

Retraction

Retracted: Spatiotemporal Pattern Evolution in Global Green Trade Networks: Implications for Health Economics

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] H. Zhou, S. Wei, X. Xi, H. Zhou, and H. Hu, "Spatiotemporal Pattern Evolution in Global Green Trade Networks: Implications for Health Economics," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 3159747, 15 pages, 2021.

Research Article

Spatiotemporal Pattern Evolution in Global Green Trade Networks: Implications for Health Economics

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Big health industry is an industry that provides whole process and all factor products and services for human comprehensive physical and mental health. With the increasingly close relationship between health and environment, green products take into account the characteristics of environmental protection, resource intensification, safety, and health, so that the green product industry for the purpose of health and environmental protection has become an important branch of the big health industry. To give a clear portrayal of changes in the global green product trade system, this study derives relevant trade data from the World Bank and the UN Comtrade and by analyzing the spatiotemporal evolution characteristics of the global green product trade pattern from 2001 to 2018, and it explores the product structure and status changes of countries (regions) in the global trading system for green products. According to the research findings, the closely connected global trade network for green products continues to expand. This is a typical network comprising “smaller worlds”; the focus of green product exports has largely stayed unchanged, while imports are shifting from North America and East Asia towards North America, Europe, and the Middle East; the spatial structure of the network shows a transition away from the original transcontinental “dual arch” pattern with the United States at the core towards a “transcontinental + intracontinental” one characterized by the coexistence of “multiple arches” centering around Europe and Asia; the trade network adopts a “point-to-point” model, with no obvious interdependence and competition between countries (regions); furthermore, geographically proximate and culturally similar countries are prone to have closer trade ties. By clarifying the global trade network of green products industry under the background of big health industry, it will help to deepen the understanding of the relationship between participating countries, promote the long-term and stable development of national health industry trade, provide the public with more safe and harmless products, better meet the global public’s health needs, and effectively enhance the sustainability of public health.

1. Introduction

In recent years, with the continuous extension and expansion of global innovation chain and industrial chain, seizing the commanding height of global health industry division of labor has become an important strategic choice for many countries in the world, especially European and American countries and emerging economies. This is because, under the epidemic, the proportion of people’s

health consumption has increased, and the market size of the big health industry will show an order of magnitude growth. In addition, the new generation of cutting-edge information technologies such as mobile Internet, big data, and artificial intelligence has brought new development opportunities for the traditional medical and health industry. Mobile Internet promotes more convenient information communication, big data enhances the level of intelligence in diagnosis and treatment, and artificial

intelligence intelligently transforms all links in the medical treatment process.

The health industry aims to promote human life and health, covering biotechnology, pharmacy, medical equipment, healthcare, and other fields. It is known as the “fifth wave of wealth” after land, industry, commerce, and information network. In European and American developed countries, the health industry can account for more than 8.8% of GDP [1]. However, due to the prevalence of trade protectionism in some countries and the increase of relative cost of production factors in various countries, especially the impact of COVID-19 on the import and export trade of various countries, the development of the global industrial chain and innovation chain system is facing adjustment and atrophy [2–4]. The health industry not only includes the traditional health service industry with healthcare as the core, but also involves many departments in the primary, secondary and tertiary industries of the national economy. The primary industry includes organic agriculture, Chinese herbal medicine planting, and other industries. The secondary industry covers health food processing and manufacturing, pharmaceutical manufacturing, health equipment manufacturing, and other industries. The tertiary industry covers medical and health services, wholesale and retail of health products, public facilities management, health management, health financial services, and other industries, as well as public welfare undertakings that provide a good ecological environment, healthcare combined with healthcare services, and ecological leisure tourism [5, 6]. From this point of view, the health industry has the dual attributes of people’s livelihood and science and technology. It is a global green industry, sunrise industry, and high-tech industry. At the same time, it is also closely related to people’s life safety and health. The development of China’s health industry, guided by effectively meeting people’s health needs and promoting biomedical science and technology research and development, will provide a breakthrough for integration into the global innovation chain and industrial chain. At present, although the proportion of China’s health industry is only 4-5%, with the public’s attention to topics such as population aging, food hygiene, and safety and health preservation, the industry will generate huge consumer demand in the future [7, 8]. China also issued the outline of “healthy China 2030” plan in 2016, raising the development of health industry as a national strategy.

At present, there is a consensus on the classification of health industry at China and abroad, mainly in medicine and medical devices, while there is no unified standard for other subdivided industries, mainly based on the classification standards of major countries in the world such as China, the United States, the United Kingdom, and Germany. Referring to the definition of Shao et al. [9], this paper summarizes the health industry as based on medical and health, biotechnology, and life science, with the characteristics of high-tech R&D, high-end manufacturing, and green environmental protection [10, 11], covering pharmaceutical products, medical devices, green agricultural products, digital health management, health consulting, and other manufacturing or

service industries related to people’s health [12–15]. In the above industries, medical devices and green agricultural products are often recognized as green products. With the increasingly close relationship between health and environment, green products take into account the characteristics of environmental protection, resource intensification, safety, and health, so that the green product industry for the purpose of health and environmental protection has become an important branch of the big health industry. The development of green products industry can provide the public with more safe and harmless products, closely combine environmental protection and people’s health, and promote a virtuous circle of environment. Therefore, green products are analyzed as a subindustry of health industry, in order to provide suggestions for improving ecological environment, developing industrial economy, and meeting public health needs.

Taking into account the advantages of environmental protection, resource intensification, and sustainable development, green product trade can not only provide the public with a healthy and environmentally friendly living environment and help guide green consumption investment and industrial structure upgrading, but also provide an entry point for China to seize the division of labor of the global health industry chain and integrate into the extension of the global innovation chain. Green product trade is the common denominator of environmental protection, resource intensification, and sustainable development—meaning it could furnish guidance to green consumption, green investment, and industrial structure upgrading. According to data from UN Comtrade, a look at the 54 environmental products in the APEC List of Environmental Goods reveals that the world’s environmental product exports rose from US\$ 156.918 billion to US\$ 528.90 billion during 2001–2018, with an average annual growth rate of 6.10%. More countries have been involved in China’s green product trade, thanks to China’s years of R&D investment and manufacturing in the field of green products, various taxes, and fee concessions, subsidy policies, etc. By 2012, 98% of the world’s countries (regions) became counterparts in China’s green product trade—meaning an extensive network of trade partnerships had been established [16]. However, with the accession of more and more countries, China’s green product trade network and the relationship between participating countries have become more and more complex, forming a typical complex network structure. In 2020, China’s annual total import and export value and export value both hit record highs, and the international market share set a record for the best in history, becoming the only major economy in the world to achieve positive growth in trade in goods. At the same time, China has become the largest trading partner of more than 120 countries and regions including the United States, the European Union, Japan, and India. From January to February 2021, China’s total import and export value of goods trade was 5.44 trillion yuan, an increase of 32.2% over the same period last year. Therefore, based on the complex network theory, analyzing the network structure and community distribution formed by global green product trade and clarifying the characteristics of global green

product trade network structure will help to deepen the understanding of the relationship between trading countries and provide decision-making reference for trade exchanges. Establishing a stable and long-term green product trade relationship can not only promote the development of domestic health industry, but also more efficiently meet the national health needs.

2. Theoretical Basis and Research Hypotheses

Complex network analysis has been widely used in international trade research in recent years. Originally applied to the world trade network to analyze whether there are trade relations between countries (regions), this method denotes an analysis of network characteristics based on the connections between multiple subjects. Due to its distinctive nodes, orientation, and weight-adjustment, global trade networks usually have similar topological characteristics (small-world, scale-free, community structure, etc.) [17–19]. Similar characteristics may also exist for green products—making further studies necessary. As research in global trade networks continues to evolve, the tendency of hierarchical network structure has gradually caught on among economists. Common spatial structure characteristics, including nonequilibrium, “core-periphery,” hierarchical grading, etc., have been discovered and are mainly reflected in the research of global economic integration and the hierarchical stratification of the world economic system, such as the three-level and the four-level world-system theory [20–22]. Regardless of the level of the global trading system, the general growth of developing economies has been a feature since 1978. Along with the rise of emerging economies of which China serves as a prime example, the structure of the world trade network shows an evolutionary trend of “ascendency of the east over the west” although the original pattern of “the west stronger than the east” remains [23–26]. In the context of health industry, Zhu and Zhuang [27] analyzed the global trade network pattern of green agricultural products, health food, and pharmaceutical industry and summarized the impact of scientific research investment, health concept, industrial policy, and other factors on the global health industry. Hu and Xu [28] discussed the mechanism of urban health geography from the perspective of complexity theory. Yuan and Xin [29], based on the social network analysis method, analyzed the trade network topology and key characteristics of high-end manufacturing industries such as medical devices, pharmaceutical chemicals, and plant medicine manufacturing and summarized the impact of industrial added value and geographical proximity on trade. As a subindustry of health industry, green products may also face similar pattern evolution. Therefore, this paper intends to answer the following questions:

H1: with the changes in the ecological environment and the improvement of people’s living standards, more and more people are beginning to pay attention to health issues, which promotes the development of the health industry. Especially in the past 10 years, the

health industry in various countries around the world has developed rapidly, and governments around the world have carried out various forms of exploration and practice around the construction of the health service industry and the creation of health industry clusters. What changes have taken place in the network topology of global green product trade? Is it small-world and scale-free?

The regional trade network research development can be attributed to the growing trend of clustering in the global trade network and the continuous emergence of regional trade groups under regional trade agreements [30–32]. As of May 2018, the World Trade Organization had been notified of 673 regional trade agreements, of which 287 had entered into force. As China’s “One Belt One Road” regional trade agreement grows ever more widely accepted, the research on trade networks focusing on countries and regions along the “Belt and Road” has gained traction nowadays. Several studies have reflected on China’s central position in the trade bloc and on how China has been moving closer to the center as its trade network has gradually become more closely linked [33–35]. Moreover, concerning factors affecting regional trade networks, scholars have found that geographical distance, cultural distance, institutional differences, economic scale, innovation level, etc., tend to have a profound impact on regional transnational trade [36, 37]. There is still a scarcity of research on trade network cluster groupings for the green product industry, for which in-depth studies are therefore needed. In the context of the health industry, Xia et al. [38] analyzed the evolution of the global antiviral drug trade pattern and revealed that the global antiviral drug trade network community gradually gathered and China gradually separated from the American community, approached the Western European Community represented by Germany and Belgium, and played an increasingly important role in the network. The research on green product related trade network group is still blank and needs to be further studied. Therefore, this paper intends to answer the following questions.

H2: under the background of the development of health industry, what is the competition and cooperation relationship among countries in the global green product trade? What are the characteristics of the distribution and spatial pattern of trade groups?

Health is not only the eternal theme of mankind, but also an important symbol of social progress. Health has become the basic goal of people’s life in the new century. Some developed countries began to pay attention to “great health.” For example, a few years ago, Japan proposed and implemented the “new health development strategy,” focusing on balanced health medicine and strengthening national health management and education. The first content of the strategy is children’s health, which also includes nine contents,

such as women's health, combating obesity, and reducing cancer. China should learn from the experience of developed countries, raise national health security to a strategic height, and establish a permanent leading decision-making body at the national and regional levels to systematically plan and design the reform of green trade network and health security system. Through the effective constraints and norms of various multilateral frameworks, the coordinated development of global green trade and big health industry can be carried out orderly and stably. The maturity of these constraints indicates that the globalization of green trade and big health industry has entered a new stage.

3. Structural Evolution of Global Green Trade Product

The APEC List of Environmental Goods was released at the 20th APEC Leaders' Informal Meeting in 2012, and for the first time a consensus was reached regarding the definition and recognition of certain green products versus conventional ones [39]. On the macroscale, the list enhances sustainability and advances the high-quality trade development to protect the environment, reducing trade frictions, and improving trade structure; from a microperspective, it is conducive to promoting the formulation, interpretation, and application of related policies. Green products can be classified from different perspectives. For example, they can be divided into improved and improved types according to the degree of differentiation from the original products, or they can be classified according to the degree of environmental protection and the degree of "green." "Green" is a relative concept. It is difficult to have a strict standard and scope definition. Its standards can be formed by social habits, formulated by social groups, or prescribed by law. APEC green products are mainly classified according to the type of energy consumption of the products, the size of energy consumption, and the materials consumed. Based on the list and the International Convention on the Harmonized Commodity Description and Coding System of the World Customs Organization, this article classifies 54 types of APEC green products with 6-digit customs tariff numbers, grouping them, respectively, into HS44 (raw bamboo, bamboo products, activated bamboo charcoal, healthy home, etc.), HS84 (clean household appliances, health food, pharmaceutical machinery, mechanical appliances and their parts, etc.), HS85 (clean household appliances, electrical equipment and parts, etc.), and HS90 (medical instruments, precision instruments and equipment, and parts and accessories of the above articles). The division of these four categories of products will be adopted for a detailed analysis of green trade. An online trade database (ITC Trade Map) was sifted through to gather information on four categories of product data. From the macrolevel, the list of environmental products can enhance the sustainability and high-quality development level of trade from the aspects of protecting the ecological environment, reducing trade friction, and improving the trade structure. At the microlevel, the list of

environmental products promotes the formulation, interpretation, and application of relevant policies, helps countries protect the environment and develop health industries, forms a virtuous circle of environmental, resource, economic, and social development, provides the public with more safe and harmless products, and improves public health. Combined with the APEC catalogue of environmental products with 54 six-digit tariff numbers in the above "APEC List of Environmental Goods" and based on the 2011–2018 trade data of each product in UN Comtrade, countries (regions) of green product trade are abstracted as nodes in this study, and 100 countries (regions) including mainland China and the US are selected as research objects. The import and export volume of green products in these countries (regions) accounted for 99.51% of the global total from 2001 to 2018; hence these countries could be deemed as highly representative samples. A 100 * 100 green product trade network matrix can be established by looking at the mutual trade flows of 100 countries (regions). The characteristics of the network could be analyzed with UCINET, and the network itself could be visualized by using Gephi. Additionally, social network analysis can be conducted by adopting the following methods:

- (1) Community detection: the clustering structure within the trade network can be identified by examining the actual trade flows between countries (regions), and the community detection method can be applied to analyze the topological relationship of the trade network [40]. A common application of community detection method adopted for the international trade network consists in assigning to countries (regions), intercountry (cross-region) trade links, and intercountry (cross-region) trade flows: the weights of nodes, connections, and peripheries in the trade network, respectively; and a module optimization algorithm is adopted for calculation [41].

$$Q = \frac{1}{2m} \sum_{i,j} \left[A_{ij} - \frac{k_i k_j}{2m} \right] \delta(c_i, c_j). \quad (1)$$

In equation (1), we find Q as modularity, and the higher the value of Q , the better the effect of clustering division; A_{ij} as the trade flow between countries (regions) i and j ; k_i and k_j , respectively, as the sum of all trade flows connected to countries (regions) i and j ; c_i and c_j as the community index of countries (regions) i and j ; $\delta(c_i, c_j)$ as indicating whether countries (regions) i and j are in the same community (if yes, the return value is 1; otherwise it is 0); m as indicating the sum of the trade flow of the entire network. The greater the value of Q , the greater the degree of modularity.

- (2) Centrality: this is a main index describing the control power of a node in the entire network. The degree of standardization is often adopted to eliminate the influence of the total number of nodes.

$$C_D(n_i) = d(n_i) = \sum_j X_{ij} = \sum_i X_{ji}, \quad (2)$$

$$C'_D(n_i) = \frac{d(n_i)}{g-1}. \quad (3)$$

In equation (2), we find $C_D(n_i)$ as the absolute degree of centrality of point i ; X_{ij} as 0 or 1, indicating whether any form of relationship exists between node j and node i ; g as the number of nodes in the network; in equation (3) we find $C'_D(n_i)$ as representing the degree of centrality after standardization. The degree of centrality includes two types, i.e., outbound and inbound, also known as outgoing and incoming types, with the former representing the connections emanating from a certain node which affect other nodes, and the latter, indicating the opposite, refers to those affected by other nodes. The outgoing type represents an economy's exports to other economies, and the incoming type represents an economy's imports from others [42].

- (3) Network density. This measures the degree of connection between network members. Network density actually refers to the closeness of trade activities between various countries in the trade network. The higher the value, the closer the trade exchanges between different countries.

$$\Delta = \frac{2L}{g(g-1)}. \quad (4)$$

In equation (4), we find L as the number of midlines in the network and g as the number of nodes in the network.

- (4) Dotted line rate: this indicator measures the average number of connections to each node in the network.

$$\beta = \frac{L}{g}. \quad (5)$$

- (5) The average length of the shortest paths: this measures the average of the number of edges that the shortest path passes between all pairs of nodes in the network.

$$B = \frac{2}{g(g-1)} \sum_{i=1}^g \sum_{j=i+1}^g d_{ij}. \quad (6)$$

In equation (6), d_{ij} indicates the number of edges traversed by the shortest path between node i and node j .

- (6) Clustering coefficient: this indicates the average probability that two nodes connected to the same node in the network are connected to each other.

$$CB_i = \frac{2L_i}{k_i(k_i-1)}, \quad i = 1, 2, 3, \dots, N. \quad (7)$$

In equation (7), L_i is the number of edges existing between the adjacent nodes of node i . This gives us

formula (8) for calculating the clustering coefficient C of the network:

$$C = \frac{I}{N} \sum_{i=1}^N CL_i. \quad (8)$$

- (7) Closeness centrality: this measures the degree to which a node is not controlled by other nodes on either side of a trade relation.

$$CC_i = \frac{(g-1)}{\sum_{j=i, j \neq i}^N d_{ij}}, \quad (9)$$

d_{ij} refers to the number of steps included in the shortest path between node i and node j .

- (8) Mediation centrality: this indicator measures the extent to which a node is located in the "middle" of other nodes, to reflect a country's channel control and intermediary capacity for energy flow in the trade network. Assuming g_{jk} as the number of shortcuts between node j and node k , and $g_{jk}(i)$ as the number of shortcuts between node j and k that passes through node i , then the capacity of node i to control the association of nodes j and k could be defined as $b_{jk}(i) = (g_{jk}(i)/g_{jk})$ [43].

$$BC_i = \frac{2 \sum_j^n \sum_k^n b_{jk}(i)}{N^2 - 3N + 2}, \quad j \neq k \neq i. \quad (10)$$

4. Analysis of Network Topology Evolution

Based on the 2001–2018 green product trade data in the UN Comtrade database, a 100×100 green product trade network matrix was constructed by examining the mutual trade flows of 100 countries (regions). UCINET was then used to analyze the characteristics of the network, and Gephi was adopted to visualize the green product trade network. The evolution characteristics and changing pattern of the topological structure of the global green product trade network from 2001 to 2018 were scrutinized, and the following conclusions could be drawn.

- (1) The network complexity has been ever growing, presenting the characteristics of a "small-world" network. First, trade links between countries (regions) are directly proportional to network density, network complexity, and dotted line rate (see Figure 1). Regarding the characteristics of network density changes, notably, the green product trade network density has increased annually, with the minimum value being 0.095 in 2001 and the maximum being 0.229 in 2017. From 2001 to 2018, the overall network density fluctuates and shows a general trend of gradual growth, before soaring dramatically in 2014 and finally landing between 0.21 and 0.22. An inspection of changes in the dotted line rate reveals that the minimum value appears in 2001 at 66.79; and henceforth, the rate shows a trend of gradual increase. A comprehensive comparison of

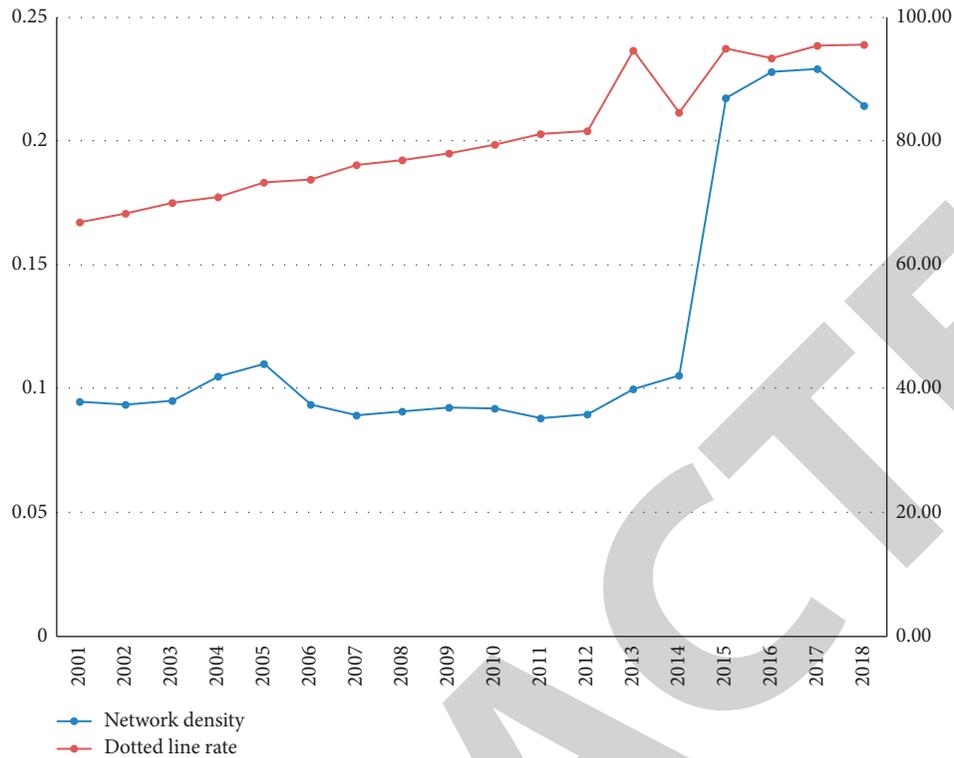


FIGURE 1: The evolution of global green product trade density and dotted line rate from 2001 to 2018.

network density and dotted line rate shows that the evolutionary trend of these two indicators has stayed basically the same from 2001 onwards, with a growth trend being present in both. This shows that the world's green product trade relations are gradually growing more complicated, with network connectivity gradually improving.

Second, although the clustering coefficient and the average shortest path length show opposite trajectories, these two indicators show that the clustering state of the network has gradually become more closely knit with time evolution since 2001, as evinced by the evolutionary trend of both measurements. Particularly, the clustering coefficient stands at a value of 0.83 in 2001, before gradually increasing to 0.96 in 2015 and dipping marginally after that (see Figure 2). This shows that the trade cooperation between countries has a tendency to decentralize.

Third, if the clustering coefficient of a network is of a considerable value and when the average shortest path length is small, this generally indicates that the network is endowed with the characteristics of a "small-world" (see Figure 2). The average shortest path length of the world's green product trade network is 1.21 at maximum, with the clustering coefficient at about 0.83. This shows that "small-world" features characterize the green product trade network.

- (2) The network shows a scale-free feature, and changes have already occurred in its import pattern. As an

important indicator reflecting the role of nodes in the network, centrality shows the relative importance of countries (regions) in the green product trade network. An examination of the time-series of the average value shows that it stands at only 64.99 in 2001 and grows to as high as 93.13 in 2015. The average degree is therefore shown to have increased by nearly a half amidst all the ups and downs (see Figure 3). Despite the slight fluctuations, however, it can be found from the changing pattern of the time-series that the influence and role of different countries (regions) in the global green product trade network have been increasing. Furthermore, it is evident from the degree distribution curve that the world's green product trade network in 2001 and 2018 conforms to the principle of power law distribution, indicating that the network is a scale-free one. The fact that the degree distribution curve in 2001 is under the 2018 curve indicates that the scale-free feature of the green product trade network has gradually strengthened over time (see Figure 4).

The degree of weighting in a trade network reflects an economy's diversification of import and export commodities and the diversified distribution of import and export regions [44]. Table 1 shows the global green product trade weighting degree and inbound/outbound degree. The top ten countries (regions) have changed significantly regarding the weighted inbound/outbound degree along with the elapse of time. The top three outbound countries in

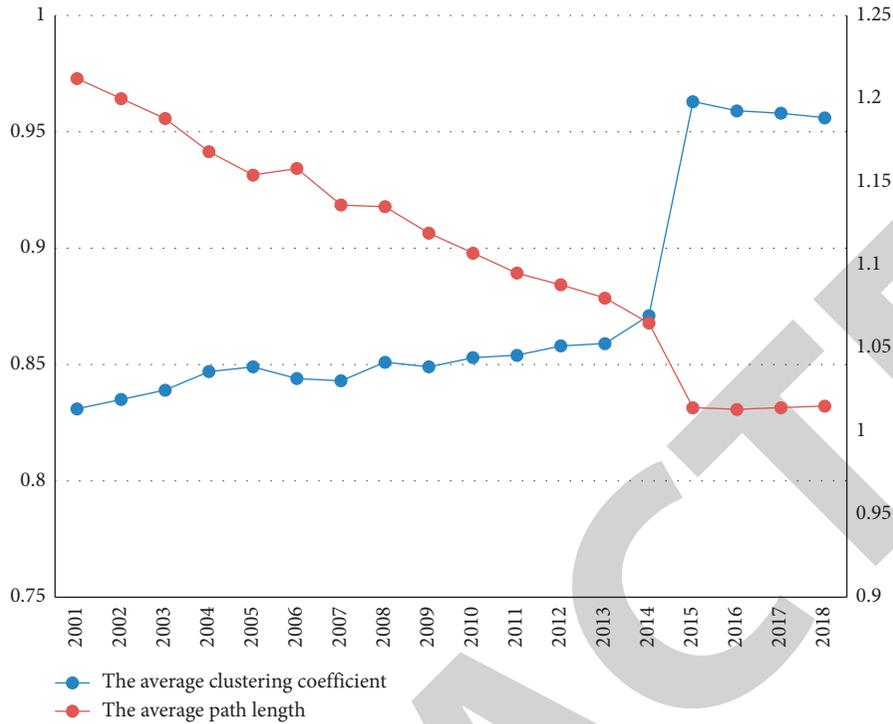


FIGURE 2: The evolution of global green product clustering coefficient and average shortest path length from 2001 to 2018.

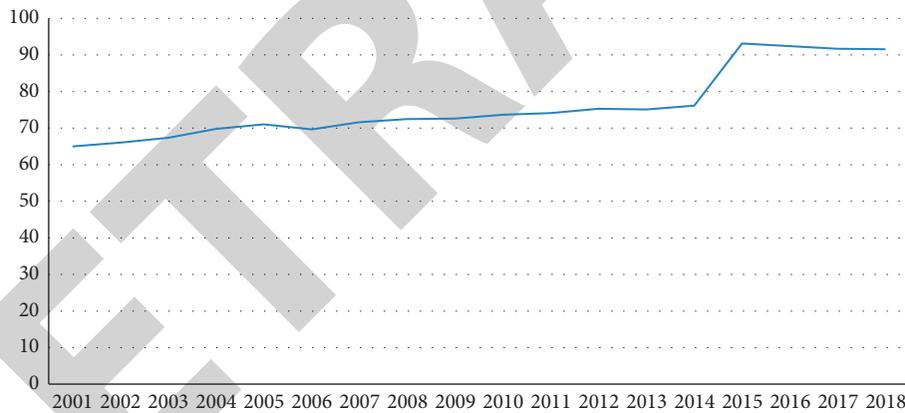


FIGURE 3: Evolution of the average degree of global green product trade from 2001 to 2018.

2001 were the US, Germany, and China, and the outbound top three were Serbia, Angola, and the US. China, the US, and Germany ranked as the top three for outbound in 2018, while the top three inbound changed to Panama, United Arab Emirates (UAE), and Egypt. Notably, in 2001, the average degree of mainland China did not enter the top three, but mainland China ranked first on this front in 2018. Second, an analysis of the geographical distribution of the top 10 countries (regions) in terms of weighted degree in 2001 and 2018 shows that the import pattern of the world's green products has changed along with the diversification of import and export countries (regions) and the diversification of products; the gravity of green product imports has shifted

from North America and East Asia to North America, Europe, and the Middle East, although the gravity of exports has not changed much.

- (3) The network is manifested as a “point-to-point” model, and the dependence and competition between countries (regions) are not obvious. Closeness centrality refers to the level at which a node is not controlled by the relationship, be it emanating or recipient, with another node, while mediation centrality denotes the level of control a node country (region) in the network has over resources [45]. These two indicators describe the pattern of green product trade to a sufficient extent. Despite certain fluctuations, closeness centrality shows a general trend of growth from 2001 to 2017 (see Figure 5).

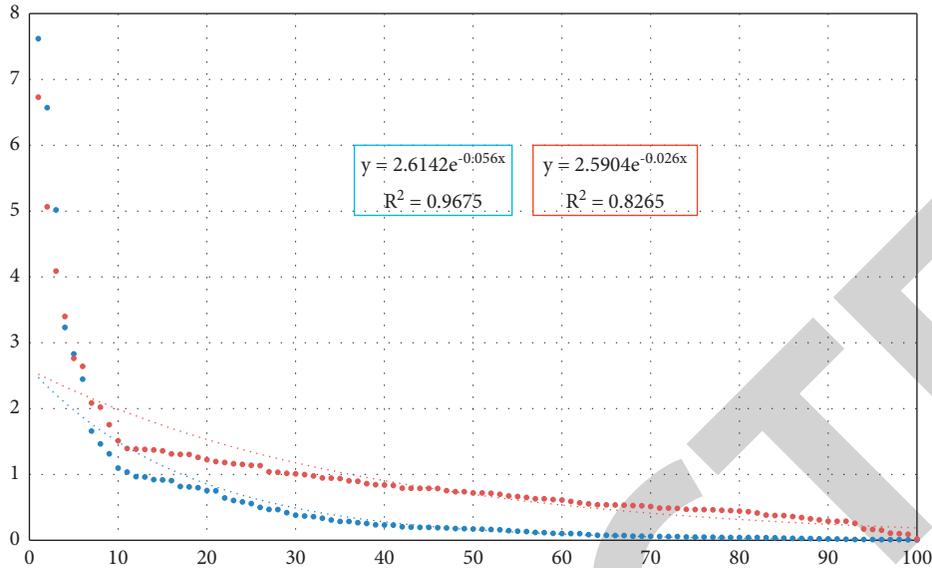


FIGURE 4: Degree evolution of global green product trade from 2001 to 2018.

TABLE 1: The distribution of the top 10 countries in terms of weighting degree and inbound/outbound degree.

2001					
Country	Degree of centrality	Country	Inbound	Country	Outbound
Serbia	7.618	Serbia	7.61	The US	4.955
Angola	6.57	Angola	6.569	Germany	3.095
The US	5.017	The US	3.807	China	2.61
Germany	3.232	Germany	2.09	Japan	2.369
China	2.829	Japan	1.894	Italy	1.478
Japan	2.446	The UK	1.065	The UK	1.302
Italy	1.657	Cyprus	0.963	France	1.22
The UK	1.462	Canada	0.856	South Korea	0.988
France	1.312	China	0.843	Singapore	0.811
Belgium	1.095	France	0.815	Canada	0.809
2018					
Country	Degree of centrality	Country	Inbound	Country	Outbound
China	6.729	Panama	5.004	China	6.69
Panama	5.064	UAE	2.904	The US	4.084
The US	4.088	Egypt	2.513	Germany	2.746
UAE	3.398	Indonesia	1.441	Russia	2.017
Germany	2.762	Saudi Arabia	1.391	Italy	1.507
Egypt	2.64	Morocco	1.2	Japan	1.391
Saudi Arabia	2.084	Greece	1.163	South Korea	1.373
Russia	2.02	Nigeria	1.08	France	1.301
Indonesia	1.754	Colombia	1.03	India	1.255
Italy	1.51	Portugal	1.017	Spain	1.192

Judging from the 2001–2017 results, the top 10 countries (regions) in 2001 were Japan, Belgium, France, Germany, Italy, the Netherlands, Switzerland, the UK, the US, and Canada; and the top 10 countries (regions) in 2018 were Turkey, China, Germany, Greece, Italy, Lebanon, Mexico, Morocco, Pakistan, and Portugal (Table 2). Evidently, over half of the above countries (regions) appear in the top 10 in terms of inbound or outbound degrees, which indicates that the trade model of the world’s green product trade network is characterized by a “point-to-point” pattern.

Mediation centrality has been on a declining spiral since 2001 (Table 2). The top ten countries (regions) pertaining to mediation centrality in 2001 were Turkey, China, Germany, Greece, Italy, Lebanon, Mexico, Morocco, Pakistan, and Portugal, while the top ten in 2018 were Turkey, Lebanon, Oman, Jordan, Chile, Colombia, Bahrain, Qatar, Kuwait, and Peru. A comparison of mediation centrality and outbound degree shows that there is no overlap in the top 10 countries in 2018, indicating that dependence and competition between countries are not significant in terms of green product relations.

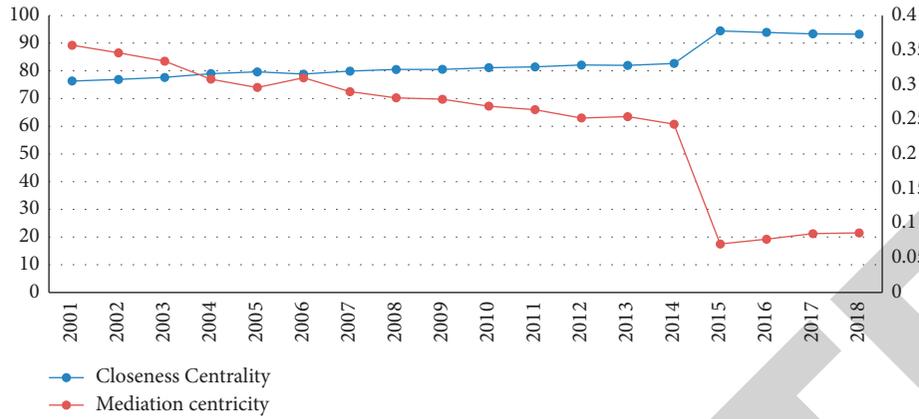


FIGURE 5: Evolution of closeness centrality and mediation centrality in the global green product trade network.

TABLE 2: Distribution of the top 10 countries in terms of closeness centrality and mediation centrality.

2001		2001	
Country	Closeness centrality	Country	Mediation centrality
Japan	100	Japan	1.67
Belgium	99	Belgium	1.103
France	99	France	1.103
Germany	99	Germany	1.103
Italy	99	Italy	1.103
The Netherlands	99	The Netherlands	1.103
Switzerland	99	Switzerland	1.103
The UK	99	The UK	1.103
The US	99	The US	1.103
Canada	98.02	Serbia	1.061
2018		2018	
Country	Closeness centrality	Country	Mediation centrality
Turkey	100	Turkey	0.272
China	99	Lebanon	0.265
Germany	99	Oman	0.231
Greece	99	Jordan	0.228
Italy	99	Chile	0.227
Lebanon	99	Colombia	0.224
Mexico	99	Bahrain	0.211
Morocco	99	Qatar	0.208
Pakistan	99	Kuwait	0.208
Portugal	99	Peru	0.205

(4) The spatial structure of the global green product trade network has shifted from a transcontinental “dual arch” model with the US at its core to a “transcontinental + intracontinental” and “multiarch” pattern with the US, Europe, and Asia at the center (see Figure 6). The topological structure of the global green product trade network as described above reveals that the US’s position in the network has declined, while

China’s position therein has continued to increase. As illustrated in Table 3, among the top 20 bilateral trade links for green products, those involving the US have dropped from 11 pairs in 2001 to 7 in 2018, while the bilateral links involving mainland China have increased from 2 in 2001 to 11 pairs in 2018; the bilateral trade pairs with European countries as participants have decreased from 8 in 2001 to 3 in 2018 (Table 4). The

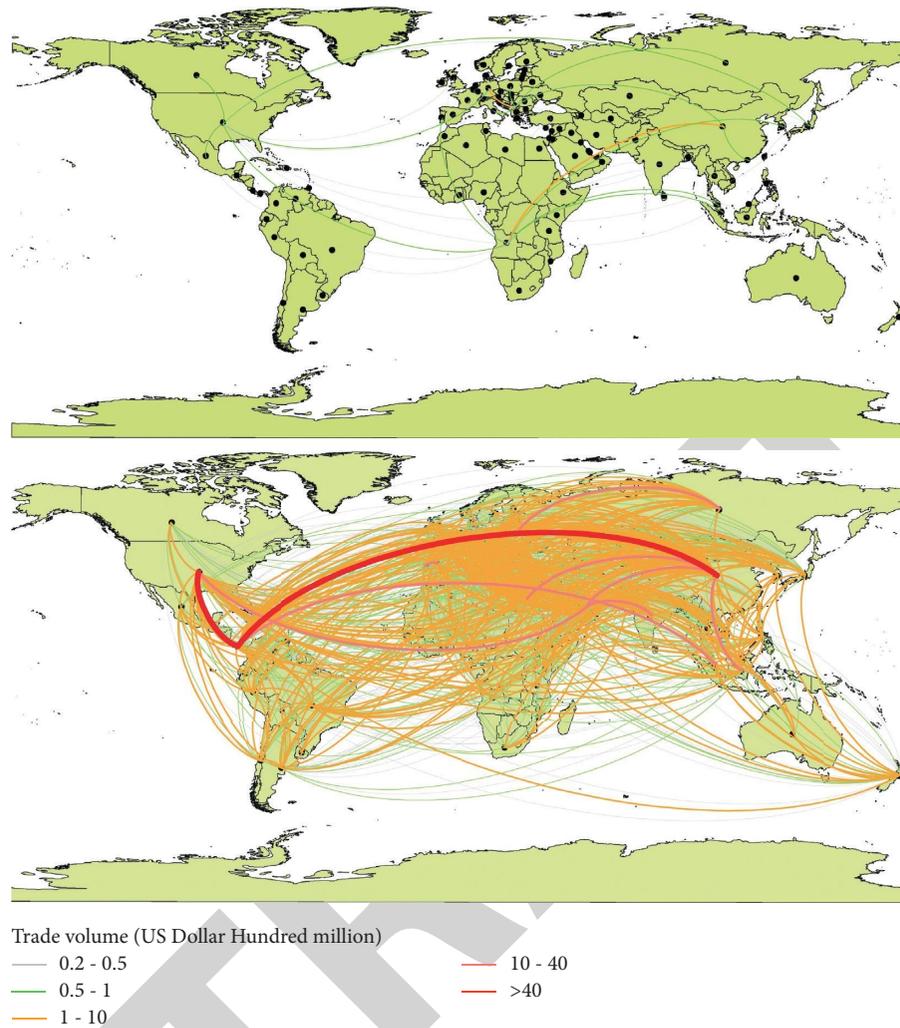


FIGURE 6: The spatial pattern of the global green product trade network in 2001 and 2018. Note: for a lucid representation of the dynamic evolution of the global green product trade pattern, this figure only includes network trade links with an export value of over US\$ 20 million.

TABLE 3: The division of global green product trade network clusters in 2018.

Cluster	Country/(region)
Cluster 1	China, UAE, Egypt, Saudi Arabia, Indonesia, Japan, South Korea, Vietnam, India, Kuwait, Philippines, Pakistan, Qatar, Iran, New Zealand, Jordan, Thailand, Oman, Ethiopia, Bahrain, Switzerland, Kenya, Malaysia, South Africa, Taiwan (China), Ghana, HK (China), Australia, Tanzania, Mozambique, Brunei, Venezuela, Sri Lanka, Syria
Cluster 2	Germany, Russia, Italy, Turkey, Greece, Nigeria, France, Morocco, Spain, Portugal, Ireland, The UK, Ukraine, Slovakia, Libya, Romania, Netherlands, Belgium, Bulgaria, Lithuania, Belarus, Lebanon, Serbia, Norway, Kazakhstan, Poland, Israel, Hungary, Croatia, Finland, Tunisia, Latvia, Estonia, Azerbaijan, Slovenia, Luxembourg, Cyprus, Iraq, Sweden, Czech Republic, Austria, Bosnia and Herzegovina, North Macedonia, Denmark, Algeria, Turkmenistan
Cluster 3	Panama, The US, Colombia, Brazil, Argentina, Peru, Chile, Singapore, Mexico, Dominican Republic, Ecuador, Angola, Guatemala, Costa Rica, Uruguay, Canada, Bolivia, Bangladesh, Trinidad and Tobago

most intense bilateral trade pairs were no longer between Western European countries, but occurring within Asia.

In 2001, the spatial structure of the global green product trade network took on a US–Europe intercontinental “dual arch” pattern with the US as the core. By 2018, however, the US–Europe intercontinental “arched”

structure had gradually declined, while the Asian intercontinental “arched” structure continued to develop. Meanwhile, the European “arched” structure had come to maturity. This shows that the intercontinental “dual arch” pattern centered on the US has changed to the “intercontinental + intracontinental” and “multiarch” pattern with Europe and Asia as the core.

TABLE 4: The top 20 global green product export links in 2001 and 2018.

Ranking	2001		2018	
	Export link	Export value	Export link	Export value
1	The US → Canada	58.15	South Korea → China	143.16
2	Japan → The US	57.19	Mainland China → HK, China	134.66
3	The US → Mexico	43.05	HK, China → Mainland China	129.23
4	Canada → The US	39.97	Japan → China	120.27
5	HK, China → Mainland China	35.80	Mexico → The US	115.50
6	The US → Japan	35.49	Taiwan, China → China	91.02
7	Mexico → The US	35.49	The US → Mexico	87.66
8	Japan → Taiwan, China	30.44	China → The US	86.99
9	Germany → The US	29.33	Germany → China	81.38
10	Japan → China	22.27	Germany → The US	76.54
11	The UK → The US	21.68	The US → Canada	71.42
12	The US → Germany	21.51	China → Japan	63.17
13	The US → The UK	18.95	Canada → The US	60.12
14	Japan → South Korea	18.64	Japan → The US	59.63
15	Germany → France	18.45	The US → China	53.81
16	The US → South Korea	18.12	China → Mexico	52.60
17	The US → Taiwan, China	17.51	South Korea → Vietnam	49.69
18	Germany → Italy	12.92	China → South Korea	45.97
19	Germany → The UK	12.30	China → India	45.45
20	Germany → Spain	12.13	Germany → France	42.12

(5) There are geographical and cultural affinities between countries within a cluster, and trade ties are closer for clusters centering around China. In complex networks, a community refers to a subset composed of nodes having a certain relationship with one another. Countries in the international trade network can be divided into multiple communities according to the closeness of cooperation. Nodes located within the same cluster are more closely related to each other, while nodes in different clusters are more sparsely connected [46]. The trade gravity model formation could, in general, explain trade clusters [47]. This study adopts the Gephi clustering algorithm and divides the global green product trade network in 2018 into three clusters. The division results are as follows (Table 3).

The Gephi clustering algorithm results reveal that cluster distribution is infused with obvious geographical and cultural characteristics, i.e., countries with geographical and cultural affinities tend to have closer green product trade links. This observation lends theoretical support to the promotion of green product trade and the reduction of trade distance.

China is geographically close to Southeast Asia and South Asia. Because of cultural similarities and convenient trade access, with China’s “One Belt, One Road” initiative, South Asia and Southeast Asia have become an important strategic zone for the “Silk Road Economic Belt” and the “21st Century Maritime Silk Road.” On the basis of political and economic cooperation, China and Southeast Asia have similar cultural backgrounds

and cultural identities, as well as countries’ increasing emphasis on the development of cultural industries. Asian countries such as Japan and those in Southeast Asia and South Asia including Malaysia and Indonesia are grouped into Cluster 1, with China as the trading center. UAE, Qatar, and Saudi Arabia are also classified into this cluster because of their close trade relations with Asian countries, especially with China. European countries such as Germany and France are put into Cluster 2 due to their geographical proximity and historical trade exchanges, which have generated close green product trade ties. Similarly, countries such as the US and Mexico are subsumed into Cluster 3 owing to their contiguosity and close trade relations (see Figure 7).

Cluster 1 has an internal network density of 0.0431, the highest in the entire network. This means Cluster 1, with China at the core, occupies an important position in the network. Cluster 1, to which China belongs, also had the highest share of green product exports in 2018, accounting for as high as 45% of the total. China ranked second (33%) in export volume of green products to Cluster 2 countries—including European countries such as Germany and France. The US and Mexico, among other countries, combine to form Cluster 3—ranking third with a 21% share.

Statistics further indicate that the main export destination of China’s green products includes countries in Southeast Asia. Additionally, China also exports numerous products to European countries. However, China’s exports of marine energy products to the Americas are relatively small—showing that the competitiveness of China’s green products in the region needs improving.

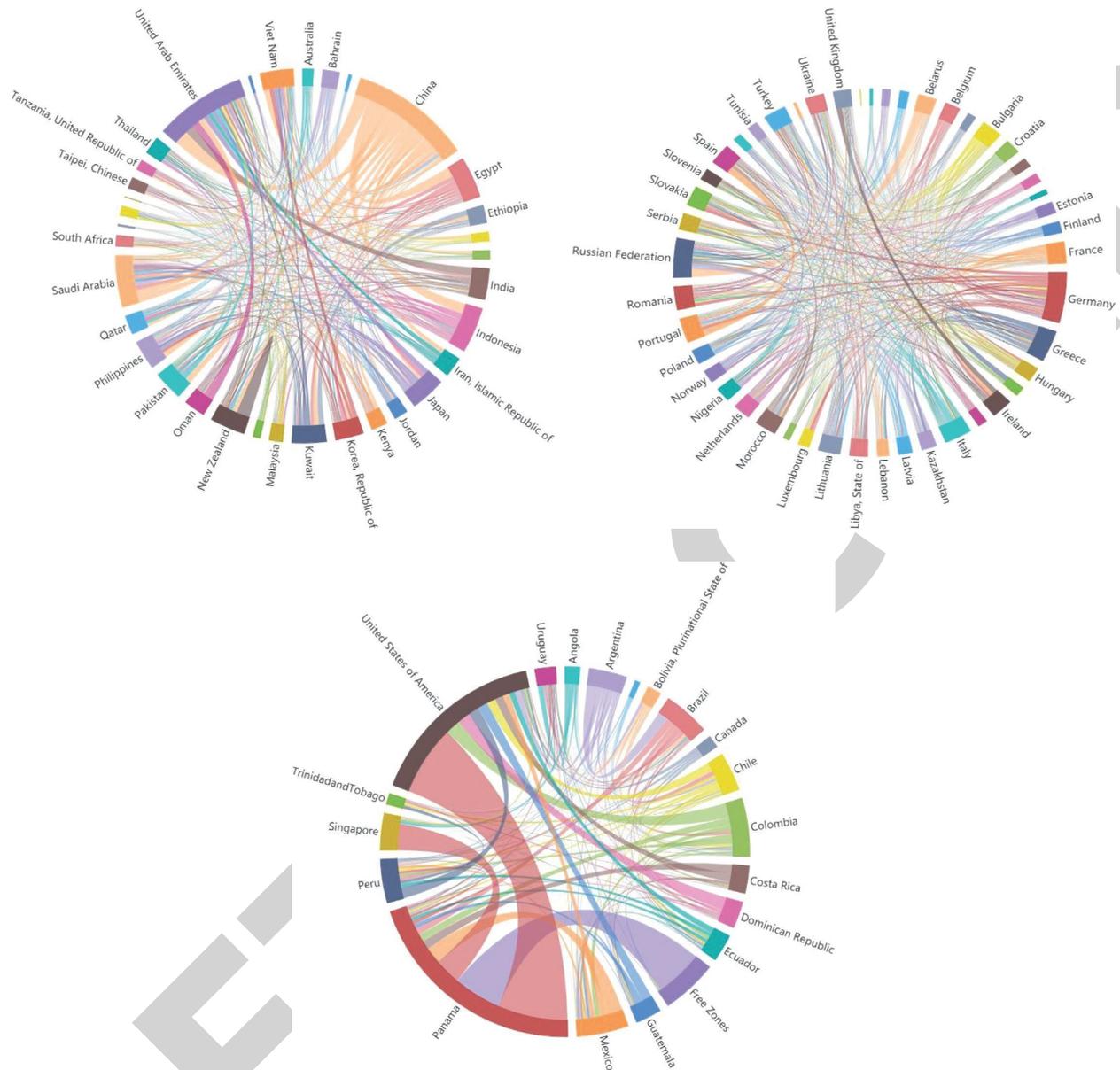


FIGURE 7: Network structure of the world's green product trading clusters.

5. Conclusion and Outlook

5.1. Conclusion. Big health industry is an industry that provides whole process and all factor products and services for human comprehensive physical and mental health. With the increasingly close relationship between health and environment, green products take into account the characteristics of environmental protection, resource intensification, safety, and health, so that the green product industry for the purpose of health and environmental protection has become an important branch of the big health industry. To give a clear portrayal of changes in the global green product trade system, this study

derives relevant trade data from the World Bank and the UN Comtrade and by analyzing the spatiotemporal evolution characteristics of the global green product trade pattern from 2001 to 2018 it explores the product structure and status changes of countries (regions) in the global trading system for green products. Research findings: The closely connected global trade network for green products continues to expand. This is a typical network comprising “smaller worlds”; the focus of green product exports has largely stayed unchanged, while imports are shifting from North America and East Asia towards North America, Europe, and the Middle East; the trade network adopts a “point-to-point” model, with no obvious interdependence and

competition between countries (regions); the spatial structure of the network shows a transition away from the original transcontinental “dual arch” pattern with the United States at the core towards a “transcontinental + intracontinental” one characterized by the coexistence of “multiple arches” centering around Europe and Asia; furthermore, geographically proximate and culturally similar countries are prone to have closer trade ties. By clarifying the global trade network of green products industry under the background of big health industry, it will help to deepen the understanding of the relationship between participating countries, promote the long-term and stable development of national health industry trade, provide the public with more safe and harmless products, better meet the global public’s health needs, and effectively enhance the sustainability of public health.

The results of this paper show that green trade liberalization is conducive to the health level of global residents to a certain extent, and this impact will increase with the improvement of the centrality of green trade network. And this paper believes that the green trade network affects the health level of residents in various countries through environmental protection technology and environmental effects. In general, the green trade network has an important impact on the development of big health industry. It is necessary to optimize the green trade network structure to better meet people’s growing demand for healthy life.

5.2. Theoretical Contribution. As the development of health industry has gradually become a global consensus, seizing the division of labor in the global health industry chain through various subdivided industries has become an important strategic means for countries to actively integrate into the global innovation chain and value chain. As a subindustry of health industry, green products have the advantages of improving the environment, promoting industrial economy, and promoting national health. It is of great and far-reaching significance for countries to attain high-quality development of trade, sustainable development, and healthy industrial structure upgrading by endorsing green consumption and green investment and improving green industries layout. Given the complex global economic landscape at present, counter-globalization and a new wave of trade protectionism gaining traction, green product trade therefore also stands to be impacted. It will be beneficial for us to conduct an in-depth analysis of the global trade network of green products to endorse green product trade, improve China’s trading quality, and optimize China’s green products governance. To rationally calibrate the orientation of China’s green product policies, improve imports and exports quality, and optimize green products governance, this article intends to answer the following two questions: First, how has the product structure of the world’s green trade changed? Second, what changes have taken place in the network topology of the world’s green product trade? Is it characterized by “small-world” and scale-free features? What is the relationship between competition and cooperation between different countries? What are the characteristics of the distribution and spatial pattern of trade clusters?

This article proposes from the perspective of complex networks “small-world” and “scale-free” features of global green products and assumptions about the shift in the gravity of imports and exports. It is also assumed that there is a relationship of dependence and competition regarding green products between countries and regions. The results of the analysis verify part of the hypothesis that the global green product trade network continues to expand and is closely connected. It is a typical “small-world” network, although the export gravity has changed a little, and imports have been gravitating towards North America, Europe, and the Middle East, instead of only concentrating on North America and East Asia as has been witnessed before. Meanwhile, the network manifests a “point-to-point” model, while the dependence and competition between countries (regions) are not obvious. This article also proposes the reconstruction of the global green product trade network spatial pattern, and the assumption about the gravitational pull of Asia can be verified through social network analysis. A social networks analysis has shown a transition from a transcontinental “dual arch” pattern, with the US as the core to a “transcontinental + intracontinental” and “multiarch” pattern with Europe and Asia as the core. Finally, the analysis results have verified the assumption that the global green product trade network has formed trading clusters centered around China and that geographical and cultural factors are important to the clusters.

Through the above conclusions, this paper reveals the temporal and spatial pattern evolution characteristics of global green product trade under the background of big health industry and verifies and explains the changes of characteristics from different angles. The research conclusion can provide a reference for the adjustment of China’s green product import and export policy, looking for a breakthrough in the development of emerging markets, and seizing the division of labor in the global health industry chain. This is also a useful exploration for the exchange and cooperation of green products for other countries and the common development of trade clusters. This study also plugs the gaps in previous studies on the temporal and spatial evolution of green trade under the background of big health industry and for the first time answers questions about green product trade clusters, spatial patterns, and shifts in import and export structures. Thus, this is a meaningful discussion both theory-wise and practice-wise.

On the whole, this article has two new angles when compared with the existing research results: on the one hand, this study seeks to investigate the subject from a new perspective. The existing research mostly discusses the development status of the green trade industry, trade potential, among others; there is little literature that pays attention to the temporal and spatial evolution of import and export trade of green products such as raw bamboo, bamboo products, activated bamboo charcoal, healthy home, pharmaceutical machinery, clean household appliances, medical devices, and precision instruments, and the macro-trend control of temporal and spatial pattern has important reference value for the import and export of green products in the health industry. Conversely, this study adopts novel

applications of research methods and draws on the social network analysis method to analyze the green product trade network—a first attempt of this kind in the green product industry. Not only has this method expanded the application of network analysis scope, but also the status quo of green trade networks in various trading countries (regions) will be analyzed in a more lucid fashion. Finally, the current global economic situation is complex, the trend of antiglobalization and new trade protectionism is on the rise, and the development of health industry is also affected by the international situation. In the context of health industry, in-depth analysis of the trade network of global green product sub-industries and clarification of the characteristics of network structure will help deepen the understanding of the relationship between participating countries, provide decision-making suggestions and opinions for trade exchanges, form stable and long-term trade relations, and finally promote the development of national health industry and better meet the global public health needs, effectively enhancing the sustainability of public health.

5.3. Limitations and Future Research Possibilities. Compared with previous studies, this paper analyzes the network structure evolution of global green product trade under the background of big health industry for the first time, puts forward corresponding evolution questions under the combing of relevant theoretical basis, discusses the evolution characteristics of global green product trade from the perspective of complex network, and summarizes relevant evolution conclusions. However, due to the availability of data, this paper only takes the sample data of 54 environmental products related to the health industry listed in the APEC list of environmental products as an example and does not involve the data of other similar products under the health industry. This deficiency needs to be further made up in the follow-up research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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