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RESEARCH ARTICLE

Investigating Characteristics and Influence Mechanism of Value-Added Trade Network of Producer Services

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ABSTRACT The process of economic globalization and the deepening of industrial division of labor increases the flow frequency of producer services between countries and regions, which affects the industrial upgrading and economic system construction. Producer services industry is an important engine of future world economic development. Understanding the evolution of its value chain network plays a significant role in clarifying a country's position in the division of labor system and carrying out global early warning and prevention. The traditional statistical caliber ignores the trade of intermediate goods generated by global piecemeal production, which is prone to misjudge the real trade pattern. Therefore, from the perspective of global value chain (GVC), this paper constructs the global value network of producer services by adopting value-added accounting method and complex network analysis, and explores its structural characteristics and the determinants of the network hub status of various countries, so as to reveal the real benefits and international status of each country in the pattern of producer services trade. There are several findings yielded from this study as well. Firstly, domestic value-added (DVA) absorbed abroad and foreign value-added (FVA) contribute the most to the growth of producer services trade. Both the breadth and depth of trade in DVA network and FVA network have developed evidently, which helps countries to extend the length of production and the degree of embeddedness in the value chain. Secondly, the community distribution of value-added trade network of producer services shows regional characteristics, which can also break through the constraints of geographic location, and the change of community is in line with the trend of globalization. China's enhanced status in the trade network enables it to participate in more links of the global value chain, which dilutes the leading ability of western economies such as the United States and Germany in the producer services trade. Finally, economic scale, physical capital and infrastructure can significantly improve a country's position in the value-added trade network of producer services. In the case of conditional distribution, technological innovation and regional trade agreements also play a positive role. Based on this, we propose that countries should strengthen the construction of digital infrastructure and implement diversified and open strategies to enhance the network status of their producer services in the global value chain.

INDEX TERMS Global value chain, producer services, value-added trade, complex network.

I. INTRODUCTION

Global value chain (GVC) has broken the traditional production process of ''national manufacturing'', and the international division of labor has been transformed from ''intra-industry'' to ''intra-product''. With the help of global value chain, the production process can be jointly completed by different countries and regions, and intermediate trade has become the mainstream international trade mode [1], [2], [3]. Producer services industry, a service sector derived from

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the manufacturing industry, plays an important role in the intermediate links of the value chain. It is the bridge for human, technology, knowledge and other capital to integrate into the production sequence. It is not only a critical source to realize the value-added of product value, but also the main segment of product differentiation and enterprise survival competition [4], [5], [6].

The perspective of GVC is characterized by value-added trade, which avoids the problem of double calculation due to ignoring the composition and flow of value-added and intermediate trade in the traditional accounting framework, and has gradually become a hot issue in the field of international trade. The concept of GVC was first defined by Krugman and Venables [7]. Hummels [8] pointed out vertical specialization index and proposed the HIY method based on input-output table to calculate the value chain. Later, Daudin [9] developed the DRS method to analyze the distribution of value-added of final product production in various countries. Koopman [10] built the ICIO database on the basis of HIY and DRS methods, decomposed the export value-added of various countries under a unified analytical framework, and evaluated the position of a country or region in the global value chain. Wang [11] further improved the GVC decomposition framework of industrial and bilateral sectors based on the study of Koopman's model, and more generally formed the theory of value-added accounting from the level of global value chain. Due to the more obvious characteristics of fragmentation and modularity in the production process of manufacturing industry, the research results on the status climbing and restructuring of manufacturing global value chain are relatively abundant [12], [13], [14]. By investing producer services activities in the production of manufacturing industry, more service value-added is included in its indirect export, thus improving the position of enterprises in GVC. It can be seen that service, as an adhesive, plays a vital role in coordinating the various links of GVC. This also attracts some scholars to study the global trade pattern of service industry by using trade decomposition frameworks such as KPWW and WWZ [11]. Chen [15] took Taiwan and South Korea as examples to discuss value-added of service industry, emphatically analyzed their bilateral trade with China, and found that the proportion of value-added of Taiwan's intermediate goods exported to China lags behind that of South Korea. Eduardo [16] estimated the value-added of services contained in export goods of different Latin American countries by using interregional input-output analysis. As a core sector in the service industry, the research on the global value chain of producer services is still in the development stage. Cheng [17] discussed whether the producer services industry has cost disease in the context of global value chain, and found that the competition of global value chain has led to the diffusion of producer services industry and the improvement of productivity, thus reducing the supply cost of the industry. Claudio [18] used the world input-output table to expand the subsystems set up in many countries, and found that the specialization degree of producer services in the manufacturing subsystem was getting higher and higher. Therefore, manufacturing servitization is an important content to study the participation of producer services in GVC [19].

When analyzing international trade issues with the help of complex network method, many studies are carried out from the trade in goods and services such as virtual water trade and waste copper trade [20], [21], [22], [23]. However, in fact, this method is quite consistent with the analysis of global value chain, which focuses on the industrial association between countries. The status of a country in the global division of labor system needs to be identified through its interaction with other countries in the relationship network, which is also in line with the characteristics of complex network analysis taking ''relevance'' as the research object [24], [25]. Global value chain distinguishes the international trade network from the gross value framework, the input-output method is used to decompose the value-added trade links between countries. The obtained value-added network can better reflect the value flow pattern in the international division of labor composed of the value creation, flow and distribution activities of countries or industries [26], [27], [28], [29]. Sui [30] compared the structural evolution of trade network and value-added trade network along the ''Belt and Road'', and revealed the dynamic characteristics of the actual trade pattern. Wang [31] constructed total exports (TEX), domestic value-added (DVA) and foreign value-added (FVA) networks in manufacturing, and revealed the impact of regional trade agreements on manufacturing value-added trade by using QAP method. Wu [32] further decomposed the domestic value-added of exports, constructed the global energy trade domestic value-added network and three sub-networks, and analyzed their characteristics and driving factors. Yao [33] adopted WWZ decomposition accounting method and complex network method to analyze the topological structure and evolution characteristics of value-added trade network in the service industry. However, the existing literature has not demonstrated the value-added trade network of producer services in detail.

In view of this, this paper uses the world input-output table data and WWZ value-added accounting method to study the features of global value network of producer services. On the one hand, we can more accurately reflect the real gains of producer services trade and identify the flow and direction of different value sources to effectively overcome the misjudgment caused by direct trade volume. On the other hand, we can measure the relative positions of countries in the value-added trade network of producer services from multiple perspectives to comprehensively evaluate their international status in the global division of labor system and enhance their voice and international influence. The main contribution of our research lies in the following three aspects. First of all, this paper presents the actual picture of international trade in producer services from the perspective of global value chain by absorbing the latest achievements of value-added accounting. Secondly, this paper uses complex network method to construct domestic value-added network

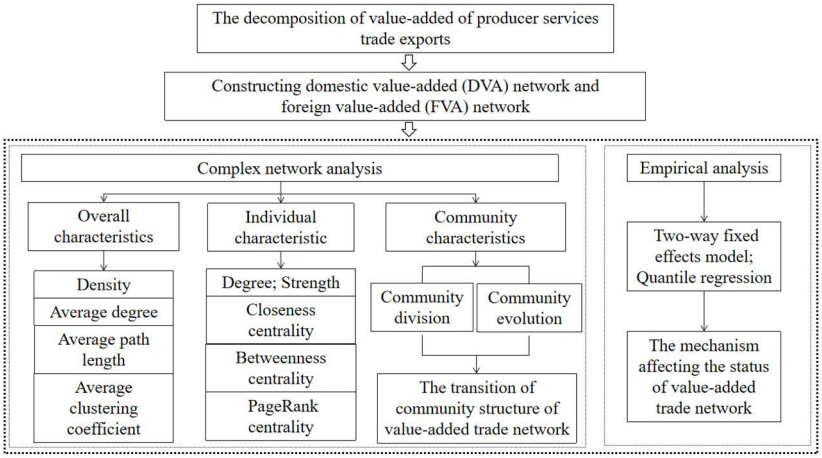


FIGURE 1. The flow chart of the research framework.

TABLE 1. The fifteen producer services sectors involved in this paper.

No.	Service	No.	Service
c28	Wholesale and retail trade and repair of motor vehicles and motorcycles	c40	Computer programming, consultancy and related activities; information service activities
c29	Wholesale trade, except of motor vehicles and motorcycles	c41	Financial service activities, except insurance and pension funding
c31	Land transport and transport via pipelines	c42	Insurance, reinsurance and pension funding, except compulsory social security
c32	Water transport	c43	Activities auxiliary to financial services and insurance activities
c33	Air transport	c45	Legal and accounting activities; activities of head offices; management consultancy activities
c34	Warehousing and support activities for transportation	c47	Scientific research and development
c35	Postal and courier activities	c48	Advertising and market research
c39	Telecommunications		

and foreign value-added network, and analyzes its structural evolution from three dimensions of whole, individual and community. Finally, the econometric model is used to analyze the driving factors affecting the pivotal position of countries in the trade network, which provides a theoretical basis for a country to realize local upgrading and power governance in the global trade pattern.

The rest of this article is arranged as follows. Section 2 is the data sources and decomposition of value-added trade. Section 3 shows the results of network analysis and influencing factor analysis. Section 4 is the conclusion and policy.

II. DATA SOURCES AND RESEARCH METHODS

A. DATA DESCRIPTION

The flow chart of this paper is shown in Figure 1. We use the newly released input-output table of the WIOD Database to calculate value-added trade, which includes data from 56 industrial sectors in 43 countries and regions from 2000 to 2014. According to the division of services trade by the United Nations and the definition of producer services in WIOD database by Huang [34], the producer services investigated in this paper are 15 sectors in the world input-output table, as shown in Table 1.

B. RESEARCH METHODS

1) THE DECOMPOSITION OF VALUE-ADDED OF PRODUCER SERVICES TRADE EXPORTS

Using the WWZ theoretical framework [11], this paper decomposes the total export of producer services trade into the following parts: Domestic value-added (DVA), including domestic value-added of final exports (DVA_FIN), intermediate exports absorbed by the direct importing countries (DVA_INT), intermediate exports absorbed by exports produced by direct importing countries to third countries (DVA_INTREX); Domestic value-added returned and absorbed by home country (RDV); Foreign value-added (FVA), including value-added of importing country implied in exports (MVA), value-added of third country implied in exports (OVA); Pure double counted item (PDC), including domestic pure repeat calculation (DDC) and foreign pure

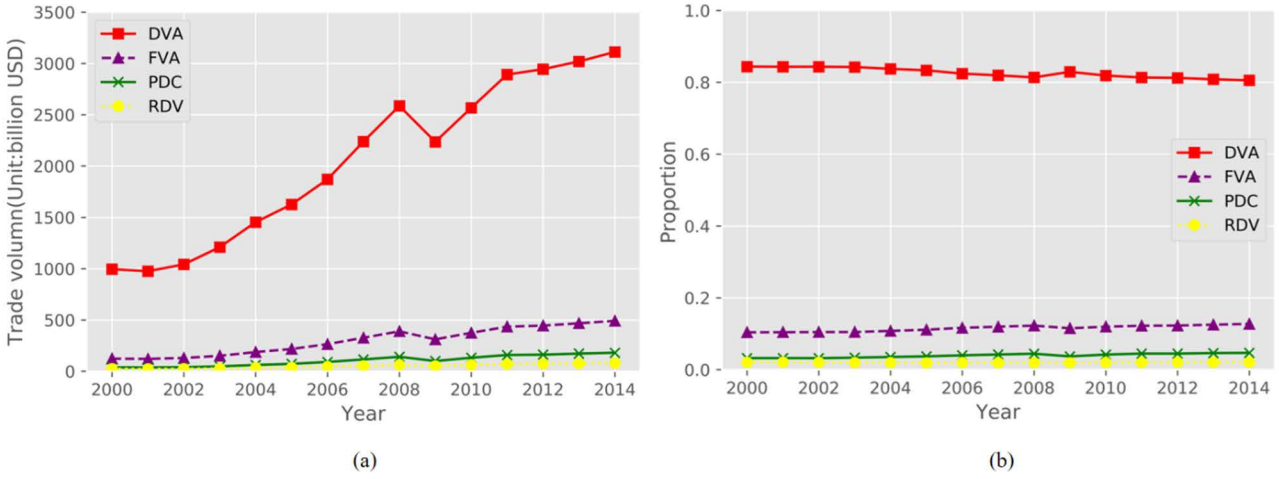


FIGURE 2. Decomposition of value-added of producer services trade. (a) Value-added scale of each part. (b) Value-added proportion of each part.

repeat calculation (FDC). Each part satisfies the formula:

$$DVA = DVA_{FIN} + DVA_{INT} + DVA_{INTREX} \quad (1)$$

$$FVA = MVA + OVA \quad (2)$$

$$PDC = DDC + FDC \quad (3)$$

Figure 2(a) shows the size and variation of each component of producer services export trade, and Figure 2(b) reveals the proportional composition of value-added. According to the decomposition results, the value-added of global producer services showed a trend of steady increase in other years, except that the impact of the financial crisis caused a significant decline. Meanwhile, DVA accounted for more than 80% of the export value-added of producer services trade, followed by FVA, while RDV and PDC had a smaller proportion. DVA and FVA are the main components in the decomposition of producer services trade, and DVA is a direct source of profits for a country to participate in international trade. FVA is an important symbol of a country's integration into the global value chain and international division of labor. Therefore, this paper focuses on these two types of value-added trade to investigate the basic pattern and evolution of producer services trade.

The further decomposition results of DVA, FVA and PDC are shown in Figure 3, the variation trend of added value after decomposition was the same as that of the whole. The domestic value-added of final export and the intermediate export absorbed by the direct importing country are the main parts of DVA. Implicit third country value-added in exports and foreign double counting account for a large proportion of FVA and PDC, respectively. This shows that the foreign value-added in producer services exports mainly comes from other economies other than the direct importing countries, and the international division of production is significantly higher than the domestic division of production.

2) NETWORK CONSTRUCTION

Based on the decomposition result of value-added trade, domestic value-added export and foreign value-added export are the most important two parts. Therefore, taking countries and regions involved in value-added trade as nodes and their trade relations as edges, the weighted directed DVA network and FVA network are constructed to investigate the evolution of value-added trade network of producer services from the perspective of global value chain. At the same time, we use the threshold method adopted by Amador & Cabral [26] for reference to binarize the network, and set the thresholds of DVA and FVA networks as 100 and 20 million US dollars, respectively. The network trade volume after taking the threshold over the years accounts for more than 90% of the corresponding all-unicom network trade volume, indicating that the network after extracting the threshold is representative.

3) NETWORK INDICATORS

On the basis of constructing the value-added trade network of producer services, the following indicators are used to describe its topological characteristics from the three dimensions of the whole, individual and community.

a: DENSITY

$$D = L/(n(n-1)) \quad (4)$$

where L is the actual number of edges in the network, and n is the actual number of nodes.

b: AVERAGE DEGREE

$$\langle k \rangle = \frac{1}{n}\sum_{i=1}^{n} k_i \quad (5)$$

where k_i represents the degree of node i.

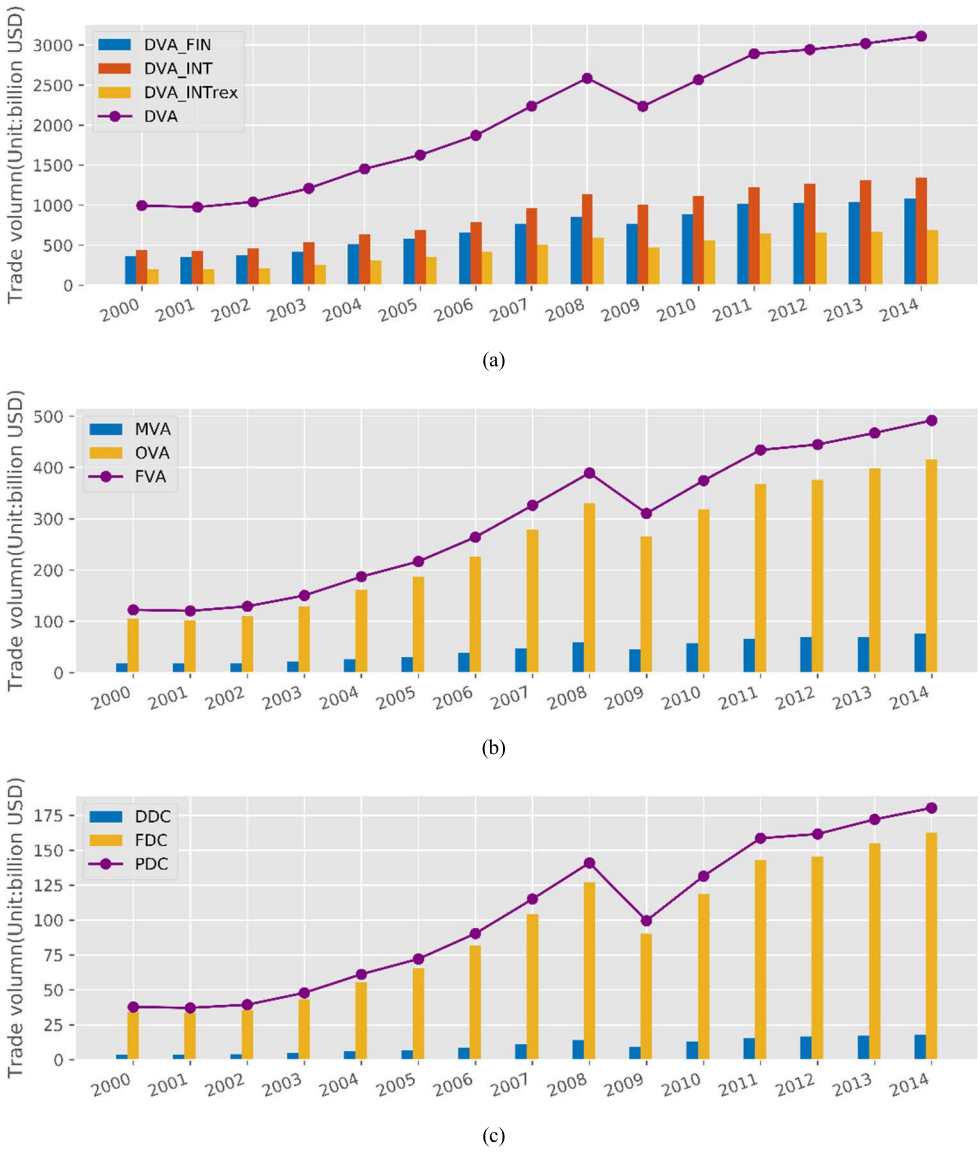


FIGURE 3. Decomposition results of DVA, FVA and PDC of producer services trade. (a) The decomposition of DVA. (b) The decomposition of FVA. (c) The decomposition of PDC.

c: AVERAGE PATH LENGTH

$$l = \frac{\sum_{i,j} d(i,j)}{n(n-1)} \tag{6}$$

where $d(i,j)$ represents the shortest distance between any two nodes.

d: AVERAGE CLUSTERING COEFFICIENT

$$\overline{C} = \frac{1}{n}\sum_{i=1}^{n} \frac{e_i}{k_i(k_i-1)} \tag{7}$$

where e_i is the number of edges between k_i neighbors of economy i.

e: NODE CENTRALITY

Centrality is the core index to measure the criticality of nodes, including node degree, node strength, closeness centrality, betweenness centrality and PageRank centrality.

First, the node in-degree k_i^{in} and out-degree k_i^{out} are defined according to the direction of edges:

$$k_i^{out} = \sum_{j=1}^{n} a_{ij} \tag{8}$$

$$k_i^{in} = \sum_{j=1}^{n} a_{ji} \tag{9}$$

If there is a trade relationship between node i and j, $a_{ij} = 1$, otherwise $a_{ij} = 0$.

Second, the node in-strength S_i^{in} and out-strength S_i^{out} are defined as:

$$S_i^{out} = \sum_{j=1}^{n} a_{ij} w_{ij} \tag{10}$$

$$S_i^{in} = \sum_{j=1}^{n} a_{ji} w_{ji} \tag{11}$$

Third, closeness centrality is expressed as:

$$C_{(c)i} = \frac{1}{\sum_{i \neq j}^{n} d(i,j)} \tag{12}$$

Fourth, betweenness centrality is defined as:

$$C_{(b)i} = \frac{2}{(n-1)(n-2)} \sum_{p=1}^{n} \sum_{q=1}^{n} g_{pq(i)} / g_{pq} \quad (i \neq p \neq q; p = 1, 2, 3, \ldots, n; q = 1, 2, 3, \ldots, n) \tag{13}$$

where g_{pq} represents the shortest path between nodes p and q, and $g_{pq(i)}$ is the shortest path from node p to q through node i.

Fifth, PageRank centrality holds that the significance of nodes depends on the number and quality of neighbor nodes, that is, the weighted combination of the importance of nodes pointing to it. The measure of PageRank index needs to be iterated continuously through the correction rules to make it converge to a stable value. The initial state requires that the PageRank(0) value of all nodes meet $\sum_i PageRank(0)_{it} = 1$, where i stands for nodes in the network, and t represents the time. The PageRank value of the step k of the iteration is obtained by modifying the PageRank value of the step $k-1$. The specific calculation formula is:

$$PageRank(k)_{it} = \alpha \sum_{j=1}^{n} \overline{a_{ji}} \frac{PageRank(k-1)_{jt}}{out\ \deg ree_{jt}} + \frac{1-\alpha}{n} \tag{14}$$

The PageRank centrality is set with a scale constant α between [0,1]. Following Brin and Page [35], α is set as 0.85. $\overline{a_{ji}}$ is the element in Google matrix A^t. $out\ \deg ree_{jt}$ is the out-degree centrality of country j in year t,and n is the number of nodes in the network. The larger the PageRank index, the stronger the country's leading ability in the network.

f: TRADE COMMUNITY DIVISION

Modularity is not only an effective method to estimate the structural strength of complex network community, but also an index to measure the quality of network community division [36]. This paper adopts the Fast Unfolding algorithm to calculate the community modularity. The main goal of this iterative algorithm is to continuously divide communities so that the modularity of the entire network after division continues to increase [37]. The calculation formula is:

$$Q_w = \frac{1}{\sum_{ij} w_{ij}} \sum_{ij} [w_{ij} - \frac{s_i s_j}{\sum_{ij} w_{ij}}] \delta(C_i, C_j) \tag{15}$$

where s_i and s_j represent the strength of node i and j, and w_{ij} is the edge weight of node i and j in the network, C_i and C_j refer to the communities of node i and j. If node i and j are in the same community, $\delta(C_i, C_j)$ is 1, otherwise 0. The value of Q ranges from $[-0.5,1]$. The higher the value of Q, the higher the degree of modularity.

III. RESULTS AND ANALYSIS

A. HIERARCHICAL DIVISION OF VALUE-ADDED TRADE NETWORK OF PRODUCER SERVICES

According to the strength of countries (regions), PAJEK's hierarchical clustering algorithm is used to identify the hierarchical level of value-added trade network of producer services. After obtaining the hierarchical files, they are converted into partition files and imported into VOSviewer in 2D format for visualization. The results are shown in Figure 4.

Figure 4 shows that from 2000 to 2014, DVA network gradually developed from single core circle layer structure to multi-core circle layer structure, the hierarchical pyramid structure emerged, and the node size was directly proportional to the strength. In 2000, only the United States was at the core, which was the global leader in the value-added trade of producer services. The United Kingdom, Canada and other European and American countries, as well as Japan in East Asia, constituted the second echelon of DVA network. Germany, France, the United Kingdom and the Netherlands jumped from the semi-periphery layer to the core layer in 2014. China, which was at the periphery layer in 2000, also climbed to the core layer of DVA network with the increase of trade scale, which is closely related to the rapid development of China's producer services industry and its growing importance in trade activities.

FVA network showed a more notable multi-level structure. From 2000 to 2014, the "core-edge" structure evolved from three levels into four levels, with the United States maintained at the center. Countries in the middle circle, such as the United Kingdom and France, were the ties of the FVA network, which inherited core nodes and other marginal nodes from top to bottom. China and Ireland have significantly improved their hierarchical status and gradually became the major participants in the global value chain.

B. THE OVERALL CHARACTERISTICS OF VALUE-ADDED TRADE NETWORK IN PRODUCER SERVICES

The number of nodes and edges, network density and average degree are used to describe the basic integrity characteristics of the network. The results are shown in Table 2.

The number of nodes and edges manifests the scale evolution of DVA network and FVA network. It can be seen that the number of countries and regions participating in the network was stable but kept rising, and the scale of the two networks has expanded. Due to the impact of the financial crisis and the spread of the sovereign debt crisis in the Eurozone, the number of value-added trade relations of DVA network and FVA network declined significantly from 2008 to 2009 and after 2011, they showed a similar trend of first increasing and then decreasing. The density and average degree of the DVA network of producer services export were higher than that of the FVA network. The fluctuations of the two networks were similar, but the DVA network was denser than the FVA network. The change range of the average degree of FVA network over the years was greater than that of DVA network,

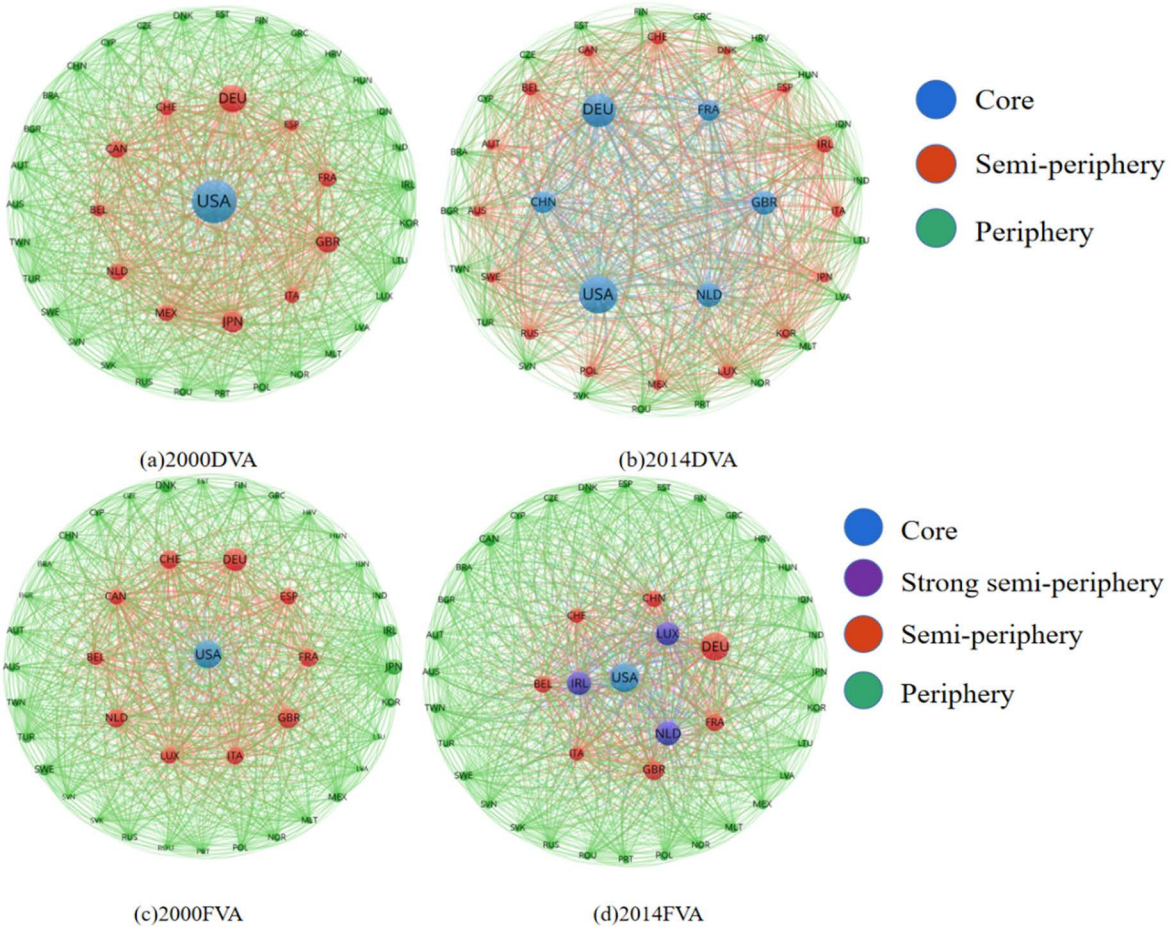


FIGURE 4. Hierarchical structure of value-added trade network for producer services.

TABLE 2. Scale and closeness of the value-added trade network in producer services.

Year	DVA				FVA			
	No.nodes	No.edges	Density	Average degree	No.nodes	No.edges	Density	Average degree
2000	41	505	0.3079	24.634	39	382	0.2578	19.590
2001	41	500	0.3049	24.390	39	366	0.2470	18.769
2002	41	523	0.3189	25.512	40	395	0.2532	19.750
2003	42	597	0.3467	28.429	41	465	0.2835	22.683
2004	43	658	0.3643	30.605	42	535	0.3107	25.476
2005	43	709	0.3926	32.977	42	584	0.3391	27.810
2006	43	744	0.4120	34.605	43	633	0.3505	29.442
2007	43	832	0.4607	38.698	43	713	0.3948	33.163
2008	43	867	0.4801	40.326	43	775	0.4291	36.047
2009	43	813	0.4502	37.814	43	696	0.3854	32.372
2010	43	856	0.4740	39.814	43	752	0.4164	34.977
2011	43	907	0.5022	42.186	43	815	0.4513	37.907
2012	43	890	0.4928	41.395	43	796	0.4408	37.023
2013	43	891	0.4934	41.442	43	788	0.4363	36.651
2014	43	889	0.4922	41.349	43	786	0.4352	36.558

indicating that the trade connection of FVA network was more vulnerable to macroeconomic fluctuation.

Further, this part uses the average path length and average clustering coefficient to describe the characteristics

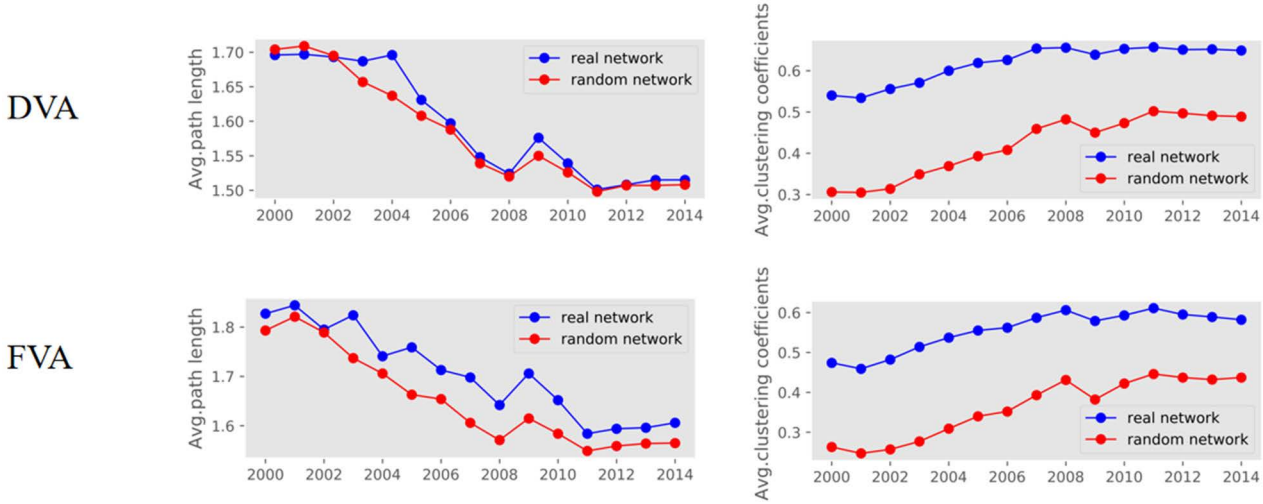


FIGURE 5. Accessibility and agglomeration of value-added trade network of producer services.

of small-world network, and the results are shown in Figure 5.

The average annual clustering coefficients of DVA network and FVA network were 0.617 and 0.555, respectively, and both of them presented an upward trend, indicating that these two networks possessed the characteristics of trade agglomeration. The average path length of DVA network fluctuated around 1.6, which means that two countries in the network can establish trade relations through at least another intermediary, while the average path length of FVA network changed to a large extent. Combining the average clustering coefficient and average path length of random network with the same scale, it can be found that the average clustering coefficient of value-added trade network of producer services is higher, but the average path length is larger than the value of random network. The DVA network and FVA network of producer services export do not demonstrate the characteristics of small-world network.

C. INDIVIDUAL CHARACTERISTIC ANALYSIS

1) NODE CENTRALITY OF UNWEIGHTED NETWORK

Figure 6 shows the ranking of degree centrality of DVA network and FVA network in 2000 and 2014.

From the perspective of the node degree centrality of DVA network, the out-degree and in-degree of most countries have significantly improved, indicating that the connection breadth of value-added trade in producer services has been expanded in the network. Among them, Germany, the United States, the United Kingdom, the Netherlands and France were the countries with high ranking in out-degree and in-degree centrality. In the FVA network, the degree centrality ranking of these countries was also in the top position. This is due to the fact that developed economies are at the upstream of the division of labor in the value chain of service industry, and as the power center of the global value network, they support the development of domestic value-added trade and foreign value-added trade. Japan was the only country where the out-degree centrality decreased in both DVA network and FVA network, indicating that the creation and output capacity of value-added of producer services in Japan was relatively weakened. Combined with the rising trend of China's out-degree and in-degree centrality, the segmentation of global share in the value network of producer services in East Asia was strengthening the leadership of China.

Figure 7 demonstrates the spatial distribution characteristics of betweenness centrality and closeness centrality in DVA and FVA networks.

The betweenness centrality measures the country's control over the value flow of producer services, while closeness centrality reflects the performance of not being controlled by other countries. In the DVA network, the betweenness centrality of Germany, the United States, the United Kingdom, Russia, Italy, France and the Netherlands were in the top ten in 2000 and 2014. Europe was the key region that grasped the exchanges and communication of value-added in the network. Disturbing the status of these countries may reshape the global value chain pattern. High closeness centrality was widely observed in Western Europe countries, represented by the United Kingdom, the Netherlands and France, which were comparatively independent in value-added trade network and relied less on other countries in trade intercourse process.

In FVA network, the change of network power center was the response of the trade game of large countries, which mainly occurred between the United States and the core countries of Europe. The betweenness centrality of the United States dropped from the first place in 2000 to the tenth place in 2014, while the ranking of Luxembourg and Belgium rose from 18th to 7th and from 17th to 3rd respectively. Meanwhile, the United Kingdom and France consistently ranked high in the betweenness centrality. It can be seen that the control power of the United States over the foreign value-added of producer services has shifted a lot to Western

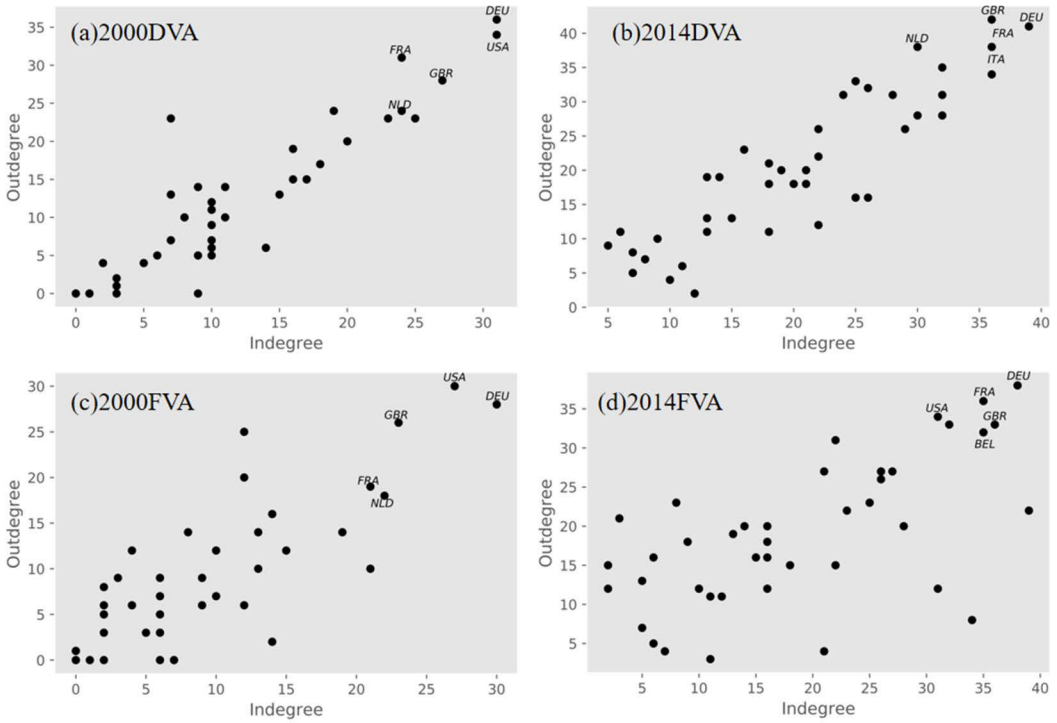


FIGURE 6. The out-degree centrality and in-degree centrality of nodes.

Europe in recent years, and their intermediary influence in FVA network showed the characteristics of ''one ebb and flow''. Japan's betweenness centrality ranking fell from 9th to 20th, while China and South Korea remained stable and had no upward trend, and East Asia's grip on the FVA network of producer services decreased. Germany's closeness centrality ranked first in 2000 and 2014, and other European countries also maintained an upper level due to their participation in the high-end production of GVC by mastering core technologies. The ranking of these countries coincided with the node degree centrality to a certain extent. They not only affected the value-added trade flow of other countries, but also made the trade process smoother. In 2014, the overall increase of the closeness centrality of each country shows that the spatial accessibility of FVA network was stronger.

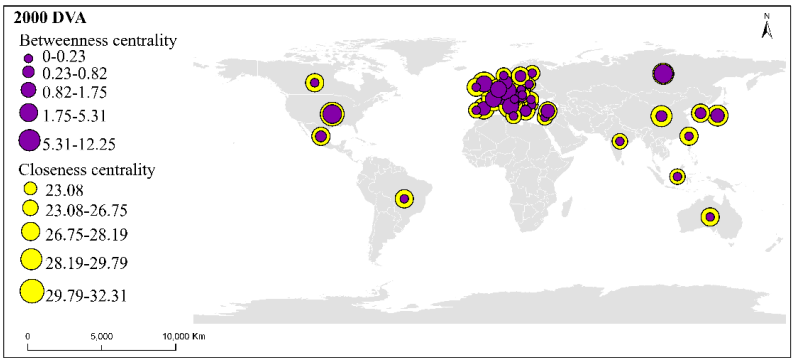
2) NODE CENTRALITY OF WEIGHTED NETWORK

Figure 8 shows the spatial evolution of PageRank centrality of nodes in the weighted network, which is used to represent the hub status of a country in the value-added trade network of producer services.

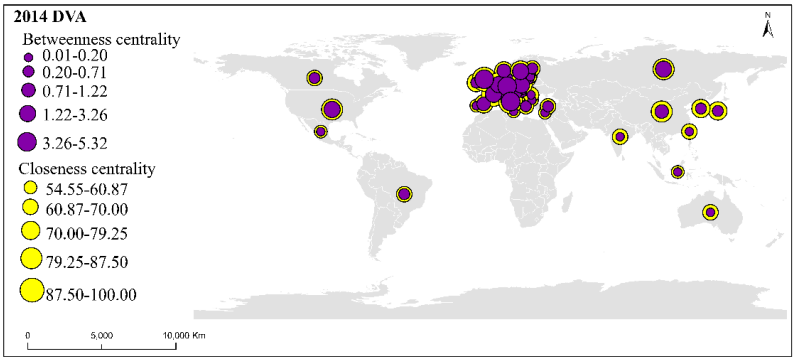
Figure 8(a) and (b) describe the changes of PageRank centrality of countries in the DVA network. In 2000, the PageRank centrality indexes of the United States, Germany and the United Kingdom were ahead of other economies, and they were the ''absolute central hub'' in the network. In 2014, Germany, the United States and China were the top three countries in the PageRank centrality of DVA network, among which China's PageRank value increased the most. Japan, France and other countries also had high PageRank index, resulting in a regional trade pattern dominated by East Asia, North America and Europe, which is related to the production network system formed under the in-depth adjustment of supply chain and industrial chain.

Figure 8(c) and (d) exhibit the evolution of PageRank centrality in FVA network. The relative importance of each country in FVA network was clearly differentiated. The United States ranked first in 2000 and 2014, and it was the only country with PageRank value exceeding 0.1. Germany, the United Kingdom, Japan and Italy had PageRank values of more than 0.05 in 2000, and the PageRank value of China, Germany, France and the United Kingdom in 2014 exceeded 0.05, featuring prominently in the value-added trade network. PageRank values of other countries were all less than 0.05, showing their weak influence in the network. China's PageRank centrality increased from 0.022 to 0.098, and it was also the country with the largest increase in FVA network. The reason is that China's trade structure and processing mode require it to import high value-added intermediate goods from abroad for re-export, which leads to a high proportion of foreign value-added in its export trade. The scale effect of trade may gradually increase China's status in the FVA network.

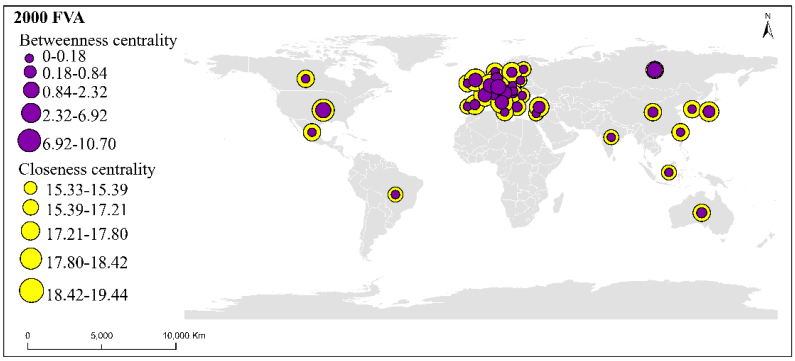
As shown in Figure 9, the node strength reflects the ability of a country or region to output its own domestic added value and absorb other countries' domestic added value in the value-added trade network, which is directly interpreted as the production market capacity and consumption absorption



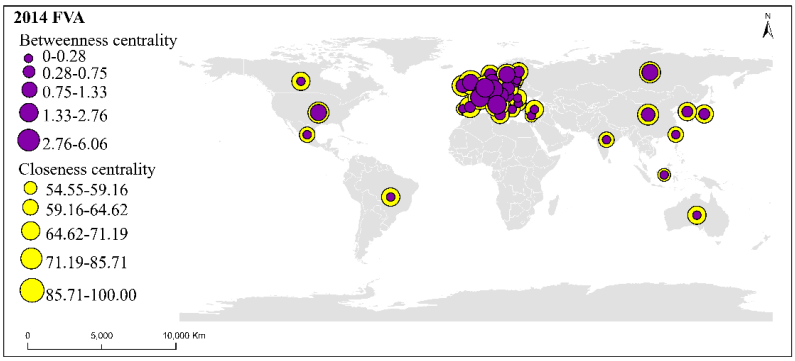
(a)



(b)



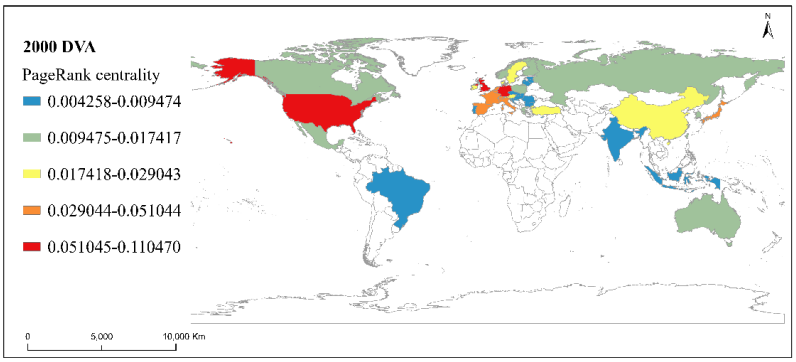
(c)



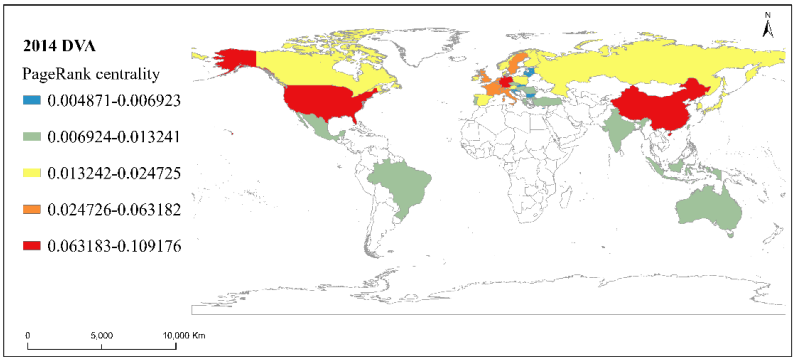
(d)

FIGURE 7. Spatial distribution of betweenness centrality and closeness centrality of nodes. (a) 2000DVA. (b) 2014DVA. (c) 2000FVA. (d) 2014FVA.

capability of the country or region. In the DVA network, the connection strength of nodes showed the distribution pattern of ''one super and many strong''. In terms of the scale of domestic value-added exports, the United States was



(a)



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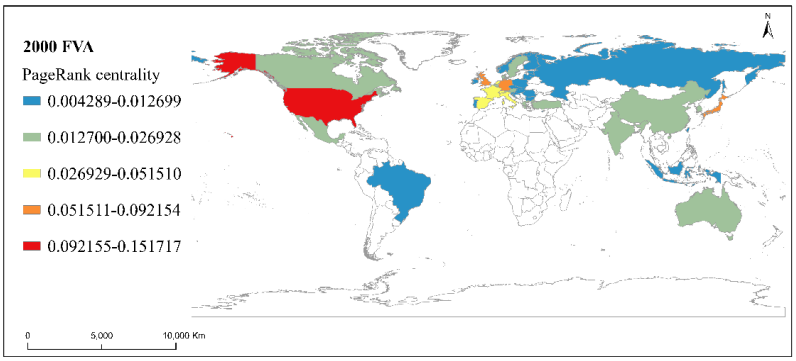

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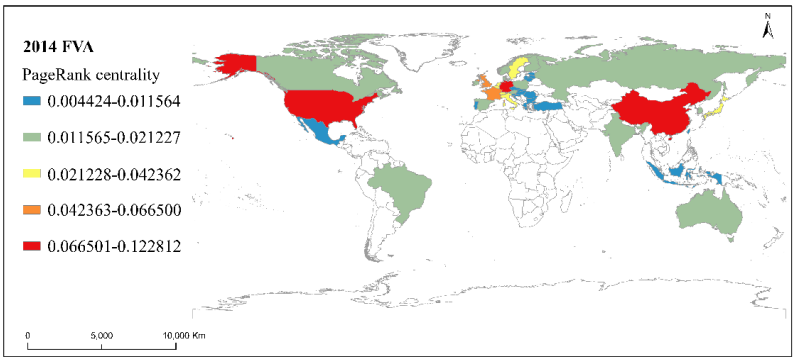


(d)

FIGURE 8. Spatial distribution of PageRank centrality. (a) 2000DVA. (b) 2014DVA. (c) 2000FVA. (d) 2014FVA.

a superpower and ranked first in the world continuously. Developed European countries such as Germany, the United Kingdom and France and China in East Asia were in the scope of powerful countries, and the trade volume gap between

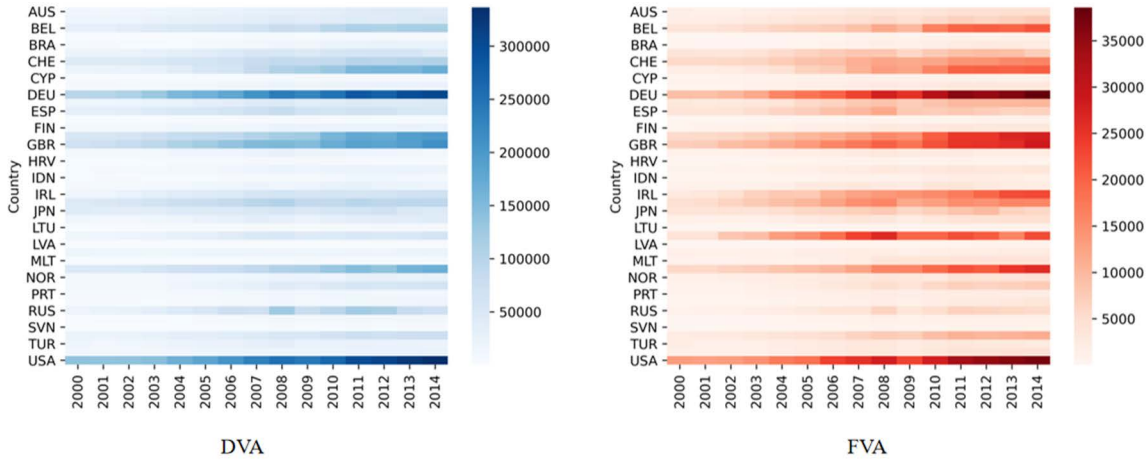


FIGURE 9. Node strength distribution.

TABLE 3. The modularity of DVA network and FVA network.

Year	DVA	FVA
2000	0.170	0.216
2001	0.172	0.200
2002	0.162	0.199
2003	0.160	0.204
2004	0.161	0.204
2005	0.160	0.207
2006	0.158	0.205
2007	0.150	0.206
2008	0.150	0.190
2009	0.149	0.164
2010	0.160	0.163
2011	0.153	0.168
2012	0.159	0.176
2013	0.159	0.187
2014	0.160	0.171

other countries and them was relatively evident. The distribution of node connection strength in FVA network was more even. Asia-pacific, North America and Europe were the three growth poles in FVA network, which emerged active foreign value-added trades due to monopolistic resources.

D. COMMUNITY DIVISION OF TRADE NETWORK

1) DIVISION OF COMMUNITY MEMBERS

This paper calculates the modularity of the weighted network for community analysis, and describes the transition of community structure of the network from the meso-level. The results are shown in Table 3 and Table 4, and the evolvement of value-added trade within the community is shown in Figure 10.

Table 3 describes the division quality and evolution trend of community structure in the value-added trade network of producer services. The community evolution of DVA network and FVA network in producer services from 2000 to 2014 presented differentiated features, which were described as follows: Firstly, in the sample years, the modularity of DVA network was lower than that of FVA network, which shows that the globalization trend of domestic value-added exports was more evident than that of foreign value-added exports. Secondly, affected by the financial crisis that emerged in 2006 and broke out in 2008, the modularity of both DVA network and FVA network showed a slight bottoming and rising trend, and the decline time point of the former (2006) was earlier than that of the latter (2008). It reflects that the value-added trade network pattern of producer services in this period gradually evolved towards the mainstream trend of globalization, and the domestic value-added export was more sensitive to the response of the financial crisis. Finally, after 2011, the modularity of DVA network and FVA network has increased to a certain extent, which means that in the later stage of the financial crisis, the pattern of value-added trade in producer services changed to collectivization and fragmentation, and trade groups formed among economies were more significant. However, on the whole, the modularity of the two networks basically showed a downward trend with fluctuations, and the degree of globalization was deepening.

Table 4 shows that the community division of DVA network and FVA network was slightly discrepant in different years. Some economies remained unchanged, and individual economies were separated between diverse communities. From 2000 to 2014, both DVA network and FVA network evolved from four communities to three communities. On the one hand, the distribution of countries in value-added trade network communities had geographical characteristics. On the other hand, it provided support for breaking through regional restrictions, shortening trade distance and accelerating the process of economic globalization. From the perspective of DVA network, D1 community in 2000 was composed of 13 economies in Western Europe, Central Europe and

TABLE 4. Results of community division in 2000 and 2014.

Year	Network	Community	Community members
2000	DVA	D1	AUT,BEL,CHE,DEU,ESP,FRA,ITA,MLT,NLD,PRT,ROU,SVN,TUR
		D2	BGR,CZE,HRV,HUN,LTU,LVA,POL,RUS,SVK
		D3	DNK,EST,NOR;SWE
		D4	AUS,BRA,CAN,CHN,CYP,FIN,GBR,GRC,IDN,IND,IRL,JPN,KOR,LUX,MEX,TWN,USA
2014	DVA	D1	AUT,BEL,BGR,CHE,CYP,CZE,DEU,ESP,FRA,GBR,GRC,HRV,HUN, ITA,LTU,LVA,MLT,NLD,POL,PRT,ROU,RUS,SVK,SVN,TUR
		D2	DNK,EST,FIN,NOR,SWE
		D3	AUS,BRA,CAN,CHN,IDN,IND,IRL,JPN,KOR,LUX,MEX,TWN,USA
2000	FVA	F1	CHE,GRC,ITA,LUX,LVA,MLT
		F2	AUT,BEL,BGR,CYP,CZE,DEU,ESP,FRA,HRV,HUN,LTU,NLD,POL, PRT,ROU,RUS,SVK,SVN,TUR
		F3	DNK,EST,FIN,NOR,SWE
		F4	AUS,BRA,CAN,CHN,GBR,IDN,IND,IRL,JPN,KOR,MEX,TWN,USA
2014	FVA	F1	AUT,BEL,BGR,CHE,CYP,CZE,GRC,HRV,ITA,LUX,LVA,ROU,SVK, SVN,TUR
		F2	AUS,DEU,ESP,FRA,GBR,HUN,IRL,LTU,MLT,NLD,POL,PRT
		F3	BRA,CAN,CHN,DNK,EST,FIN,IDN,IND,JPN,KOR,MEX,NOR,RUS, SWE,TWN,USA

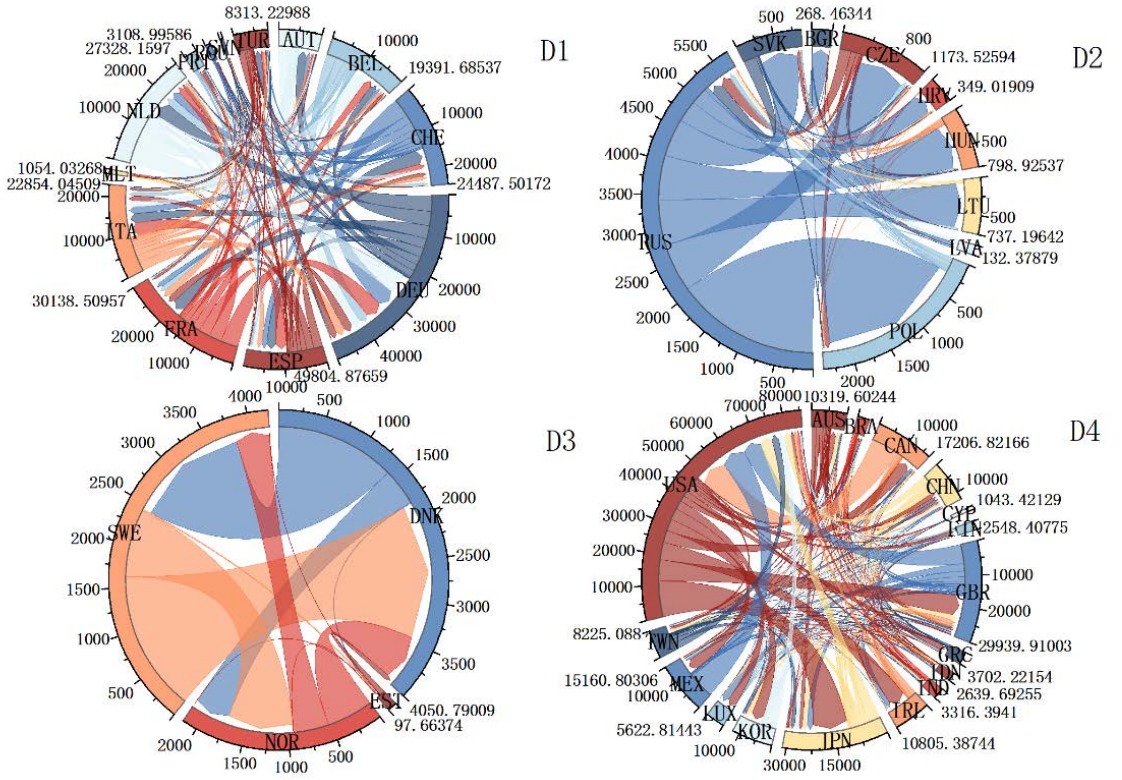
Southern Europe; D2 community was dominated by Central and Eastern European countries, including 9 economies; D3 community had 4 countries, including Estonia and 3 Nordic countries; D4 community was an association mainly in Asian and American countries, including 17 economies represented by China and the United States. In 2014, the members of D1 community altered tremendously, and became a club dominated by core European economies such as the United Kingdom, Germany and France; D2 community was still dominated by Nordic countries; D3 community was an Asia-Pacific club mainly composed of American and Asian countries.

According to the FVA network, the F1 community in 2000 included six economies dominated by Southern European countries. F2 community was composed of Lithuania and Russia in Eastern Europe and other major countries in Central, Southern and Western Europe, and there were 29 economies in total. These countries had adjacent geographical locations and cultural characteristics, which facilitated value-added trade. The members of F3 community included Denmark, Estonia, Finland, Norway and Sweden, which were in the typical Nordic society. F4 community was composed of three countries in North America (the United States, Canada, Mexico), Japan, China, South Korea and other Asian countries, including 13 economies. In 2014, the F1 community included 15 economies represented by Southern European countries. F2 community was mainly from Western and Central European countries. Apart from countries in Asia and North America, F3 community also included major countries in Northern Europe, which were far away from each other but broke through regional restrictions by virtue of their own comparative advantages to realize value-added trade exchanges and resource complementarity of producer services.

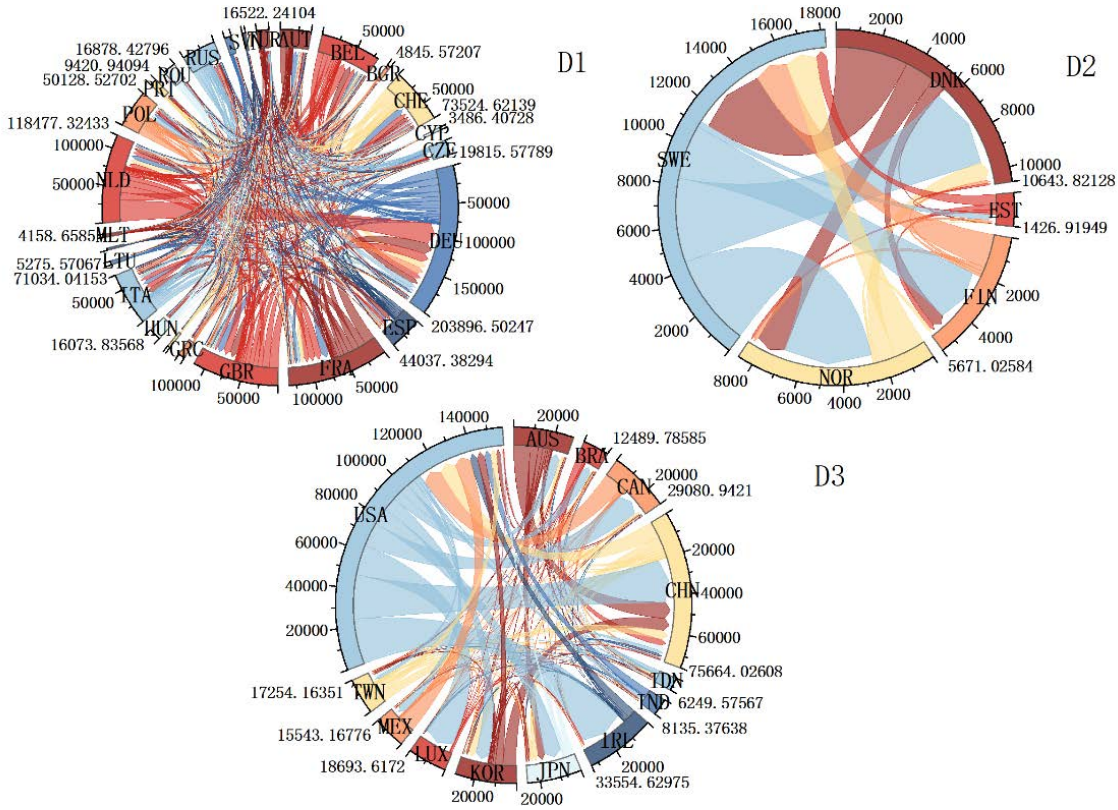
2) INTERNAL EVOLUTION OF COMMUNITY MEMBERS

Furthermore, according to the flow direction and trade relationship between nodes, the chord diagram between node pairs of DVA network and FVA network is acquired to study the characteristics of value-added trade in different communities.

Figure 10(a) shows that in the DVA network in 2000, D1, D2 and D4 were single core communities. The D1 community was centered in Germany, with France, Italy and the Netherlands as the secondary centers. As the core node of this community, Germany has established a large amount of domestic value-added export trade with the members of the sub center. In the D2 community, Russia occupied the core dominant position, followed by Poland, and other trading objects had relatively equal status. D4 was the community with the largest trade scale and the most trade members, the United States had the largest trade volume in this association, and the United Kingdom and Japan were the second important nodes. Compared with other communities, D3 community did not have a prominent trade focus, and the development gap between countries was small. The degree of regional economic integration was higher, and the community development was mainly polycentric. In the 2014 DVA network, D1 community evolved into the association with the closest two-way interaction between countries and the largest trade scale among members, and formed a network structure with Germany as the core and France, the United Kingdom, Italy and the Netherlands as the secondary core. D2 community was an association with Sweden and

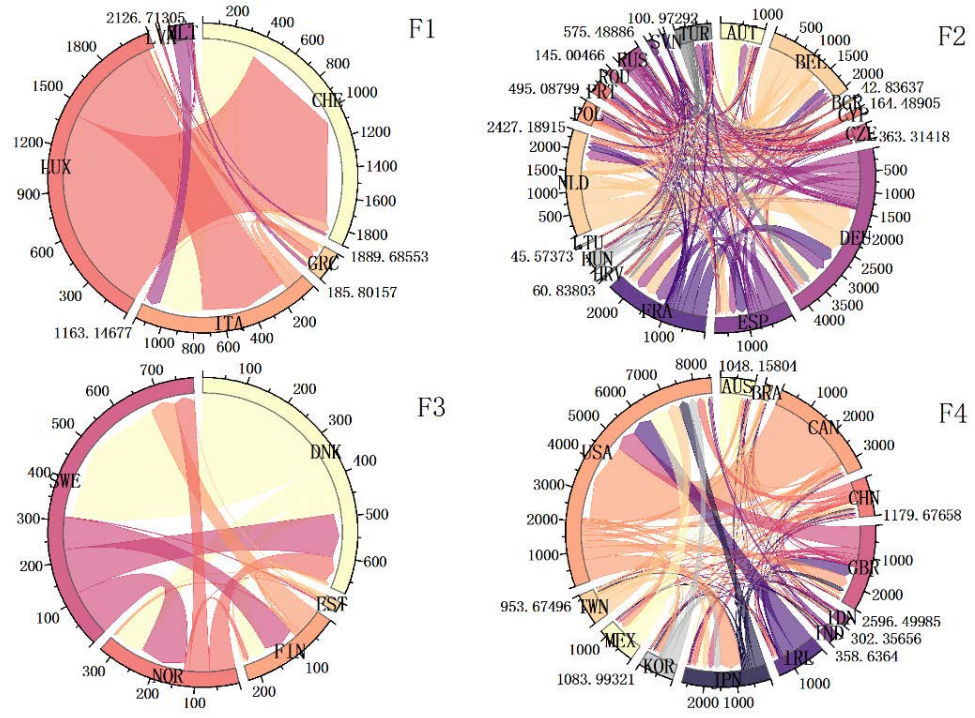


(a)2000DVA

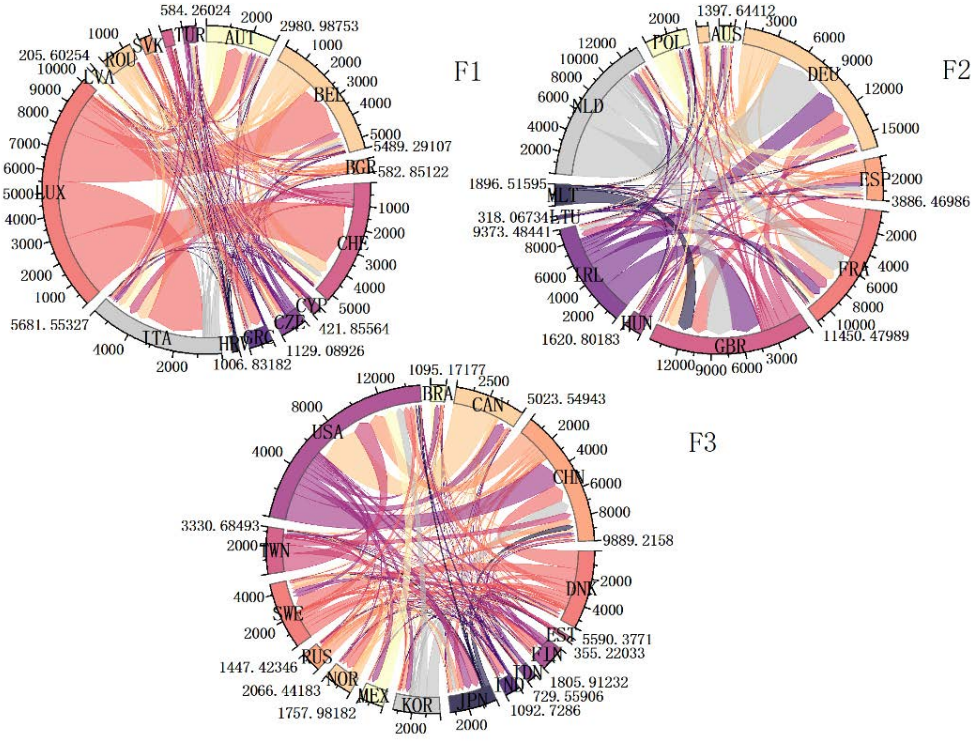


(b)2014DVA

FIGURE 10. Evolution of network structure within the community.



(c)2000FVA



(d)2014FVA

FIGURE 10. *(Continued.)* **Evolution of network structure within the community.**

Denmark as the dual cores. Due to its adjacent geographical location, the exports from Sweden to Denmark, Finland and Norway contained a large amount of domestic value-added. D3 community became a dual core club with the United States and China as its cores. Over time, China's producer services industry has deepened its trade gains in the global

value chain, and its position in the Asia-pacific community of DVA network has also improved significantly.

Figure 10(c) shows that in the FVA network in 2000, the core nodes of the F1 community were Luxembourg and Switzerland, followed by Italy. The largest trade flow came from the foreign value-added contained in Luxembourg's exports to Switzerland, accounting for 51.55% of the total trade volume within the community. The value-added trade links between Luxembourg and Italy, Switzerland and Italy were also relatively tight, indicating the interdependence of the export markets of the European economies within the community. Germany in the F2 community still occupied an remarkably dominant position. Most of the foreign value-added contained in its producer services exports came from secondary important nodes such as the Netherlands and France. There were clear divergences in the trade status of other countries in the community, indicating that there was asymmetric dependence on producer services among them. F3 community shows that Sweden and Denmark were at the core of the Nordic trading area. The foreign-value added contained in Sweden's producer services exports mainly came from Denmark, Finland and Norway, while the foreign value-added in Denmark's exports came from Sweden, Finland and Norway. In other words, the Nordic region formed a separate and compact entity. F4 community did not have the most trade members, but it had the largest trade scale. Most of the foreign value-added contained in the exports of producer services of major countries such as South Korea and Mexico in the community came from the United States, Japan, the United Kingdom and Canada, indicating that they were the main export markets of producer services in the community and held a relatively high share of value-added due to the remarkable value-added capacity of products. In the FVA network in 2014, the F1 community developed into a multi-center network structure, and the national groups with Luxembourg, Italy, Switzerland and Belgium as the core nodes dominated the community. Due to the factors of economic size, the proportion of foreign value-added flows in producer services exports of Latvia, Croatia and other countries in the community was not high. The leading nodes of F2 community were the Netherlands, Germany, France, Britain and Ireland, and the trade flow within the community was more balanced. Among F3 community, the United States, Canada and China were all trade centers. China's position in the community has improved, and a large proportion of the value-added contained in the exports of producer services in core countries comes from China, which reveals that as a large developing country, the added value and value-added capacity of Chinese products are increasing, and China's status in the global value chain is also climbing.

E. ANALYSIS ON THE INFLUENCING FACTORS OF TRADE NETWORK STATUS

1) INDEX SELECTION AND VARIABLE DESCRIPTION

In the trade network, the centrality can reflect the importance and pivotal position of a country. Countries with higher centrality have stronger ability to obtain and control value-added trade resources [38]. Therefore, this paper selects node strength and PageRank centrality as the explained variables for empirical analysis. Since there are many variables missing in Taiwan, this part uses the data of 42 countries and regions other than Taiwan from 2000 to 2014 to explore influencing factors of trade network status.

If the formation of trade network hub is explained from the perspective of national characteristics, it can be considered that the influencing factors include market advantage, economic scale, technological innovation level, institutional environment, factor endowment, infrastructure guarantee and openness, which constitute the favorable advantages of a country in participating in the international division of labor [39], [40], [41]. At the same time, considering that the rise of free trade agreements (FTA) is related to the development of global value chain, concluding regional trade agreements (RTA) may have an impact on a country's embeddedness in GVC [42], [43]. Based on the above analysis, the following econometric model is established:

$$\begin{aligned} centrality_{it} = {} & \alpha + \beta_1 urban_{it} + \beta_2 pgdp_{it} + \beta_3 rd_{it} \\ & + \beta_4 rta_{it} + \beta_5 ins_{it} + \beta_6 fcr_{it} + \beta_7 \inf_{it} \\ & + \beta_8 open_{it} + \lambda_t + \gamma_i + \varepsilon_{it} \end{aligned} \tag{16}$$

where i represents the country (region), t represents year, the dependent variable $centrailty_{it}$ refers to the position in the value-added trade network of producer services of country i in year t. $urban_{it}$ refers to market advantage, which is represented by the proportion of urban population in the total population. $pgdp_{it}$ is the economic scale, measured by the per capita GDP of each country (constant price US dollars). rd_{it} refers to technological innovation support, expressed as the proportion of R&D expenditure in GDP. rta_{it} refers to the number of regional trade agreements signed by a country. ins_{it} is the institutional environment, which is expressed by the means of the voice and accountability, political stability, government effectiveness, regulatory quality, rule of law and control of corruption in WGI database. fcr_{it} is the endowment of production factors, expressed as the proportion of gross fixed capital formation in GDP. inf_{it} is an infrastructure condition, represented by the percentage of Internet usage. $open_{it}$ refers to the degree of openness, expressed as the share of total imports and exports of goods and services in GDP. In order to eliminate the influence of heteroscedasticity and dimensional difference of data, the node strength and per capita GDP are processed logarithmically. Among them, the data sources of urbanization level, per capita GDP, R&D expenditure, fixed capital, Internet use, import and export of goods and services are WDI database of the World Bank. The institutional quality data are from WGI database, and the number of RTA is from CEPII database.

2) EMPIRICAL RESULTS AND ANALYSIS

The econometric analysis aims to explore the influence mechanism of the network status of producer services trade in

TABLE 5. Baseline regression results.

Variables	Node strength		PageRank centrality	
	(1)DVA network	(2)FVA network	(3)DVA network	(4)FVA network
urban	-0.0146***	-0.0121*	0.000319**	0.000467***
	(0.00510)	(0.00632)	(0.000134)	(0.000169)
pgdp	1.268***	1.186***	0.0238***	0.0319***
	(0.0918)	(0.114)	(0.00240)	(0.00305)
rd	-0.0411	0.0247	0.00363***	0.00489***
	(0.0356)	(0.0441)	(0.000932)	(0.00118)
rta	0.00369***	0.00323***	0.0000189	0.0000301
	(0.000749)	(0.000927)	(0.0000196)	(0.0000249)
ins	0.137*	0.101	-0.00463**	-0.00884***
	(0.0810)	(0.100)	(0.00212)	(0.00269)
fcr	0.0113***	0.0174***	0.000302***	0.000401***
	(0.00341)	(0.00422)	(0.0000892)	(0.000113)
inf	0.00294**	0.00665***	0.000139***	0.000174***
	(0.00116)	(0.00144)	(0.0000303)	(0.0000385)
open	0.00188***	0.00405***	-0.0000501***	-0.0000996***
	(0.000701)	(0.000868)	(0.0000183)	(0.0000233)
intercept	-2.877***	-4.813***	-0.237***	-0.322***
	(0.821)	(1.017)	(0.0215)	(0.0273)
Year fixed effect	Yes	Yes	Yes	Yes
National fixed effect	Yes	Yes	Yes	Yes
Sample size	630	630	630	630
R^2	0.917	0.911	0.345	0.367

Standard errors in parentheses： * p<0.1, ** p<0.05, *** p<0.01

various countries. This paper uses two-way fixed effects model for baseline regression and quantile regression for heterogeneity analysis. In addition, we utilize the variance inflation factor (VIF) method to test the multi-collinearity, and find that the VIF values of all variables are less than 10, indicating that the model do not have multi-collinearity.

Table 5 summarizes the results of baseline regression. Columns (1) - (4) refer to strength and PageRank centrality of the nodes as explained variables.

As can be seen from the regression results, urbanization level has similar influence on DVA network and FVA network. Its regression coefficient is significantly negative in model (1) and model (2), which means that it has no positive effect on the node strength of a country. In addition, its constructive influence on PageRank centrality in models (3) and (4) is also small. The main reason may be that most of the sample countries are developed countries, and the urbanization process is basically completed. In this case, the population flow and factor concentration caused by urbanization do not effectively promote the upgrading of consumption structure, nor do they bring more demand for producer services, which is not conducive to the establishment of value-added trade links. The regression coefficient of per capita GDP is significantly positive in all the four models, and the value of this coefficient is the largest among all variables, indicating that the enhancement of economic strength can significantly improve the status of a country in the value-added trade network of producer services. Technological innovation has no evident effect on the node strength of a country, but can improve the PageRank centrality. This shows that although increasing technical support does not directly affect the depth of individual trade links, it can promote a country's hub status in the network by raising the importance of adjacent nodes. The conclusion of regional trade agreements can enable countries to improve the node strength, but it has no significant effect on the promotion of PageRank centrality. The possible reason is that PageRank index reflects the feature of ''keeping close to others'', that is, if an economy has closer ties with the ''central economy'' with a higher centrality value, the node centrality of the economy will increase more easily. But the countries signing regional trade agreements do not necessarily have high centrality value themselves, so they cannot enhance their network status in this way. Institutional quality only plays a positive role in enhancing the nodes strength in the DVA network, but has no beneficial effect on the foreign value-added contained in producer services exports of each country. The regression coefficients of fixed capital and Internet use are significantly positive in the four models, indicating that relying on resource endowment and infrastructure construction, a country can complete the export expansion of producer services, participate in value-added trade and enhance its network position. The degree of openness can directly improve a country's node strength in the network by expanding the trade scale. However, with the

TABLE 6. Quantile regression results.

Variables	DVA network			FVA network		
	(1)25%	(2)50%	(3)75%	(4)25%	(5)50%	(6)75%
urban	0.0221***	0.00294***	-0.0151***	0.0197***	0.00852***	-0.0141***
	(0.000789)	(0.000378)	(0.000488)	(0.000521)	(0.000366)	(0.000223)
pgdp	1.960***	1.448***	0.884***	2.070***	1.333***	0.567***
	(0.0174)	(0.0213)	(0.0235)	(0.0206)	(0.0116)	(0.00507)
rd	0.529***	0.622***	0.822***	0.376***	0.411***	0.598***
	(0.0207)	(0.00713)	(0.00646)	(0.0117)	(0.00684)	(0.00335)
rta	0.00992***	0.00807***	0.00751***	0.0126***	0.00624***	0.00402***
	(0.000238)	(0.000103)	(0.000180)	(0.000322)	(0.000271)	(0.0000633)
ins	-2.301***	-1.885***	-1.059***	-2.053***	-1.428***	-0.587***
	(0.0248)	(0.0282)	(0.0200)	(0.0186)	(0.0166)	(0.00640)
fcr	0.0000946	0.0314***	0.0157***	0.00247	0.00237	0.0152***
	(0.00200)	(0.00182)	(0.00285)	(0.00187)	(0.00149)	(0.000406)
inf	0.000718	0.00948***	0.0131***	0.00214***	0.00798***	0.0167***
	(0.00111)	(0.000495)	(0.000368)	(0.000567)	(0.000614)	(0.000221)
open	-0.00521***	-0.00273***	-0.00554***	-0.00122***	0.00104***	0.000343***
	(0.0000931)	(0.000190)	(0.0000890)	(0.000169)	(0.0000815)	(0.0000378)
Sample size	630	630	630	630	630	630

Standard errors in parentheses：* p<0.1, ** p<0.05, *** p<0.01

increase of intermediate goods' round-trip between countries participating in the international division of labor, the negative effect of the increase in the proportion of processing trade and the reduction of technology spillovers may also be amplified, thus inhibiting the rise of a country's producer services value chain and the advancement of its position in the network.

The above traditional regression method can clarify the average effect of explanatory variables, but it cannot reveal the influence difference of explanatory variables on the explained variables under different quantiles. Considering the two-way fixed effect, the results imply that the regression model with the explanatory variable of node strength has a higher goodness of fit. In the heterogeneity analysis, node strength is used as the dependent variable for quantile regression, and three representative quantiles of 25%, 50% and 75% are selected to investigate the impact of various factors on different parts of the status of producer services value-added trade network.

The results of Table 6 demonstrate that the regression coefficient of urbanization level presents a homologous change trend in DVA network and FVA network, indicating that market advantage has a more positive impact on countries located in the low quantile of producer services value-added trade network. Per capita GDP has a profitable impact on the value-added trade network status of different quantiles, but the impact shows a downward trend. When the position of a country's producer services industry in the global value-added network evolves from the low end of conditional distribution to the high end, the promotion effect of economic scale decreases. The influence trend of R&D investment on the position of value-added trade network is opposite to per capita GDP, which may depend on the industrial characteristics of producer services with a large amount of intellectual capital. Therefore, countries with high quantiles in the position of trade network can better transform the input technical support into high value-added products, so as to enhance their participation in the global value chain network. The coefficient of RTA number is positive at each quantile of DVA network and FVA network, and the value at the low quantile is higher in both networks. Especially in the FVA network, countries located at the low quantile of value-added trade network status can benefit more from the trade creation effect generated by the conclusion of agreements with a higher degree of integration, consequently improve the control ability of foreign value-added and the pivotal position of the country. In the case of conditional distribution, the improvement of institutional quality may lead to the rise of domestic trade protectionism and restrict the global division of production of domestic products, which is not conducive to enhancing the hub status of value-added trade network. In the low quantile of dependent variable, the coefficient of total fixed capital formation does not pass the significance test. The possible reason is that the accumulation of factor endowments of countries with the status of value-added trade network at the low quantile is not enough to advocate their involving with high-end links such as R&D and after-sales of producer services. The coefficient of Internet use proportion is not significant only at the 0.25 quantile of DVA network, and the promoting effect of this variable is evidently enhanced as the position of value-added trade network moves from low quantile to high quantile. This is due to the fact

TABLE 7. The 43 economies in this paper and their abbreviations.

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

that high-quantile countries with superior infrastructure can reduce transaction costs, which indirectly affect the trade of capital intensive producer services and assist the expansion of a country in the GVC network. The degree of openness is significantly positive at the 0.5 and 0.75 quantiles of the FVA network, which illustrates that only when a country reaches the high-order quantile in the FVA network can it gain more extensive and advantageous foreign value-added trade links through opening to the outside world.

IV. CONCLUSION AND POLICY RECOMMENDATIONS

A. CONCLUSION

Based on the framework of WWZ bilateral value-added decomposition, this paper constructs the DVA network and FVA network of producer services trade export. The complex network method is employed to analyze the structural characteristics of the two networks. Besides, the influencing factors of countries' position in the value-added trade network are empirically investigated. The main conclusions are as follows:

Firstly, both the DVA network and FVA network have core-edge hierarchical structure, and present the trend of evolution from single-core circle to multi-core circle. Excluding the impact of financial crisis, the two basically show a trend of denseness from 2000 to 2014.

Secondly, the global value network of producer services has a trade status pattern of "big countries competing for supremacy while small countries are subordinate". The developed economies of Western Europe are at the core of the DVA network, and East Asia, North America and Europe are the three growth poles of the global value chain for producer services. The control force in the FVA network has changed from the pattern dominated by the United States to the world image dominated by Germany and Italy, and the developing economies in the division of value chain have begun to emerge, exerting an increasingly profound influence on the FVA network.

Thirdly, in the process of community evolution, the members of the community change over time. The DVA network eventually formed two European communities and Asia-pacific community dominated by Germany, Sweden and the United States, among which the Northern European community had typical geographical characteristics. The integration and division of FVA network communities reflect the phenomenon of interweaving and overlapping among trade groups, and the trade boundary is gradually blurred.

Finally, in the international division of labor, the improvement of comparative advantage brought by economic development, infrastructure and physical capital can enhance the hub status of a country, and they have discrepant impacts

on DVA network and FVA network of value-added trade of producer services. Considering the conditional distribution, technological innovation and regional trade agreements are the key factors that could enhance the status of the network. The impacts of other indicators such as market advantage on GVC network have heterogeneity and trend for countries located in different quantiles of value-added trade network.

B. POLICY RECOMMENDATIONS

According to the above conclusions, it can be found that a country's participation in the division of labor in the global value chain not only relies on the ''export income'', but is also related to its relative position in the global value network and the factors affecting the change of its network status. In order to improve the profitability of producer services in the global value chain and for countries to accumulate more value creation in this field, the following suggestions are put forward. First of all, developing economies need to strengthen digital infrastructure construction and realize industrial upgrading and value network climbing through high-quality development, so as to improve the situation that the global value chain of producer services extends to developing countries but is still dominated by developed countries. In particular, countries can actively take advantage of the good opportunities of the ''the Belt and Road'' strategy to promote a new situation of mutual benefit and win-win results. Afterwards, the formation of the community structure is partly due to the influence of geographical and political factors. Therefore, while maintaining a good and stable value-added trade relationship, members of the community should rationally judge the trade status and product structure of their own producer services, reasonably select trading partners outside the community, expand opening-up and pay attention to effective protection. On the basis of the first global value chain programmatic policy document formulated by Asia Pacific Economic Cooperation (APEC), countries have gradually adapted to the trade rules guided by the global value chain. In the end, countries should actively build comprehensive strengths consisting of economic scale, material capital and other factors, differentiated policies should be employed for countries with different network status to consolidate their pivotal role in the international division of labor network.

APPENDIX

See Table 7.

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