
South korea	34	16	9	5	51	47	10	33	18
Israel	19	39	7	11	22	53	4	35	13
Malaysia	26	44	13	8	23	18	6	16	22
India	93	67	22	26	40	72	10	20	5
…	…	…	…	…	…	…	…	…	…
Thailand	87	69	19	7	21	28	6	42	22
Turkey	105	83	22	24	61	43	10	31	9
Bangladesh	76	26	4	3	3	5	1	6	0
Iran	15	32	8	20	11	16	1	0	0
Qatar	5	2	3	7	6	10	1	0	0
Myanmar	24	46	2	12	2	7	0	2	0

Results illustrated in Table 3 show that economically more developed countries are more internationally competitive in exports of capital or technology-intensive industries such as electronics, while developing countries are more competitive in labor-intensive industries such as textiles and agriculture. Taking 2020 as an example, a vertical comparison shows that China's textiles, machinery, chemicals, metals, and agriculture account for a heavier proportion of its exports. Among these sectors, textiles and metals belong to typical labor-intensive sectors, machinery and chemicals belong to capital or technology-intensive manufactured products, and agriculture belong to primary products, reflecting China's higher international competitiveness in primary products and high-end technology products, which is also in line with China's long-term economic development strategy. Japan and South Korea, as developed countries in Asia, also have a large share in the majority of product exported. Japan has a

large share of the trade in exported machinery, chemicals, metals, electronics, and South Korea has a large share of the trade in exported metals, chemicals and machinery. It can be seen that China has certain advantages compared with South Korea and Japan in basic industrial products such as textiles and agriculture, but there is still a gap at the level of medium and high-end technical products. Israel is the only developed country in West Asia, with a very high degree of industrialization and strong overall economic strength. The industries that account for a relatively large share of the country's export trade are chemicals, agriculture, and machinery. Although, India, Turkey in some primary products such as textiles, agriculture in its export trade accounted for a relatively large, but other technical sectors with a revealed advantage of fewer products, the overall trend of international competitiveness is not enough. Malaysia, Thailand, Bangladesh and other Southeast Asian countries have more products with revealed advantages in agriculture and textiles due to the natural environment suitable for the growth of a variety of food crops, and the dense population and abundant labor force in Southeast Asia. Iran and Qatar have comparative advantages in primary products such as minerals, lubricants and related raw materials, and chemicals. This is mainly because these countries are rich in oil and gas resources and their reserves are among the highest in the world.

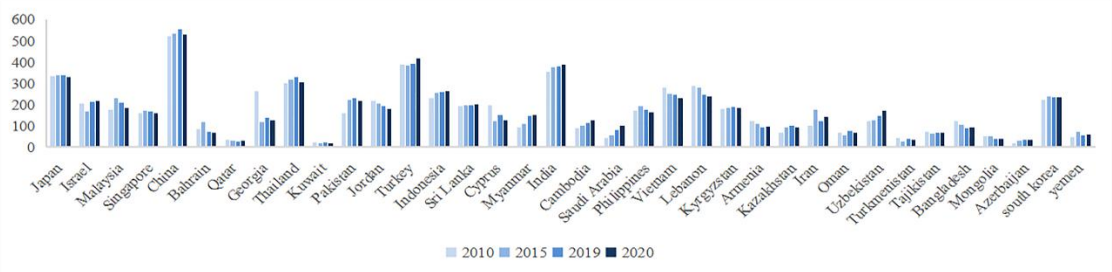


Figure 2. Quantities of Products in which Asian Countries have Revealed Comparative Advantage by Sectors in Four Years

Based on the heterogeneity of products, Hausmann (2006) argued that the production of a product requires a country combination of specific knowledge and capability, the higher the complexity of the product requires higher productivity, and the higher the diversification the more complex the production structure of the country, so the increase in the ability to produce products with comparative advantage is also a reflection of industrial structure upgrading. As can be seen from Figure 2, the number of products with revealed comparative advantage in the major sectors of most Asian countries shows a gradual rise from 2010 to 2019, which indicates that most countries have more and more products that are competitive in the international arena, which also reflects that the number of products for which the country has completed upgrading gradually increases, and the number of products with potential upgrading opportunities will also increase, laying a solid foundation for the country's industrial upgrading. It can be visualized in the figure that countries with more developed economies such as China, Turkey, India, Korea, Japan, and Thailand have a higher number of products with revealed

comparative advantage, while countries with relatively lower economic levels such as Qatar, Kuwait, Turkmenistan, and Azerbaijan have a low number of products with revealed comparative advantage, reflecting the weaker production capacity of these countries. Once again confirming Hidalgo and Hausmann's theory, the degree of diversity of a country's exports, that is, the number of products with revealed comparative advantage, fully reflects a country's productive capacity. The stronger a country's productive capacity, the greater the product diversification and the wider the range of exports.

Notably, the outbreak and rapid spread of the COVID-19 epidemic in China in December 2019 resulted in a significant decrease in the total scale of China's export trade due to the shutdown of most enterprises, transportation disruptions, and suppressed demand for foreign imports, thus causing a consequent decrease in the number of products with revealed advantage in various industries. With the spread of the COVID-19 epidemic overseas, a large number of enterprises in other neighboring countries also shut down their production, thus causing a consequent decline in the scale of exports from neighboring countries and a declining trend in the number of products with revealed advantages in each sector.

3.2 The Country-product Bipartite Network

According to the RCA index above, we can obtain the binary matrix $M = (M_{cp})$from Equation 2 and establish a bipartite network consisting of 36 countries and 1140 products exported. The country-product bipartite network is visualized (Figure 3), where the blue nodes represent countries, the orange nodes represent products exported, and the edges between the two sets of nodes represent the country with a revealed advantage in that product exported. The Figure 3 displays that the degree of node in the network is not evenly distributed, the degree of some country nodes is relatively large, which means that the number of products with comparative advantage is large, while the degree of some country nodes is small, and the number of products with revealed advantage is low, obviously in a relatively disadvantaged position in the international trade competition.

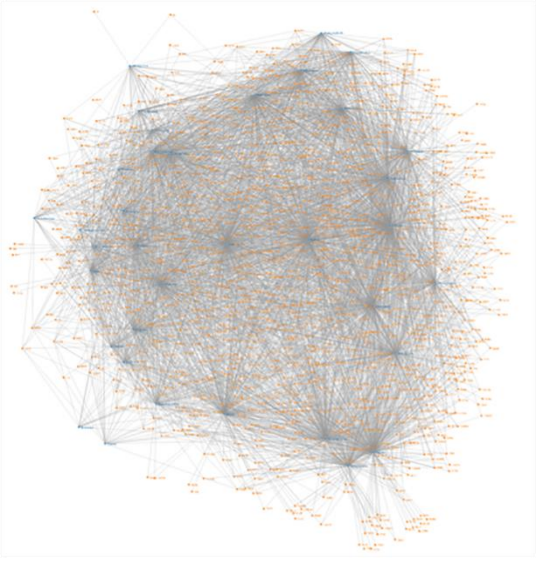


Figure 3. Topology of the Country-product Bipartite Network in 2020

3.3 Measurement of the GECI and Industrial Competitiveness of Analysis

It can be measured by Equation 7 and the GECI for each of the 36 Asian countries in four years is shown in Table 4.

Table 4. The GECI for Each Country in Four Years

country	2010	2015	2019	2020	country	2010	2015	2019	2020
Japan	81.440	216.830	250.572	252.787	Cambodia	0.012	16.094	19.416	19.765
Israel	5.844	61.750	97.274	91.957	Saudi Arabia	0.053	5.024	8.969	14.782
Malaysia	0.590	72.386	66.956	59.115	Philippines	0.881	59.324	55.106	54.155
Singapore	2.080	75.324	67.479	57.826	Vietnam	1.224	56.722	62.685	55.263
China	24.269	173.092	220.406	206.841	Lebanon	0.442	75.557	62.163	56.269
Bahrain	0.016	21.515	8.727	9.669	Kyrgyzstan	0.194	32.088	24.800	24.721
Qatar	0.014	1.396	0.633	1.255	Armenia	0.154	20.128	11.875	13.011
Georgia	1.249	16.402	19.776	14.692	Kazakhstan	0.112	11.877	9.146	13.831
Thailand	0.880	99.257	108.426	103.344	Iran	0.420	23.356	9.146	12.110
Kuwait	0.003	0.296	0.356	0.376	Oman	0.152	5.042	5.506	4.839
Pakistan	0.028	34.780	41.075	36.276	Uzbekistan	0.088	12.898	17.695	25.876
Jordan	5.449	43.440	33.791	30.619	Turkmenistan	0.008	0.859	1.524	1.369
Turkey	16.574	98.104	112.953	117.997	Tajikistan	0.105	4.698	5.062	5.548
Indonesia	0.158	64.888	59.224	62.369	Bangladesh	0.192	14.124	10.163	11.185
Sri Lanka	0.091	36.307	42.028	44.234	Mongolia	0.079	3.805	2.094	2.200
Cyprus	3.280	25.109	36.201	24.508	Azerbaijan	0.001	1.085	1.472	1.142
Myanmar	0.057	14.153	16.306	17.672	South Korea	39.307	142.169	134.588	136.807
India	3.737	92.124	115.099	116.505	Yemen	0.084	7.427	3.715	5.062

Note. The average values of the Generalized Economic Complexity Indices for the four years in the table are, in order, 5.257, 45.540, 48.543, and 47.388, respectively; the variances are, in order, 232.703, 2592.695, 3539.473, and 3403.303, respectively.

As can be seen from Table 4, from the annual cross-sectional comparison, the average value of the GECI of these countries was 5.257 in 2010, and the average value evolved to 48.543 in 2019, which is an increase compared to 2010, indicating that the industrial competitiveness of these economies are growing generally, the more diversified the products produced, and the economic development is shifting from the stage of high-speed growth to the stage of high-quality development. In particular, the GECI of China has increased to nine times its original value, which is the largest increase among all countries. The increase in the GECI indicates that, as China's industrial competitiveness grows, the division of labor within the economic system is deepening, intersectoral industrial linkages are

increasing, and the industrial chain is lengthening, and under the guidance of the export-oriented strategy, it is proactively taking over the industrial transfer from developed Western regions, resulting in an increase in the GECI. However, countries with a single export structure, such as Kuwait and Qatar, are heavily dependent on raw materials and their economies are too fragile to withstand shocks over time, so the GECI has increased at a low rate and the economy has basically stagnated.

As a whole, the variance of the GECI in 2019 is 3539.473, which shows an increasing trend compared with 232.703 in 2010, indicating that the gap of the GECI has increased and the variability of national economic development gradually increased and economic development became more and more uneven. With the promotion and deepening of the process of economic globalization, the scale of transnational flow of innovation factors such as technology and talents among countries is increasing, and the countries with complex industrial structure and abundant production capacity have experienced rapid economic growth, while countries with a single industrial structure are unable to take full advantage of the benefits of economic globalization due to their inherently weak productivity, resulting in slower economic growth, which directly leads to an increasing disparity in economic levels between countries. Due to the recession in import and export trade brought on by the contraction of both domestic and international demand and the emergence of transportation bottlenecks in Asian economies as a result of the COVID-19 outbreak in December 2019, the GECI for the majority of countries decreased in 2019-2020.

Table 5. The GECI Rankings for Each Country in Four Years

country	2010	2015	2019	202	country	2010	2015	2019	2020
Japan	1	1	1	1	Cambodia	33	23	20	20
Israel	5	11	7	7	Saudi Arabia	29	30	27	22
Malaysia	14	9	9	9	Philippines	12	12	13	13
Singapore	9	8	8	10	Vietnam	11	13	10	12
China	3	2	2	2	Lebanon	15	7	11	11
Bahrain	31	20	28	28	Kyrgyzstan	17	17	18	18
Qatar	32	33	35	34	Armenia	20	21	24	25
Georgia	10	22	19	23	Kazakhstan	22	27	23	24
Thailand	13	4	6	6	Iran	16	19	26	26
Kuwait	35	36	36	36	Oman	21	29	29	31
Pakistan	30	16	15	15	Uzbekistan	25	26	21	17
Jordan	6	14	17	16	Turkmenistan	34	35	33	33
Turkey	4	5	5	4	Tajikistan	23	31	30	29
Indonesia	19	10	12	8	Bangladesh	18	25	25	27
Sri Lanka	24	15	14	14	Mongolia	27	32	32	32

Cyprus	8	18	16	19	Azerbaijan	36	34	34	35
Myanmar	28	24	22	21	South Korea	2	3	3	3
India	7	6	4	5	Yemen	26	28	31	30

A longitudinal comparison of the data in Table 4 yields the rankings of the GECI for each country (Table 5). From the ranking in Table 5, the GECI of Japan consistently ranks No.1, representing the high complexity of Japan's production capacity, the high heterogeneity of its exported products, and the high competitiveness of its technology-intensive manufactured products, which is difficult for other countries to imitate. Combined with the diversity of the country's export products in Figure 2, although Japan has no advantage in the number of products with comparative advantage, its unique product structure makes Japan's GECI rank the first. On the contrary, although the number of products that China has comparative advantage is higher than Japan, the ranking of the GECI is inferior to that of Japan, as the complexity of China's production structure and production capacity is not complex enough, so that the originality and technology content of products exported are relatively low and heterogeneous, which can be produced by other countries. The vast majority of Central and West Asian countries are located in the bottom half or even at the end, and most of the countries in the region are high-income economies, their rankings are low due to the single export structure or inconvenient transportation.

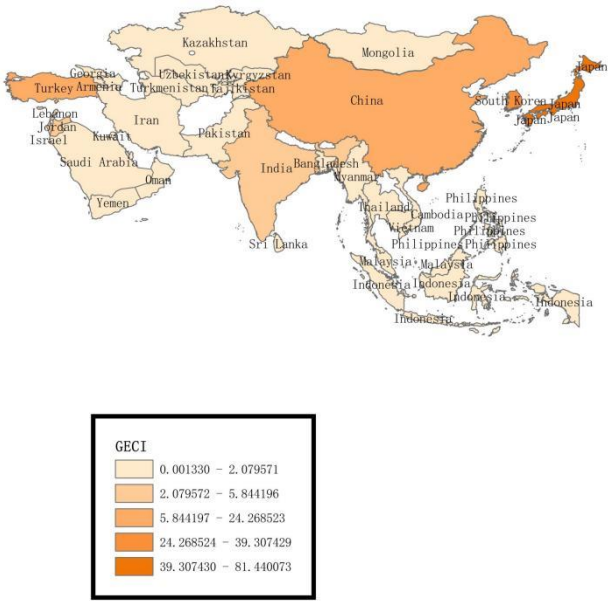
The changes in the ranking of the GECI from 2010 to 2020 vary widely, except for the top 3 countries that consistently rank: Japan, South Korea, and China. The countries that have experienced a significant improvement in ranking are Malaysia, Thailand, Pakistan, Indonesia, Cambodia, and Saudi Arabia, ranking 9th, 6th, 15th, 8th, 20th, and 22nd respectively, reflecting the fact that the industrial competitiveness of developing countries and emerging economies are rising and gradually occupying an increasingly important position in the national export network. Meanwhile, the results point out that some countries such as Georgia (dropping from 10th to 23rd), Jordan (dropping from 6th to 16th), Cyprus (dropping from 8th to 19th), Iran (dropping from 18th to 27th), Oman (dropping from 21st to 31st), and Bangladesh (dropping from 10th to 23rd) have seen a significant decline in their GECI rankings, and the trend is not optimistic. Georgia was at the top of the GECI in 2010 due to the implementation of economic reforms in the early 19th century, but its ranking dropped in the later years because it entered into a reform misunderstanding and did not have sound economic initiatives. Jordan's special geographical location and the frequent wars in neighboring countries have seriously affected the country's exports and the economy has been affected by the instability of the external environment for many years. Cyprus, an internationally renowned offshore financial center known as a "tax haven", experienced a sudden financial crisis in 2012-2013, resulting in an over-inflated virtual economy and a lack of real economic support for the national economy, leading to an economic recession. Iran and Oman are typical countries with high income and low GECI, where gas and oil are the pillar industries of the national economy, and the industrial chain is relatively simple. This type of

country has excellent natural resources, low export diversity, high product universality, which shows certain characteristics of weaker technological capacity upgrading and slow development. Bangladesh's single industrial structure, combined with its advantages such as a low labor force and the fact that the textile industry is its pillar industry, the lack of development momentum, and the instability of the trade environment, have exacerbated the lag in the country's economic growth.

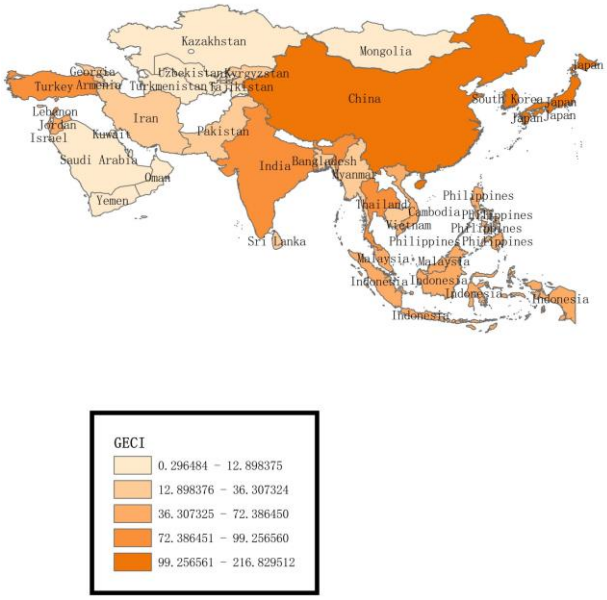
In general, with the acceleration of cross-border factor mobility and industrial transfer from developed countries, developing countries and emerging economies in Asia are emerging, knowledge and technology are being enriched, and industrial structure is gradually converting to knowledge and technology intensive, while the number of products with comparative advantage and the GECI are also rising.

3.4 Regional Differences of the GECI

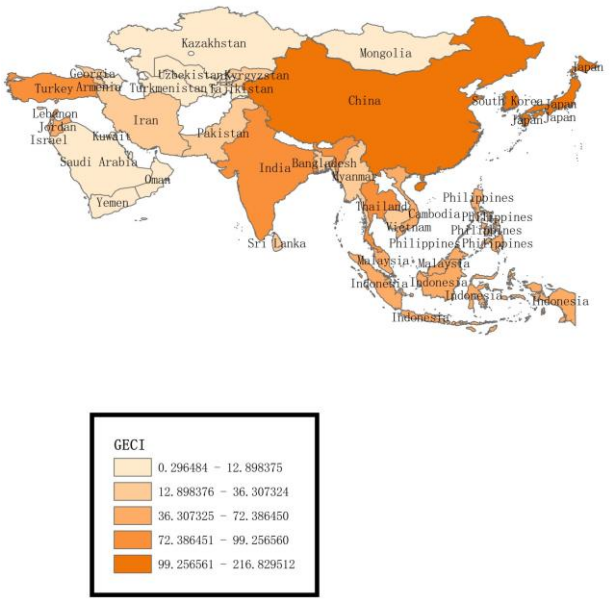
Comparing the GECI of 36 Asian countries shows that economic competitiveness is uneven across countries, do the differences have regional characteristics? Figure 4 illustrates the GECI chromatograms for each country in 2010, 2015, 2019 and 2020, a conclusion is drawn from the GECI chromatograms of 4 years that they vary significantly with geography and show obvious geographical differences. Taking 2020 as an example, East Asian countries such as Japan, China, and South Korea have the highest GECI, followed by the West Asian country Turkey, while most of the West Asian countries and Central Asian countries such as Azerbaijan, Iran, Qatar, Yemen, and Mongolia have a lower GECI. This is mainly because the vast majority of Eastern Asian countries have relatively more advanced industrial structures and more mature economic operation mechanisms, accompanied by economic globalization and a high degree of economic internationalization, while most of the West and Central Asian countries mainly rely on the superiority of natural resources, such as oil, natural gas, mineral resources, but the infrastructure of most countries is not perfect, such as the lack of a mature water and electricity transmission network, unbalanced layout of transportation modes and other problems, resulting in a low level of industrialization. In addition, the social unrest caused by oil resources in recent years has seriously restricted the economic development of these countries.



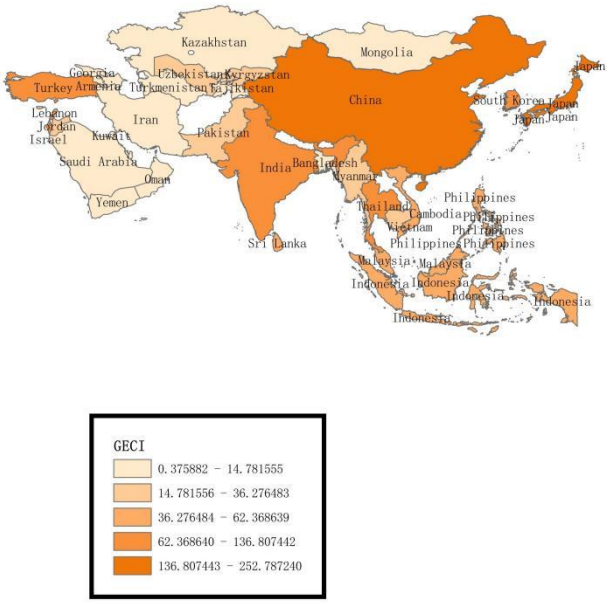
(a) The GECI in 2010



(b) The GECI in 2015



(c) The GECI in 2019



(d) The GECI in 2020

Figure 4. The Chromatograms of the GECI of Asian Countries in Four Years

4. Correlation analysis of the GECI and economic growth performance

To some extent, the GECI represents a country's ability to produce a diverse range of products and highly heterogeneous products, which enables the assessment of the level of economic development of each Asian country and the measurement of the competitiveness of each country. For a better study of how economic development depends on the GECI, we further analyze the correlation between a country's GECI and economic growth performance. Economic growth performance can reflect economic growth performance to some extent. Economic growth performance is generally is generally

expressed as the logarithm of GDP per capita (LNGDPPER). In order to observe the relationship between the GECI and economic growth performance, and data on regional GDP per capita for each country were obtained from the World Bank WDI database, as shown in Figure 5.

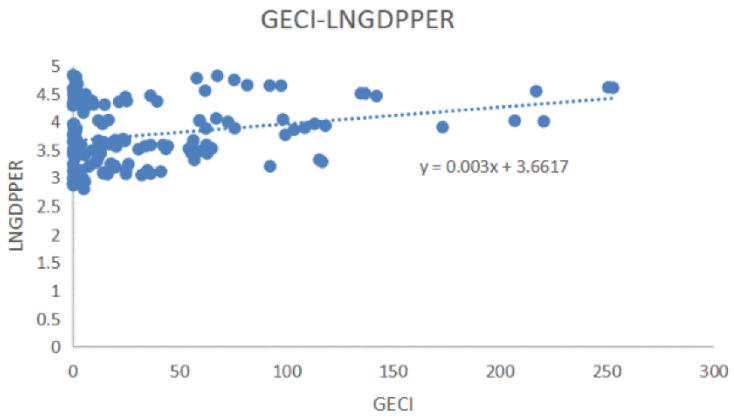


Figure 5. GECI-LNGDPPER Correlation for Each Country

As can be seen from Figure 5, the horizontal coordinate shows the GECI of these country, the vertical coordinate is the value of economic growth performance, and the fitted curve shows a linear correlation between the GECI and economic growth performance values for each country, and the data fitting model of four years from 2010 to 2020 is selected, which is more conducive to observe the trend of correlation between the two. It can be seen from the figure that the lower the GECI, the lower the income level, and the higher the GECI, the higher the income level. This is consistent with the world economic development trend, developed countries focus on cultivating human capital, usually at the frontier of high-end technology, as well as enhancing product sophistication through technological innovation, which in turn promotes economic growth. However, most low- and middle- income countries promote economic growth through physical capital accumulation and fixed asset investment, ignoring the cultivation of innovation capacity, so the product technology level is in the lower middle.

Table 6. The Rankings of the GECI and LNGDPPER in Four Years

	2010		2015		2019		2020	
	GECI	LNGDPPER	GECI	LNGDPPER	GECI	LNGDPPER	GECI	LNGDPPER
Japan	1	3	1	4	1	4	1	4
Israel	5	6	11	3	7	3	7	3
Malaysia	14	13	9	13	9	11	9	12
Singapore	9	2	8	2	8	1	10	1
China	3	18	2	14	2	13	2	11
…	…	…	…	…	…	…	…	…

Bahrain	31	9	20	8	28	8	28	8
Qatar	32	1	33	1	35	2	34	2
Kuwait	35	4	36	5	36	5	36	7
India	28	7	29	6	4	28	5	29

Combining the analysis of Table 5 and Table 6, it is found that the GECI of Bahrain, Qatar, and Kuwait and other countries is lower, but the economic performance value is higher, ranking the forefront of Asian countries. The reason for its serious deviation from the fitted curve is that these countries have extremely rich oil reserves, with the natural gas resources at this time are also unique, and the development of the natural gas industry drives the high economic development of the country. However, due to the monotonous production structure makes the GECI very low, but the per capita income of the country is high. Therefore, the performance of economic growth cannot fully reflect the level of economic development of a country.

5. Comparison of Industrial Upgrading Potential across Countries

Hausmann and Klinger proposed the product space theory for economic development and industrial upgrading, which was highly concerned by the academia. Industrial upgrading is an important driving force for economic growth. When the industry climbs from the low end to the high end, it can accurately identify the potential benefits of various industries and products. Therefore, it is of great significance to analyze the industrial upgrading potential of Asian countries at this stage in order to improve economic complexity more efficiently and promote the rapid economic growth of various countries.

Product proximity $\emptyset_{ij} = min\{p(RCA_i|RCA_j), p(RCA_j|RCA_i)\}$ is the similarity of the production capacity required to produce products i and j. $p(RCA_i/RCA_j)$ is the conditional probability of exporting product at the same time under the condition that product j is exported.

If the production capacity required for the production of a new product is close to the product that already has a comparative advantage, then the probability of the new product becoming a superior product is higher, and the possibility of industrial upgrading in this country is larger; If the gap between the production capacity required to produce the new product and the production of existing superior products is large, the country's industrial upgrading is less likely.

Product proximity $\emptyset_{ij}$ indicates the production capacity to produce a new product and the production of an already advantageous product, for any two export products, there may be two extreme cases, where the two require highly similar input conditions or require completely different production capacities, in which case they are very close or very far away. The capability distance d_{cp} denotes the ratio of the sum of the product proximity of product p to all products not currently exported by country c and product p,

$$d_{cp} = \sum_{p'} (1 - M_{cp'}) \emptyset_{pp'} / \sum_{p'} \emptyset_{pp'} \quad (8)$$

The d_{cp} ranges from (0, 1). The smaller the value of d_{cp}, the stronger the potential of industrial upgrading.

The export technology complexity index is a commonly used index of trade specialization in international trade, originally proposed by Hausmann et al., which measures the level of technology of a country's export by weighting the GDP per capita of each country by the share of that country's or region's exports in total world exports. The export technology complexity index $PRODY_p$ of product p is the sum of the product of the revealed comparative advantage index RCA_{cp} of all countries in the world exporting that product and the GDP per capita of that country (Y_c),

$$PRODY_p = \sum_{c} RCA_{cp} \times Y_c \quad (9)$$

The Complexity Outlook Index (COI) is used to measure the types of potential new products that can be developed from a country's currently available production capacity. Economies with high economic complexity have a diversified export structure and existing productive capacity to develop a large number of new products with proximity to existing advantageous products as well as to acquire the necessary missing production capacity. In contrast, those economies which are low in complexity have almost no proximity products, making it difficult to acquire new production capacity to increase their own economic complexity. The COI of country c is calculated as $COI_c = \sum_p (1 - d_{cp})(1 - M_{cp}) PRODY_p$, and the higher the value the stronger the potential for industrial upgrading.

Within the scope of this study, the COI captures how many complex products Asian countries have near the current production capacity of major export industries. The higher the COI, the greater the number of complex products near the country's current production capacity, and the greater the possibility of producing complex products.

Table 7. The COI for Each Country in 2010 and 2020

Country	2010	Ranking	2020	Ranking	Country	2010	Ranking	2020	Ranking
japan	59665880.8	7	68270312.3	5	Cambodia	25620110.6	24	38596757.3	20
Israel	44188135.6	14	50540541.9	12	Saudi Arabia	10838647.1	33	30784271.4	24
Malaysia	42787945.9	17	47274242.5	17	Philippines	46979612.3	13	47376493.6	16
Singapore	37891424.3	19	41578980.4	19	Vietnam	64284736.8	5	65724230.9	7
China	92793991.7	1	108270555.2	1	Lebanon	62960940.5	6	63353924.7	8
Bahrain	22077771.3	26	21333122.3	29	Kyrgyzstan	43542923.9	15	47764300.4	15
Qatar	8816729.5	34	8930049.7	35	Armenia	32989697.3	21	29246307.0	26
Georgia	51198607.9	9	35476191.8	22	Kazakhstan	17304194.7	29	23643787.8	27

Thailand	70094234.9	4	76726985.2	4	Iran	24985379.0	25	35545959.7	21
Kuwait	6356715.4	35	5911145.5	36	Oman	19637982.6	28	19088653.9	30
Pakistan	42096351.9	18	60561390.7	10	Uzbekistan	32101896.9	22	48351331.7	14
Jordan	49243296.8	11	48932908.0	13	Turkmenistan	12388097.0	32	11836705.8	32
Turkey	77379256.6	2	91592760.2	2	Tajikistan	20489617.7	27	21641411.8	28
Indonesia	50817572.7	10	65853400.5	6	Bangladesh	36456647.7	20	30206832.4	25
Sri Lanka	48837910.4	12	57127615.8	11	Mongolia	13033097.5	31	10635038.9	34
Cyprus	42842074.6	16	35206103.5	23	Azerbaijan	6252292.7	36	11720661.3	33
Myanmar	26575926.7	23	44384130.0	18	South Korea	54426450.0	8	63239393.0	9
India	71429541.4	3	85981838.2	3	Yemen	13508257.2	30	18690844.1	31

The COI is measured for each country from 2010-2020 using statistical software (Table 7), the top 3 are China, Turkey and India. Combined with the evolution of the GECI in Table 4, the GECI of these countries shows a sharp upward trend, which is closely related to the strong potential of national industrial upgrading.

During this period, China has rapidly complied with the process of economic globalization and pursued the economic strategy of going global, which has continuously improved its economic system. Turkey has made great efforts to develop modern service industry represented by tourism and related industries, and the economic development speed has accelerated. At the same time, India has vigorously pursued economic reforms, introducing policies such as the abolition of banknotes and the return of manufacturing industry, while actively developing advantageous industries such as the counterfeit pharmaceutical industry and the software industry. Therefore, Turkey and India have a high and stable COI during this period. However, countries with a single industrial structure, such as Kuwait and Qatar, have low potential for industrial upgrading because their over-reliance on their original advantageous industries, which directly leads to the inability of the GECI to achieve a substantial increase.

6. Conclusions and Discussion

Based on the export trade data of Asian countries from 2010 to 2020 from Atlas, this paper establishes a country-product bipartite network and studies the economic development and industrial competitiveness of Asian countries through several economic indicators. The conclusions and discussion are as follows:

(1) By measuring the sectors and quantities of products with revealed comparative advantage, it is concluded that developed countries are more competitive in the export of capital-intensive or technology-intensive industries such as electronics, while developing countries are more competitive in labor-intensive industries such as textiles and agriculture. The higher the degree of diversification of export products in more developed countries, the stronger the corresponding productivity, the wider the scope of export.

(2) The quantitative analysis of the GECI of each country summarizes that: the GECI of developed countries such as Japan is firmly in the forefront, while the GECI of developing countries and emerging economies is rising and the gap between countries is increasing; from the perspective of distribution area, the GECI of East Asia is the highest, followed by Southeast Asia, and the GECI of West Asia and Central countries is lower.

(3) The correlation analysis between GECI and the country's level of economic development reveals that the GECI is positively correlated with economic growth, so we can promote economic growth through technological innovation and industrial upgrading.

(4) Through the analysis of the COI of each country, it is found that China, Turkey and India have a significantly stronger industrial upgrading potential, countries such as Qatar and Kuwait have weaker industrial upgrading potential.

It is worth nothing that the GECI does not fully represent the degree of economic development of a country. For example, in 2019, the GECI of South Korea and Singapore was lower than that of China, but this does not mean that the economic growth of South Korea and Singapore lags behind that of China.

The reason for the deviation is that the GECI is mainly based on the dual information of country and products exported with comparative advantage, and the constitution of economic strength includes: investment, consumption, and export. The calculation of the GECI only considers the information of export products, which can not completely and truly reflect the overall production structure and economic strength of the country. Besides, the measurement data of the GECI does not include the trade data of service industry, so it may underestimate the degree of economic development of counties with a relatively heavy service industry. For example, Singapore's GDP of the service industry in 2019 accounts for 75.3 percent of its GDP, so its economic development may be underestimated.

Despite its limitations, the GECI is based on the perspective of network science to describe the economic structure of a country integrally, which remains an important indicator of national economic strength. Compared with the traditional economic indicators such as per capita GDP and CPI, which only roughly show the overall economic development level of the country, the GECI can more specifically reveal the main economic structure of the country from an international perspective. In addition to the country's economic strength and international competitiveness in terms of export trade, it can further explore the country's industrial upgrading potential and development direction. Therefore, the GECI should be given close attention by various national economic strategy decision makers, and the results of this study may provide decision-making basis and valuable resources for transnational trade investors and policy makers.

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