Proceedings of the 2nd International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/109/2024.17898

Analysis of the Structure Characteristics and Influencing Factors of the Global Flower Trade Network

Xiangmin Zhang[1,2,*], Fuchun Zhan[1,3]

[1]Economics and Management College, China University of Geosciences Beijing, Beijing, China

[2]zhangxiangmin2001@163.com
[3]fuchunsureshen@gmail.com
*corresponding author

Abstract. Global flower trade plays an important economic, cultural and environmental role in international trade, so it is of great significance to construct and analyze flower trade network. Through the construction of the global flower trade network from 2014 to 2023, this paper analyzes its structural characteristics and space-time evolution law, and finds that the global flower trade network has an obvious core-edge structure, and core countries such as the Netherlands, Germany and the United States occupy a dominant position in the trade, and the network stability is high. Then, from the perspective of flower planting, the explanatory variables were set in combination with flower transportation, national politics, economy and culture, etc., and the influencing factors of global flower trade were analyzed using the QAP model. The regression results showed that economic development level and geographical proximity had a significant positive impact on flower trade, while water resource richness had a negative impact, and language similarity promoted trade development.

Keywords: Flower trade network, Complex network, QAP model.

1. Introduction

The global flower trade is a vital component of international trade, involving producers, wholesalers, and retailers worldwide. With globalization accelerating, the flower trade network is becoming increasingly complex and diversified. Studying its structure and characteristics is crucial for understanding global trade dynamics, optimizing supply chain management, and formulating relevant policies.

Despite numerous studies on global trade networks, systematic analysis of flower trade remains limited. Existing research primarily focuses on flower production and trade within individual countries or regions, lacking in-depth analysis of the overall structure of the global flower trade network.

Thus, this paper constructs and analyzes the global flower trade network from 2014 to 2023, examining its structural characteristics and evolution through centrality and core-edge analysis. It also establishes a QAP model to analyze factors affecting global flower trade, providing valuable insights for the industry.

© 2024 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

2. Related studies

With the improvement of living standards, fresh flowers have become a necessity in daily life, attracting scholars' attention to the flower trade [1]. Seong-Hwan, Song, and others analyzed the high trade volume pattern between South Korea and Japan [2]. Rombach, M and others researched the key factors influencing consumer behavior regarding flowers in Germany [3].

The theory of complex networks originated from the random graph model proposed by Erdos and Renyi in 1959, revealing the characteristics of random networks and providing a mathematical foundation for network analysis [4-6]. Scholars have gradually adopted network analysis methods to study international trade, exploring the topological structure of international trade networks [7-10]. Snyder and Kick were the first to apply network analysis methods to international trade research in 1979 [11]. Wu and others constructed a domestic value-added network for global energy trade [12]. Chen Wei and others, developed a framework for analyzing the resilience of trade networks, exploring the evolution and development trends of trade network resilience [13]. Ma, Jinlong, and others studied the evolution of global soybean trade and network robustness under random and different attack strategies [14]. Sun, Xin, and others established an evaluation framework for the network resilience of global oil and gas resource trade from 2010 to 2020 [15]. Wang Jieyong and others constructed a global food trade network for major grains like wheat, rice, and corn based on complex network analysis methods [16].

Social network analysis is one of the earliest application areas of the QAP model. In 1988, Krackhardt used the QAP model to study trust networks within organizations, finding that trust relationships significantly impact organizational performance [17]. Borgatti and Everett further expanded the QAP model in 1992, studying centrality and group structure in social networks [18]. The core of the QAP model lies in assessing statistical significance through permutation tests, avoiding the independence assumptions of traditional regression analysis [19]. In recent years, the application of the QAP model in complex network research has been continuously expanding[20].

3. Research Data and Research Methods

3.1. Data source and data processing

The research data of this paper is the data of import and export trade of flowers around the world from 2013 to 2023. The data source is: UN Comtrade. According to the Technical Guide for Export of Flowers, flowers are defined as products of HS06.

In order to avoid the analysis of weak trade contact bias, better reflect the flower trade relationship, this paper in 2022 flower trade volume (including exports and imports) in $1 billion countries for the study sample, select 20 countries. The total flower trade volume of the above 20 countries accounted for 85.87% of the total global flower trade volume in 2022.

Table 1. Global flower trade volume in 2022 (top 20 countries)

Num	Country	Volume Of Trade	Cumulative Percentage	Num	Country	Volume Of Trade	Cumulative Percentage
1	Holland	14570883758	30.07%	11	Spain	986819237.2	74.02%
2	Germany	4597419948	39.55%	12	Denmark	930359365.7	75.94%
3	America	4485970942	48.81%	13	China	811848171	77.61%
4	Columbia	2150809398	53.25%	14	Poland	796761209	79.26%
5	Italy	1962500033	57.30%	15	Kenya	703954380.8	80.71%
6	Britain	1951883485	61.33%	16	Switzerland	666682247.8	82.08%
7	France	1794279175	65.03%	17	Japan	637055586.3	83.40%
8	Canada	1304537220	67.72%	18	Austria	514290706.8	84.46%
9	Ecuador	1075833207	69.94%	19	Portugal	343986463.5	85.17%
10	Belgium	988319137.2	71.98%	20	Czechia	341526791	85.87%

DOI: 10.54254/2755-2721/109/2024.17898

3.2. Research Methods

This paper constructs a global flower trade network using Social Network Analysis. A directed network indicates that edges have a clear direction, reflecting imports and exports. Weighted edges represent trade volume or value between nodes, allowing for an accurate description of trade intensity. This study selects 20 countries as nodes, using annual flower trade volumes as edges to construct a weighted directed global flower trade network.

Various indicators are needed to measure and analyze the overall structure of the network, among which density, correlation, average path length and reciprocity coefficient are important indicators to analyze the characteristics of the overall network structure. Network centrality is used to measure the importance of nodes within a network, including degree centrality, closeness centrality, betweenness centrality, and others.

Table 2. Measurement Index and Formula

Measurement Index	Formula	Measurement Index	Formula
Average Node Degree	$\text{Average Degree} = \frac{\sum_{i=1}^{n} k_i}{n}$	Average Path Length	$L = \frac{1}{n(n-1)} \sum_{i \neq j} d(i, j)$
Network Density	$\text{Density} = \frac{\text{Number of Actual Directed Edges}}{n(n-1)}$	Closeness Centrality	$C(x) = \frac{N-1}{\sum_{y \neq x} d(x, y)}$
Average Clustering Coefficient	$C_i = \frac{\sum_{j,k \in N_i} (w_{ij} + w_{ik}) / 2 \times \delta(j,k)}{k_i(k_i - 1)}$	Betweenness Centrality	$C_B(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$

4. Analysis of structural evolution characteristics of global flower trade network

4.1. Analysis of the overall network structure characteristics

According to the index of the overall network structure introduced in the method, the statistical values of the flower trade network from 2014 to 2023 are calculated by using the software gephi10. The number of nodes in the trade network is 20.

The number of network edges increased from 332 in 2014 to 350 in 2022, indicating that the flower trade was increasing in this 10 years. The average node degree of the network increased from 16.6 in 2014 to 17.5 in 2022. The increase in the average node degree indicates that trade ties among countries have become more intensive.

The network density increased from 0.874 in 2014 to 0.921 in 2022, and decreased to 0.784 in 2023. The increase in network density suggests closer trade ties between countries, but the decline in 2023 may reflect a loose global trade ties. The average clustering coefficient increased from 0.864 in 2014 to 0.913 in 2022, indicating the presence of tight trade groups among countries. Average path length had a little change, indicating that the overall connectivity of the network remains stable.

Table 3. Basic information of the Global Flower Trade Network from 2014 to 2023

Year	Number Of Nodes	Number Of Edges	Average Node Degree	Network Diameter	Network Density	Average Clustering Coefficient	Average Path Length
2014	20	332	16.6	2	0.874	0.864	1.142
2015	20	346	17.3	2	0.911	0.902	1.1
2016	20	341	17.05	2	0.897	0.896	1.108
2017	20	326	16.3	2	0.858	0.853	1.105
2018	20	350	17.5	2	0.921	0.096	1.087

Table 3. (continued).

2019	20	352	17.6	2	0.926	0.915	1.084
2020	20	342	17.1	2	0.9	0.894	1.105
2021	20	348	17.4	2	0.916	0.91	1.089
2022	20	350	17.5	2	0.921	0.913	1.087
2023	20	298	14.9	2	0.784	0.819	1.18

The structure diagram of global flower trade network for important time nodes within 10 years, as shown in Figure 1. In 2014, the trade network was relatively uniform, and there were many connections between nodes, showing a highly interconnected trade network. The Netherlands, Germany, and other countries occupied an important position in the network, showing their core position in the global flower trade. The trade network structure in 2017 was similar to that in 2014, but the connectivity was more intensive, showing the further strengthening of trade ties between countries. In 2020, the trade network structure is still close, but the connections of some countries become more significant, showing the dominant position of specific countries in the flower trade, and the Netherlands, Germany, and other countries continue to occupy an important position in the network. In 2023, the trade network structure is loose, and the connection in some countries is reduced, indicating the weakening of the global flower trade links.

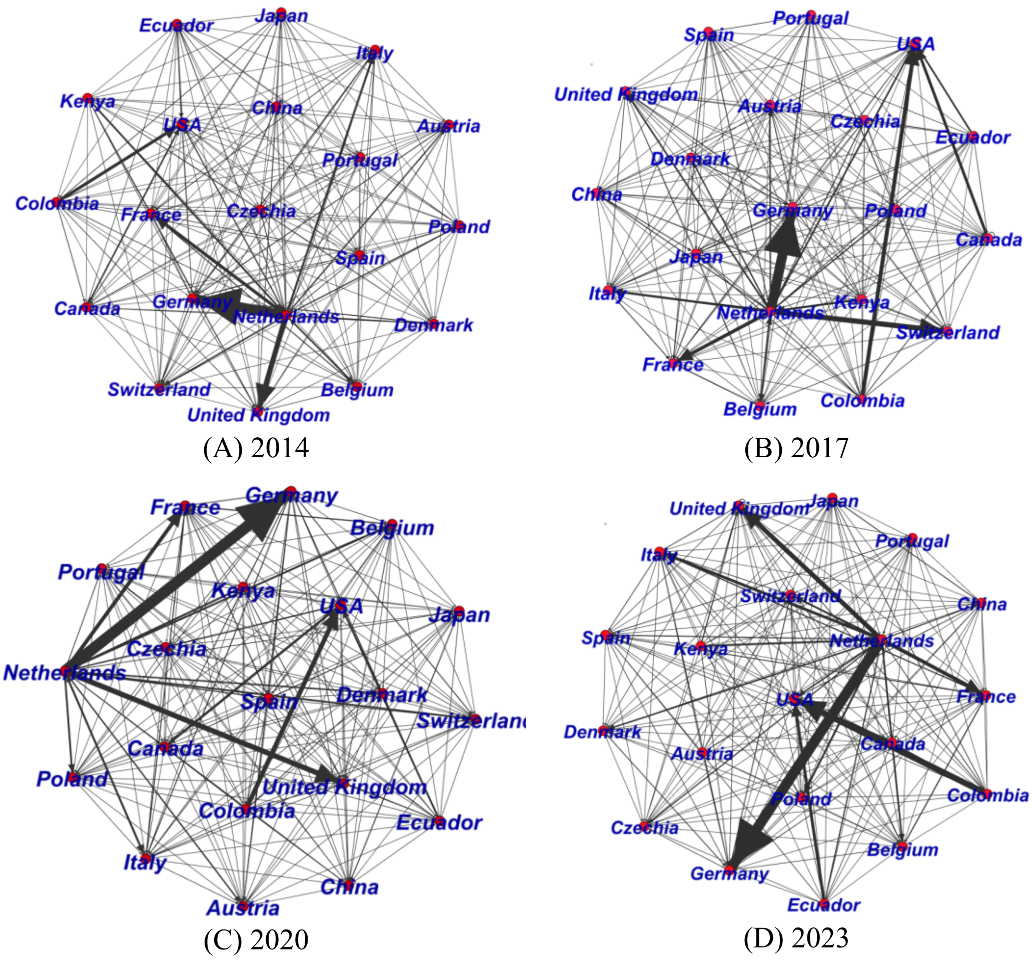


Figure 1. Structure diagram of the world flower trade weighted network

DOI: 10.54254/2755-2721/109/2024.17898

4.2. Centrality analysis

Weighted in-degree indicates the amount of trade a country receives from others, with a high value signifying that the country is a key destination for flower imports. Germany ranks first in weighted in-degree across all years. Weighted out-degree represents the trade a country exports, with a high value indicating it is an important source of flower exports. Closeness centrality measures the average shortest path length to other countries, with a high value suggesting a central location in the flower trade network. The Netherlands and Germany consistently rank in the top three, with France and the United States close behind. Betweenness centrality indicates how often a country appears on the shortest paths between others, with high values signifying a bridging role, particularly for the United States and the Netherlands. From 2014 to 2023, Germany, the Netherlands, and the United States excelled in various centrality metrics, highlighting their core positions in global flower trade. The Netherlands ranks first in both weighted out-degree and weighted degree, while Germany leads in weighted in-degree and weighted degree. The global flower trade network has maintained a stable structure from 2014 to 2023, with core countries playing significant bridging and hub roles, facilitating the flow and development of global flower trade.

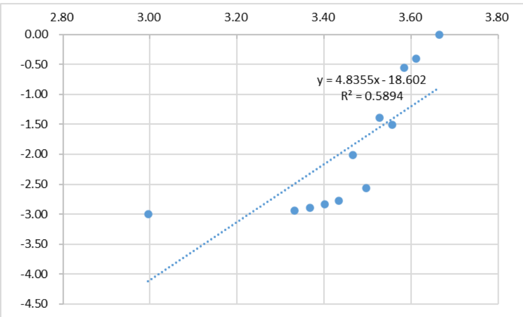
Table 4. Results of centrality index of Global Flower Trade Network in 2014-2023

Year	Ranking	Weighted Entry Degree	Weighted Out Degree	Weighted Degree	Close To The Center	Interference Center Degree
2014	1	Germany	Holland	Holland	Kenya	America
	2	Britain	Columbia	Germany	Holland	Holland
	3	America	Germany	America	Germany	Germany
	4	Holland	Kenya	Britain	America	France
	5	France	Italy	France	France	Italy
	6	Italy	Belgium	Italy	Italy	Spain
	7	Switzerland	Ecuador	Columbia	Spain	Japan
	8	Austria	Canada	Belgium	China	China
	9	Belgium	America	Canada	Japan	Portuguesa
	10	Canada	Denmark	Denmark	Columbia	Belgium
2017	1	Germany	Holland	Holland	Holland	Holland
	2	America	Columbia	Germany	Germany	Germany
	3	Holland	Germany	America	France	France
	4	Switzerland	Canada	Switzerland	Italy	Italy
	5	France	Kenya	France	Spain	Spain
	6	Italy	Belgium	Columbia	China	China
	7	Britain	Italy	Italy	Kenya	Japan
	8	Austria	Ecuador	Belgium	Ecuador	Poland
	9	Belgium	Spain	Canada	Japan	Portuguesa
	10	Denmark	Denmark	Kenya	Portuguesa	Switzerland
2020	1	Germany	Holland	Holland	Holland	Holland
	2	America	Columbia	Germany	Germany	Germany
	3	Holland	Germany	America	France	France
	4	Britain	Belgium	Britain	Columbia	America
	5	France	Italy	France	Italy	Italy
	6	Switzerland	Kenya	Columbia	Spain	Spain
	7	Italy	Ecuador	Italy	Ecuador	Belgium
	8	Poland	Canada	Belgium	China	Portuguesa

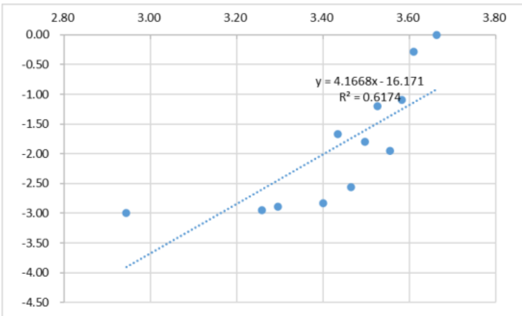
Table 4. (continued).

	9	Austria	Spain	Canada	Kenya	China
	10	Canada	America	Spain	Britain	Kenya
2023	1	America	Holland	Holland	America	America
	2	Germany	Columbia	Germany	Holland	Holland
	3	Holland	Ecuador	America	Germany	Germany
	4	Britain	Canada	Columbia	Columbia	Britain
	5	France	Italy	Britain	Britain	France
	6	Italy	Germany	Italy	Italy	Belgium
	7	Switzerland	Kenya	France	France	Poland
	8	Poland	Belgium	Canada	Ecuador	Portuguesa
	9	Canada	Spain	Ecuador	Belgium	Japan
	10	Belgium	America	Belgium	Spain	Italy

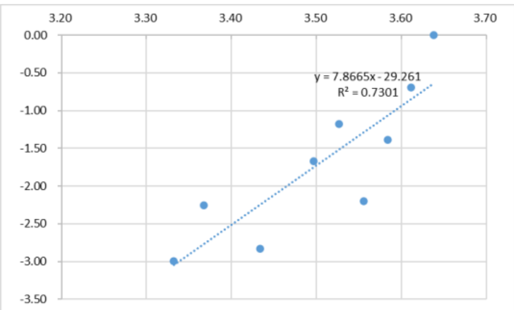
In the power law distribution analysis of weighted degree, it can be found in Figure 2 that from 2014 to 2020, the relationship between weighted degree and variables is getting stronger and stronger, and the explanatory power of the model is also increasing, indicating that the core-edge structure of the global flower trade network may become more obvious, and the influence of core countries is increasing. However, the slope and coefficients of the fitted formula in 2023, indicating a decrease in the relationship between weighting and variables and the explanatory power of the model.



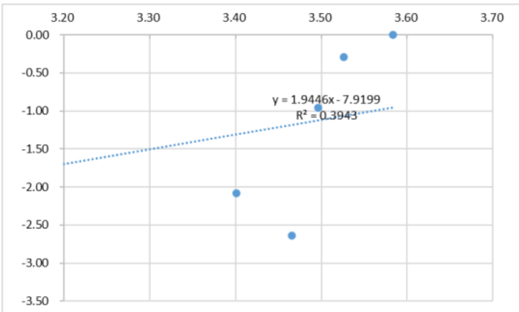
(A) 2014



(B) 2017



(C) 2020



(D)2023

Figure 2. Power law distribution diagram of the world flower trade weighted degree

4.3. Core-edge model analysis

Core-edge model is a model that describes the network structure used to distinguish between core and edge nodes in the network. Using the core-periphery model to analyze global flower trade in 2014, 2017, 2020, and 2023, countries with a node centrality greater than 0.06 are classified as core countries, those with a centrality between 0.06 and 0.01 as semi-peripheral countries, and those with a centrality below 0.001 as peripheral countries. The core-periphery structure of the global flower trade network has remained relatively stable, with the Netherlands and Germany consistently in the core area, indicating their dominant position. The core status of the UK, France, and Italy fluctuates, reflecting their secondary status. Semi-peripheral countries like Belgium and Kenya maintain moderate importance in most years. Countries such as Spain, Portugal, and others are in the peripheral area, with low centrality, indicating a minor role. In the future, the status of these countries may change with shifts in the global economy and trade environment.

Table 5. Core-edge model of the Global Flower Trade Network in 2014-2023

	2014		2017		2020		2023	
	country	Core degree	country	Core degree	country	Core degree	country	Core degree
Core Area	Holland	0.95	Holland	0.984	Holland	0.983	Holland	0.96
	Germany	0.259	Germany	0.145	Germany	0.159	Germany	0.234
	Britain	0.114	Britain	0.067	Britain	0.062	Britain	0.086
	France	0.072	—	—	—	—	France	0.063
	Italy	0.061	—	—	—	—	Italy	0.06
Semi-Marginal Area	Belgium	0.053	France	0.041	France	0.042	Belgium	0.05
	Kenya	0.035	Belgium	0.032	Belgium	0.03	Poland	0.038
	Switzerland	0.031	Italy	0.029	Italy	0.03	Kenya	0.032
	Denmark	0.029	Kenya	0.021	Kenya	0.018	Switzerland	0.029
	Austria	0.026	America	0.018	Denmark	0.017	Denmark	0.025
	China	0.022	Denmark	0.016	Switzerland	0.016	Spain	0.022
	Poland	0.02	Switzerland	0.015	Poland	0.015	America	0.017
	America	0.02	Austria	0.012	America	0.011	Ecuador	0.015
	Czechia	0.018	Spain	0.011	Austria	0.01	Czechia	0.012
	Ecuador	0.013	Poland	0.01	Spain	0.01	Columbia	0.011
	Columbia	0.011	—	—	—	—	China	0.01
	—	—	—	—	—	—	Portuguesa	0.01
Marginal Area	Spain	0.008	China	0.007	Czechia	0.008	Japan	0.008
	Portuguesa	0.007	Czechia	0.006	China	0.006	Austria	0.004
	Japan	0.003	Ecuador	0.006	Ecuador	0.004	Canada	0.003
	Canada	0	Canada	0.002	Portuguesa	0.004	—	—
	—	—	Columbia	0.002	Columbia	0.003	—	—
	—	—	Japan	0.002	Japan	0.002	—	—
			Portuguesa	0.002	Canada	0	—	—

5. Analysis of the influencing factors of the global flower trade network

5.1. Variable selection and model construction

The QAP (Quadratic Assignment Procedure) model is a method for comparing the similarity or correlation between two matrices and is often used in social network analysis. QAP regression analysis is aimed at the regression relationship between a specific relationship matrix and multiple attribute matrices. In order to better reflect the influencing factors of flower trade, explanatory variables are set from the perspective of flower planting, combined with flower transportation, national politics, economy and culture.

Table 6. Names and definitions of the explanatory variables

Influencing Factor	Variable Name	Metric	Variable Interpretation
Geographical Factors	Geographic adjacency matrix①	CON	Whether countries are adjacent
	Geographic distance matrix①	DIST	Geographical distance between the most populous cities between countries
Economic Factors	Difference matrix of economic scales②	GDP	The absolute value of the GDP difference
	Difference matrix of per-capita income②	PGDP	The absolute value of the difference in the per capita income level
Political and Cultural Factors	System difference matrix③	DI	Differences in global government governance indicators between countries
	Language adjacency matrix①	LANG	Whether the language is the same between countries
Resource Factors	Fresh water resources per capita difference matrix②	WAT	The absolute value of the difference in inland fresh water resources between countries
	Workforce quantity difference matrix②	LAB	The absolute value of the difference between the population aged between 15 and 64

Data source: ① French CEPII database, ② World Bank database

Combined with the above 8 explained variables, the QAP model of the global Flower Trade network is set as:

$$W = f(CON, DIST, GDP, PGDP, DI, LANG, WAT, LAB)$$

W is the bilateral trade volume matrix of global flowers.

5.2. Results of the QAP correlation analysis

QAP analysis was conducted using Ucinet6 software, and the number of displacement was set to 5000 to test the relationship between the eight explanatory variables and the global flower trade network.

Table 7. Regression results of QAP model for global flower trade

VARIABLE	2014	2017	2020
DI	-0.088**	-0.071	-0.065**
GDP	0.160***	0.089**	0.122***
LAB	-0.02*	-0.007	-0.017*
PGDP	0.124**	0.096***	0.099**
WATER	-0.026***	-0.027***	-0.022**
CON	0.245**	0.243**	0.257**
DIST	-0.224***	-0.225***	-0.233***
LANG	0.022**	0.022*	0.024**

According to the QAP model regression results in Table 7, it can be observed that institutional distance has a significant negative impact on flower trade in 2014 and 2020. GDP, per capita GDP, language, and geographical proximity all have a significant positive impact on flower trade in all years. Linguistic similarity promotes flower trade to some extent, and countries that are geographically close are more likely to engage in flower trade, which is why European countries occupy an important position in global international trade. Water resources and geographical distance have a significant negative impact on flower trade in all years.

6. Conclusion

As an important part of the international trade, the global flower trade not only has a significant impact on the economy, but also plays an important role in the cultural exchange and environmental protection. With the acceleration of globalization, the complexity and dynamics of flower trade network are increasing, so it is particularly important to conduct systematic analysis. By constructing and analyzing the global flower trade network from 2014 to 2023, this paper reveals its structural characteristics and evolution law, and analyzes the key factors affecting the global flower trade by using the QAP model.
The research shows that the global flower trade network has an obvious core-edge structure, among which the Netherlands, Germany and the United States and other countries are in the core position, showing its leading role in the global flower trade. These countries not only excel in flower exports and imports, but also remain high in the centrality index of the network. Moreover, the global flower trade network showed high stability, and the status of the core countries showed little change during the study period, which may be related to the strong flower production capacity and mature trade infrastructure in these countries.

As can be seen from the regression results of the QAP model, the economic development level (GDP, GDP per capita) and geographical proximity had a significant positive impact on the flower trade in all years, indicating that the economically developed countries and countries with close geographical locations occupy an important position in the flower trade. Conversely, water richness has a significant negative impact on flower trade, probably because water-rich countries prefer to produce locally rather than import. In addition, the similarity of language also promotes the flower trade, indicating that the proximity of language and culture can promote the development of trade.

References

[1] NIISATO Y, BAE K, MIYABE K. Dynamics of East Asian flower economies: China, Japan and Korea; proceedings of the 3rd Asian Horticultural Congress (AHC), Bangkok, THAILAND, *F Dec 15-17, 2020 [C]*. 2021.
[2] SEONG-HWAN S, KIM S. Analysis of Export Competitiveness and Intra Industry Trade of Korean Flower: Focusing on Roses, Chrysanthemums, and Lilies [J]. *Korean Journal of Agricultural Management and Policy*, 2021, 48(1): 106-32.
[3] ROMBACH M, DEAN D L, WIDMAR N J O, et al. The Ethically Conscious Flower Consumer: Understanding Fair Trade Cut Flower Purchase Behavior in Germany [J]. *Sustainability*, 2021, 13(21).
[4] ERDDS P, WI A. On random graphs I [J]. *Publ math debrecen*, 1959, 6(290-297): 18.
[5] Zhou Mozhu, Wang Jianyong. Evolution and enlightenment of the global rice trade pattern based on complex networks [J]. *Journal of Natural Resources*, 2020,35 (5): 1055-67.
[6] Liang Maolin, Hong Chrysanthemum, Luo Huasong, et al. Study on the spatial and temporal evolution of the APEC trade network structure and its influencing factors [J]. *World Regional Studies*,2024,33(1).
[7] SERRANO M A, BOGUNá M. Topology of the world trade web [J]. *Physical Review E,* 2003, 68(1): 015101.
[8] LI X, JIN Y Y, CHEN G. Complexity and synchronization of the world trade web [J]. *Physica A: Statistical Mechanics and its Applications*, 2003, 328(1-2): 287-96.
[9] FAGIOLO G, REYES J, SCHIAVO S. On the topological properties of the world trade web: A weighted network analysis [J]. *Physica A: Statistical Mechanics and its Applications,* 2008, 387(15): 3868-73.
[10] FAGIOLO G, REYES J, SCHIAVO S. The evolution of the world trade web: a weighted-network analysis [J]. *Journal of Evolutionary Economics*, 2010, 20: 479-514.

[11] SNYDER D, KICK E L. Structural position in the world system and economic growth, 1955-1970: A multiple-network analysis of transnational interactions [J]. *American journal of Sociology*, 1979, 84(5): 1096-126.
[12] WU G, PU Y, SHU T R. Features and evolution of global energy trade network based on domestic value-added decomposition of export [J]. *Energy*, 2021, 228.
[13] CHEN W, WANG X, LONG Y, et al. Resilience Evolution of the Trade Networks in Regions along the Belt and Road [J]. *Economic Geography*, 2024, 44(1): 22-31.
[14] MA J L, ZHAO P F, FENG J L, et al. The evolution and robustness analysis of global soybean trade network [J]. *International Journal of Modern Physics C*, 2024.
[15] SUN X, WEI Y, JIN Y, et al. The evolution of structural resilience of global oil and gas resources trade network [J]. *Global Networks-a Journal of Transnational Affairs*, 2023, 23(2): 391-411.
[16] WANG J, DAI C, ZHOU M, et al. Research on global grain trade network pattern and its influencing factors [J]. *Journal of Natural Resources*, 2021, 36(6): 1545-56.
[17] KRACKHARDT D. Predicting with networks: Nonparametric multiple regression analysis of dyadic data [J]. *Social networks*, 1988, 10(4): 359-81.
[18] BORGATTI S P, EVERETT M G. Notions of position in social network analysis [J]. *Sociological methodology*, 1992: 1-35.
[19] Wei Suhao Wei. Agricultural trade between China and "One Belt and One Road" countries: Network structure, correlation characteristics and strategy selection [J]. *Agricultural economic problems*, 2018, (11): 101-13.
[20] XU H, CHENG L. The QAP weighted network analysis method and its application in international services trade [J]. *Physica A: Statistical Mechanics and Its Applications*, 2016, 448: 91-101.