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Analysis on the spatial pattern and evolution of China's petroleum trade under the dual effect of international oil price and “Belt and Road” Framework

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ABSTRACT

“Belt and Road” is the important origin of oil import in China. Based on social network analysis and stochastic frontier gravity model, this paper studied the characteristic evolution and influence factor of oil import network between China and “Belt and Road” countries. Then by constructing a stochastic frontier gravity model including the crude oil future price and oil importing price, it found that the international crude oil future price, the oil importing price, the political situation, the trade agreements have the effects on the China's oil import from “Belt and Road” region. It provided suggestions for improving the spatial pattern of China's petroleum trade.

1. Introduction

In the year 2020, China was one of the few countries where oil consumption had increased, with an increase of 0.22 million b/d (Qiu et al., 2022). China's dependence on foreign crude oil was constantly increasing. The “2018 Domestic and Foreign Oil and Gas Industry Development Report” released by the Economic and Technological Research Institute of China National Petroleum Corporation (CNPC) says that in 2018, China's oil import was 440 million tons, up 11% year-on-year, and the dependence on foreign oil rose to 69.8%. According to the forecast of IEA, the ratio will exceed 75% in 2030 (Kong et al., 2017). There are major hidden dangers in China's petroleum security. According to the UN Comrades database, from 2014 to 2016, China's oil imports from the “Belt and Road” countries accounted for more than 66% of the total imports. With the further deepening cooperation in trade between China and the “Belt and Road” countries, the study of oil trade between them is of great significance to safeguarding China's oil security.

Although China has surpassed the United States to become the largest oil importer in 2016, and its import volume accounted for 16.3% of the world's total oil trade, it does not change the situation that China has a low say in international oil prices. On March 26th, 2018, the Shanghai Petroleum Exchange launched crude oil futures for the first time, marking the beginning of China's participation in international crude oil pricing and the establishment of an international crude oil futures market centered on China.

With this background, this paper is to study the oil trade relationship between China and countries along the “Belt and Road”. First, this paper explores the current situation and evolution characteristics of China's oil trade in the “Belt and Road” oil trade network by means of social network analysis. Then, by constructing a stochastic frontier gravity model, it examines how the international crude oil futures price and other factors affect the oil trade between China and the “Belt and Road” countries, which provide suggestions for Shanghai Petroleum Exchange on how to promote the consolidation of oil trade between China and the “Belt and Road” countries.

2. Literature review

Since Serrano and Boguná (2003) put forward the topological

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structure of the world trade network, Bhattacharya et al. (2008) studied the construction of the weighted international trade network model and further improved the International Trade Network (ITN), more scholars have begun to use complex networks to analyze international energy trade (Zhong et al., 2017; Gao et al., 2015; Ji et al., 2017).

One of the research directions was the overall pattern and characteristics of the global crude oil trade network. Some scholars all used complex networks to study the global and regional structure of the world crude oil network (Yang et al., 2015), others divided different periods according to the changes of international oil prices, and studied the evolution characteristics of international oil trade network in different periods (Jia et al., 2015; Li et al., 2022; Wang et al., 2022).

Another research direction mainly focused on the relationship and evolution characteristics of major trading countries in the international crude oil trade network. Du et al. proposed that the study of international crude oil trade should focus on the analysis of core trading countries, and combined input-output analysis and top-level network analysis to study the influence of major countries in the oil trade network (Du et al., 2017). Toshibiko and Shunsuke combined a gravity model and a complex relationship network to study the contribution of countries and mutual relationships in bilateral oil trade (Toshihiko and Shunsuke, 2017). Zhang et al. studied the structural characteristics and evolution of the competition networks among importing countries in global crude oil trade (Zhang et al., 2014). Wang et al. also studied the evolution characteristics of dependency systems among 38 major crude oil importing countries from the perspective of global crude oil import network (Wang et al., 2016). Xia and Du studied the evolution of energy trade structure in the 21st Century Maritime Silk Road and its trade relations with China (Xia and Du, 2022). The oil trade network in a specific region or country. Ma and Xu studied the structure and influencing factors of the oil trade network of countries along the Silk Road (Ma and Xu, 2016).

To sum up, scholars have conducted in-depth analyses of the relationship and evolution characteristics of oil trade networks in individual countries, regions, and multiple countries by means of complex networks. However, few scholars have paid attention to the network characteristics and changes of the oil trade between China and the “Belt and Road” countries, as well as the impact of international oil futures prices on China's oil trade with the “Belt and Road” countries. Therefore, this paper applies social network analysis to the study of the evolution of China's characteristics in the world and the “Belt and Road” oil trade network, and uses the stochastic frontier gravity model to examine the intermediary effects of international crude oil futures price and other factors on the oil trade between China and the “Belt and Road” countries. Accordingly, it proposes suggestions on how Shanghai Petroleum Exchange can further promote the oil trade between China and the “Belt and Road” countries, master the international oil pricing power and ensure the security of China's oil imports.

3. Models and data

3.1. The construction of oil trade network

The oil trade network established in this paper is divided into two parts: the world oil trade network and China's oil import network from the “Belt and Road” countries. The trade relationship between any two countries in the oil trade network is represented by the corresponding value t_{ij} (i=j=N) in the trade weight matrix. Trade network can be divided into weightless network and weighted network according to whether it reflects the difference in trade intensity between the two parties. In the weightless network, if country i exports oil to country j, then $t_{ij}=1$, otherwise $t_{ij}=0$. In the weighted network, t_{ij} reflects the trade intensity between country i and j. In this paper, t_{ij} refers to the actual oil export from country i to country j. Based on the directed weightless and weighted network of the world and “Belt and Road” region, this paper makes a centrality analysis of China's position in the world oil trade network, compares the competition degree with major oil importing countries, and analyzes the stability of the “Belt and Road” countries' oil imports to China.

(1) Analysis on centrality of international oil trade network.

In this paper, two indicators, point degree and point intensity, are used to reflect the change of China's centrality in international oil trade. In the directed weightless network, the point degree of each node is divided into point-in degree and point-out degree. The point-in degree, $k_i^{\text{in}}=\sum_{j=1}^{N} t_{ji}$, and the point-out degree, $k_i^{\text{out}}=\sum_{i=1}^{N} t_{ij}$, respectively represents the number of oil importing and exporting countries. In the directed weighted network, k_i^{in} and k_i^{out} represent the country's oil import and export respectively, reflecting the country's import and export intensity.

(2) Comparison of competition degree with major oil importing countries.

In order to compare the degree of competition between China and major oil importing countries for oil imports from the “Belt and Road” countries, this paper refers to the study of Zhang et al. (2014) and adopts the following measurement indicator.

$$S(ij)=\sum_c\left\{\left(\frac{M_{ic}+M_{jc}}{M_{\text{W}}}\right)+\left[1-\frac{\left|\frac{M_{ic}}{M_i}-\frac{M_{jc}}{M_j}\right|}{\left(\frac{M_{ic}}{M_i}\right)+\left(\frac{M_{jc}}{M_j}\right)}\right]\right\} \tag{1}$$

Here, i and j represent oil-importing countries, c represents the common export country. M_i, M_j and M_{W} represent the total crude oil imports of country i, country j and the world respectively. The indicator shows the similarity of oil import structure of country i and country j. The greater the similarity, the more intense the competition.

(3) Analysis on the stability of China's oil import from “Belt and Road” countries

Countries along the “Belt and Road” are important sources of China's oil imports, but most of the countries with large export volumes located in the Middle East, where the political situation is turbulent and unpredictable. Therefore, by referring to the study of Ji et al. (2017), this paper uses the following method to measure the stability (CV) of China's oil imports from the “Belt and Road” countries.

$$CV=\sum_{i=1}^{n} P_i * \frac{X_i}{X_W} * d_i^{-1} \tag{2}$$

Here, i represents the “Belt and Road” country that exports oil to China. P_i refers to the political stability of the exporting country and the corresponding data are from the International Country Risk Guide. X_i is the total oil exports of country i, and is the total oil exports in the world. d_i represents the geographical distance between exporting country and China. Generally speaking, the transportation distance between countries is inversely proportional to the availability of resources and the safety of transportation. $CV(i)$ refers to the stability of China's oil import when country i stops its oil import to China. Therefore, the impact of country i on the stability of China's oil import $M(i)$ is expressed as follows:

$$M(i) = \frac{CV - CV(i)}{CV} \tag{3}$$

3.2. The construction of stochastic frontier gravity model

In recent years, many domestic and foreign scholars have used the stochastic frontier gravity model to study the trade and outwork investment between countries. In China, with the development of the “Belt and Road” strategy, China's trade cooperation with the countries along the route has become closer, more and more scholars apply the stochastic frontier gravity model to the study of the efficiency and potentials of trade and outward investment between China and the “Belt and Road” countries. Therefore, this model is also used to explore the efficiency and potentials of oil trade between China and the “Belt and Road” countries in this paper, as well as the influencing factors. Here, American WTI crude oil futures price and Chinese oil import price from the “Belt and Road” area are chosen as the core explanatory variables of the stochastic frontier gravity model. Then the impacts of price fluctuation in the international crude oil futures market on China's oil imports from the “Belt and Road” region are investigated by constructing the intermediary effect model of China's oil import prices on oil imports from the “Belt and Road” countries.

The formula for calculating the efficiency of international trade by using Aigner's stochastic frontier gravity model is as follows:

$$T_{ijt} = f(x_{ijt}, \beta)\exp(v_{ijt})\exp(-u_{ijt}), (u_{ijt} > 0) \tag{4}$$

Take the logarithm of the formula as follows:

$$\ln(T_{ijt}) = \ln f(x_{ijt}, \beta) + v_{ijt} - u_{ijt}, (u_{ijt} > 0) \tag{5}$$

Here, T_{ijt} represents the trade volume between two countries. x_{ijt} refers to the factors such as GDP, population, geographical distance between two countries that affect trade. v_{ijt} is a random error that obeys $N(0, \sigma_v^2)$ distribution. u_{ijt} is trade inefficiency, being independent from v_{ijt}, and is generally considered to obey the truncated or semi-normal distribution. Its positive value indicates that there is an obstacle to the trade between two countries. When trade inefficiency does not exist:

$$T_{ijt}^* = f(x_{ijt}, \beta)\exp(v_{ijt}) \tag{6}$$

Here, the trade value T_{ijt}^* just falls on the stochastic frontier, indicating the potential maximum of trade between the two parties, that is, the trade potential. The ratio of T_{ijt} to T_{ijt}^* is the trade efficiency.

$$TE_{ijt} = \frac{T_{ijt}}{T_{ijt}^*} = \exp(-u_{ijt}) \tag{7}$$

The original stochastic frontier model assumed that trade efficiency was constant over time, while Battese and Coelli proposed a time-varying model of stochastic frontier function, which could measure the trade efficiency over time (Battese and Coelli, 1995). The formula is as follows:

$$u_{ijt} = \{\exp[-\eta(t-T)]\}u_{ij} \tag{8}$$

Here, η is an estimation parameter. If $\eta > 0$, it means that the trade inefficiency decreases with time, and vice versa; If $\eta=0$, it means that the trade inefficiency is invariant with time and it is a time-invariant model. Battese and Coelli (1995) put forward a trade inefficiency function to estimate the influencing factors of trade inefficiency. The formula is as follows:

$$u_{ijt} = z_{ijt}\delta + W_{ijt} \tag{9}$$

z_{ijt} is the relevant variable that hinders trade efficiency. δ is correlation coefficient. W_{ijt} is a random disturbance term subject to truncated normal distribution with the mean value of 0 and the variance of δ^2.

In the study, China's oil import from the “Belt and Road” countries from 2000 to 2021 is the explained variable (y). The annual average price of WTI crude oil futures (*future*) and China's oil import price (*price*) are the core trade explanatory variables of the model. Shao et al. (2017) found that the crude oil output and consumption of crude oil in exporting countries had a significant impact on China's oil imports when examining the influencing factors of China's oil imports from 55 countries. In this paper, we use China and exporting countries' GDP (*GDP*1, *GDP*2), geographical distance (*dist*), whether there is a common border (*border*), whether it is a landlocked country (*land*), oil output (*output*) and consumption (*consume*) of exporting countries as other trade explanatory variables.

As for the influencing factors of trade inefficiency, some scholars believe that trade agreements, tariffs and other artificial obstacles should be chosen. Considering the availability of data, the following four types of variables are selected in this paper: (1) Which organization the exporting country belongs to: whether the exporting country belongs to OPEC (*OPEC*) and WTO (*WTO*). (2) The political environment: the political stability (*politic*), the efficiency of the government (*govern*), and the quality of regulation (*regulate*) of the exporting country. (3) Market economy environment: the economic freedom (*economic*) of exporting country, and the ratio of FDI net inflow to GDP (*FDI*). (4) Marine transport facility: the customs clearance time of the exporting country.

In order to investigate the intermediary effect of WTI crude oil price in the United States on China's oil imports from the “Belt and Road” countries, the price of oil import (*price*) is used as an intermediary variable, and the stochastic frontier gravity model and the inefficiency model are constructed as shown below:

$$\begin{cases} (1)\ln y = \beta_0 + \beta_1 \ln future + \beta_2 \ln GDP1 + \beta_3 \ln GDP2 + \beta_4 \ln dist + \beta_5 border \\ +\beta_6 land + \beta_7 \ln output + \beta_8 \ln consume + v_{ijt} - u_{ijt} \\ (2)\ln y = \beta_0 + \beta_1 \ln future + \beta_2 \ln price + \beta_3 \ln GDP1 + \beta_4 \ln GDP2 + \beta_5 \ln dist \\ +\beta_6 border + \beta_7 land + \beta_8 \ln output + \beta_9 \ln consume + v_{ijt} - u_{ijt} \\ u_{ijt} = \alpha_0 + \alpha_1 OPEC + \alpha_2 WTO + \alpha_3 politic + \alpha_4 govern + \alpha_5 regulate \\ +\alpha_6 \ln economic + \alpha_7 FDI + \alpha_8 \ln time + \varepsilon_{ijt} \end{cases} \tag{10}$$

In this paper, the trade inefficiency model is introduced to the stochastic frontier gravity model, and the "one-step method" is adopted to estimate the effects of trade explanatory variables and inefficiency variables on China's oil imports.

3.3. Data source

Data of China's oil imports from the "Belt and Road" countries from 2000 to 2016 comes from the UN Comrades database. Data of oil output and consumption of exporting countries come from BP World Energy Statistics Yearbook 2017. The annual average price of WTI crude oil futures in the United States is from the U.S. Energy Information Administration (EIA). The price of oil imports is the average of oil export value divided by export volume of the "Belt and Road" exporting countries. The data of GDP of China and the exporting countries, the proportion of FDI net inflow of exporting countries, and the customs clearance time of export are from the World Development Indicators in the database of the World Bank, in which the GDP is in 2010 constant US dollars. The political stability, government efficiency and quality of regulation in exporting countries come from the Global Governance Indicators in the World Bank database. The data of geographical distance between China and the exporting countries, whether there is a common border and whether China is a landlocked country comes from the French CEPII database and the world map. The data of economic freedom of exporting countries comes from Fraser Institute. The missing values of some year are estimated by average values.

4. Analysis of oil trade network

4.1. Analysis of the centrality of the world oil trade network

The world oil trade network in 2001 and 2021was respectively drawn with the help of Ucinet6.0, and the centrality analysis was carried out. The results are shown in Figs. 1 and 2.

In Figs. 1 and 2, the size of each node represents the country's oil import, and different colors represent different continents. In the world oil trade network in 2001, as shown in Fig. 1, it can be found that the United States is the largest oil importer, while China's oil import is not only lower than some European countries such as Germany and Sweden, but also lower than some Asia-Pacific countries such as Japan and South Korea. In the trade network in 2021, as shown in Fig. 2, the number of major trading countries has increased significantly, and the connections between the nodes are denser, which indicates that the number of oil trading objects in different countries in the world is growing and their connections are more closely. In terms of oil imports, China surpassed the United States as the largest oil importer. Compared with the condition in 2001, the number of nodes in China's oil trade network increases, so does the source of oil imports, indicating that China's influence on international oil trade has increased, and its trade status has improved significantly.

4.2. Evolution of "Belt and Road" oil import network

China's oil import networks from the "Belt and Road" countries in 2001 and 2021 are shown in Figs. 3 and 4.

In Figs. 3 and 4, compared with 2001, China's oil imports from the "Belt and Road" countries increased significantly in 2021. In 2001, only Iran exported more than 10 million tons of oil to China, but by 2021, ten countries exported more than 30 million tons to China, five of which were Middle Eastern countries. From 2001 to 2021, the Middle East has always occupied the core position of China's oil imports with the "Belt and Road". But in recent years, the proportion of China's oil imports from Russia is growing continuously, from 4.6% in 2001 to 15.5% in 2021, which makes the proportion of Middle Eastern countries in China's oil imports from the "Belt and Road" declined from 84.4% in 2001 to about 60% in 2021. Compared with other exporting countries, at present China mainly relies on increasing oil imports from Russia to avoid oil import risks in the Middle East. But the key to ensure the security of oil imports lies in the "Diversification" of imports. Some scholars found that Kazakhstan, Azerbaijan, and other countries in Central Asia have strong oil export capacity. China should enhance the oil trade cooperation with these countries in Central Asia to further ensure the stability of China's oil import from the "Belt and Road" countries.

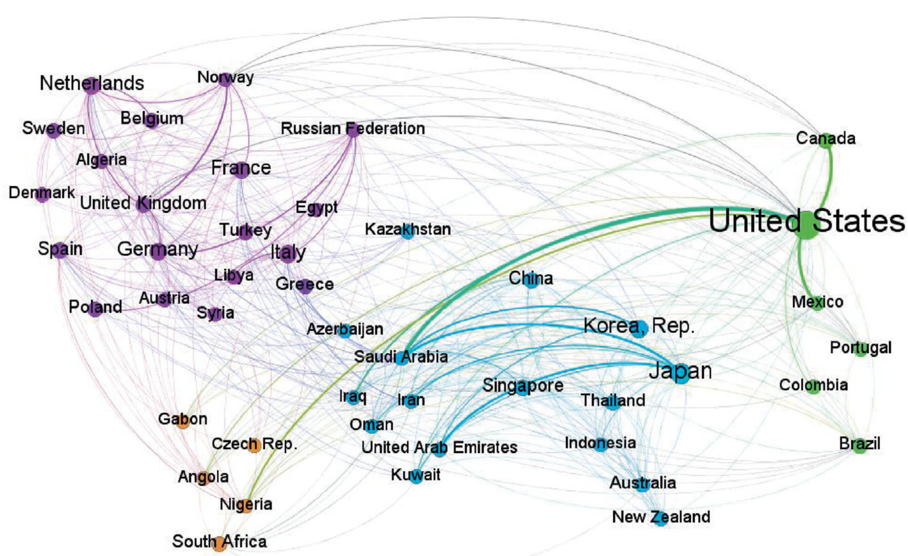

Fig. 1. World oil trade network, 2001.

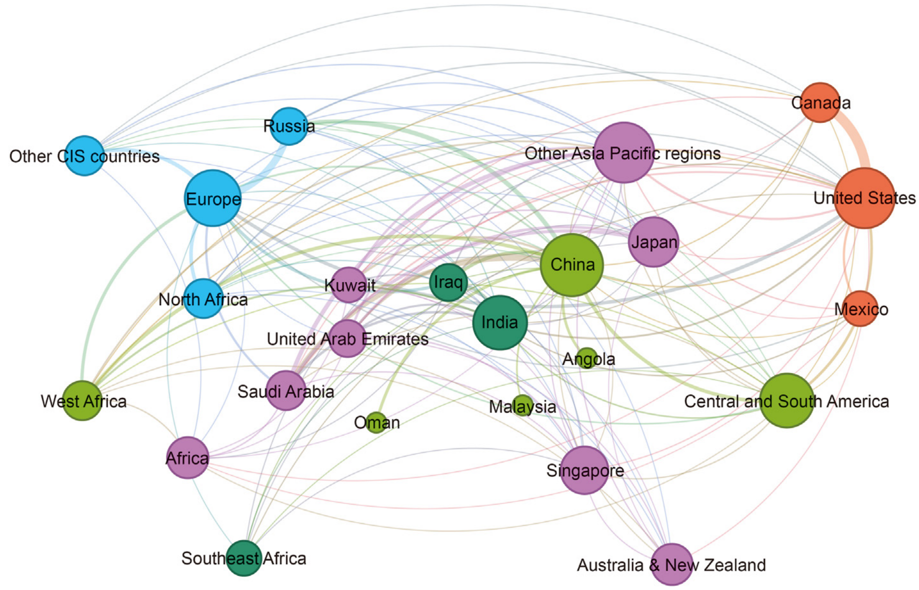

Fig. 2. World oil trade network, 2021.

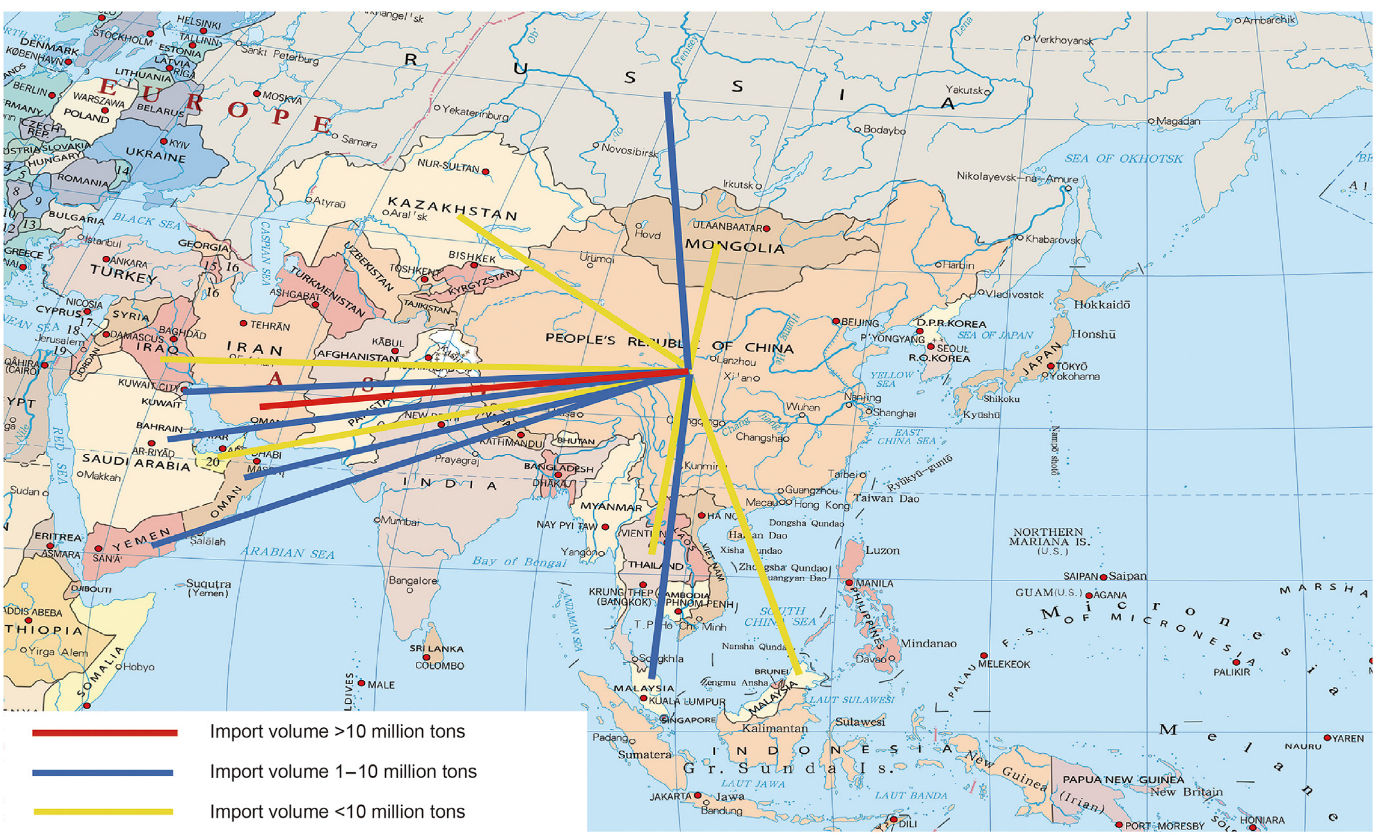

Fig. 3. China's oil import network from the "Belt and Road" countries, 2001.

5. Analysis on influencing factors of oil import from the "Belt and Road" countries

5.1. Preliminary regression results

Combined with the oil trade network and its evolution characteristics, 12 countries in the "Belt and Road" region are selected as the objects for this study, including Russia, Saudi Arabia, Iraq, Oman, Iran, Kuwait, United Arab Emirates, Kazakhstan, Indonesia, Vietnam, Thailand, and Malaysia. This paper applies the stochastic frontier gravity model to the study of the influence of international crude oil futures prices on China's oil imports, while previous studies mainly used the national oil imports as the explanatory variable when studying the international crude oil futures prices. In

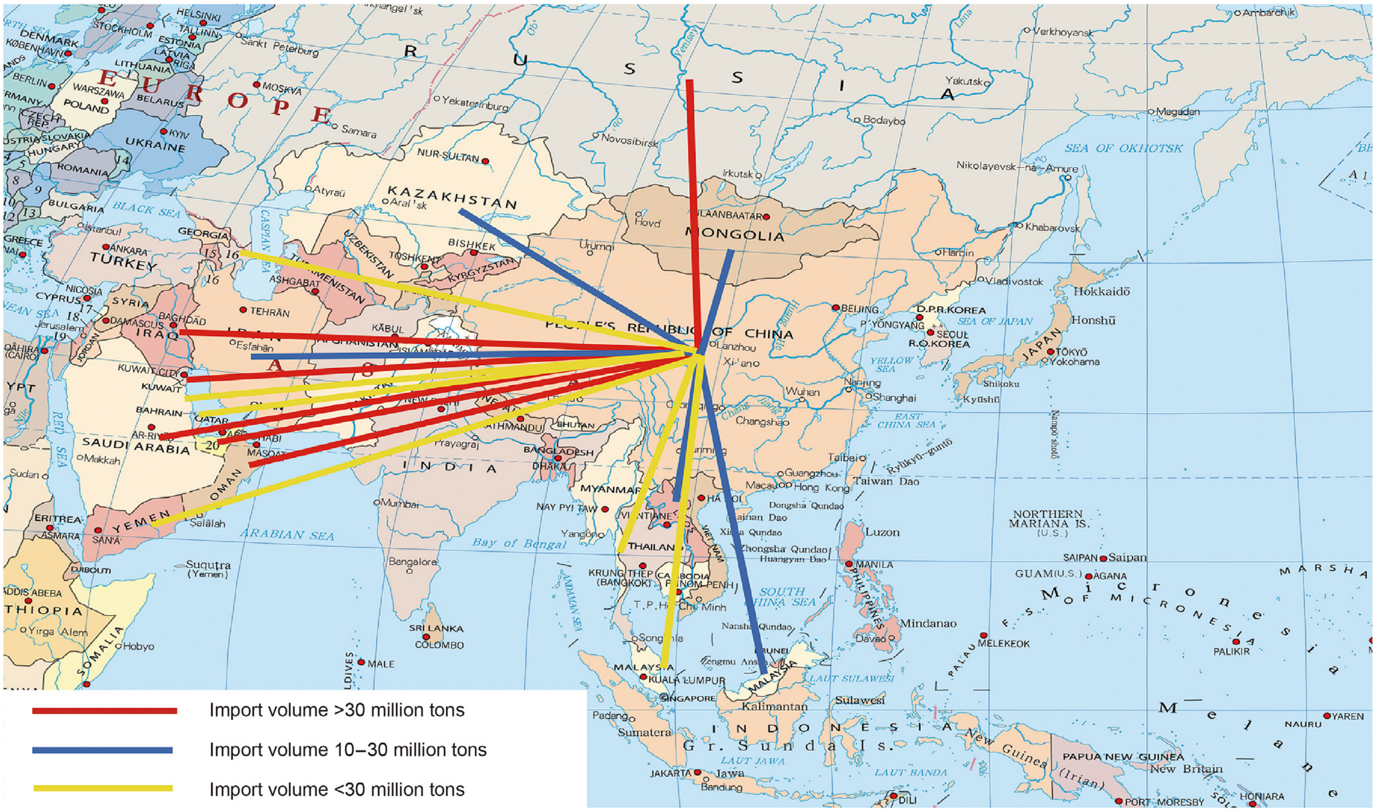

Fig. 4. China's oil import network from the "Belt and Road" countries, 2021.

Table 1
Granger causality test results.

	ln*future* → ln*y*		ln*y* → ln*future*	
	Lag order	*p*-value	Lag order	*p*-value
Indonesia	4	0.006	4	0.407
Iran	4	0.820	4	0.825
Iraq	5	0.131	5	0.092
Kazakhstan	2	0.004	2	0.137
Kuwait	5	0.000	5	0.000
Malaysia	4	0.000	4	0.067
Oman	2	0.029	2	0.189
Russia	4	0.067	4	0.000
Saudi Arabia	4	0.023	4	0.453
Thailand	1	0.001	1	0.153
United Arab Emirates	5	0.000	5	0.000
Viet Nam	3	0.005	3	0.001

this paper, firstly, we build the VAR model of international crude oil futures prices and China's oil imports, and check the relationship between them by Granger causality test. The LLC method is used to perform panel unit root test on variable ln*y* and ln*future*. The original hypothesis of unit root is rejected at the level of 1%, which means that the data is stable. The results of Granger tests of oil imports from 12 countries and the WTI futures prices are shown in Table 1.

In Table 1, all other countries are below the 10% except Iran and Iraq, and it can be considered that the WTI futures price is the Granger cause of oil import. It is reasonable to explore the influence of international crude oil futures prices on China's oil imports along the "Belt and Road".

5.2. Stochastic frontier gravity model

The maximum likelihood estimation stochastic frontier gravity mode was used to further verify the influence of international crude oil futures prices on China's oil trade and measure the inefficiency of China's oil trade with the "Belt and Road" countries. To determine whether trade inefficiency exists and whether it is time-varying, the maximum likelihood ratio test is performed on the model first. The results are shown in Table 2.

In Table 2, the null hypothesis that trade inefficiency does not exist at the level of 1% is rejected, and the maximum likelihood estimation stochastic frontier gravity model should be adopted. Moreover, the null hypothesis of trade inefficiency is also rejected, which indicates that trade inefficiency varies with time. The time-varying model is more suitable. As for the two core explanatory variables, the null hypothesis without them is also rejected, indicating that WTI futures prices and other variables should be included in the model. In order to further verify the intermediary effect of oil import price, this paper introduces the WTI crude oil futures price and the oil import price to the stochastic frontier gravity model, adopts the estimation method of efficiency time-varying model proposed by Battese and Coelli (1992), and combine the efficiency time-invariant model for estimation and comparison. At the same time, the inefficiency model is also added to the stochastic frontier gravity model, and the "one-step method" estimation is adopted with the help of Frontier4.1. The regression results are shown in Table 3.

According to Table 3, WTI futures prices are significantly positive in regression in Eqs. (2) and (5) that do not include the oil import price, while WTI coefficients are still significant in Eqs. (3) and (6) that include the oil import price, and the coefficients of oil import price are also significantly negative, which is consistent with the

Table 2
Maximum likelihood ratio test results.

Null hypothesis	Constraint model ln(*H*0)	Unconstrained model ln(*H*1)	*LR*	Critical value (1%)	Conclusion
No trade inefficiency	−475.458	−464.698	21.52	9.21	Reject
Trade inefficiencies are constant	−472.368	−464.478	15.78	6.63	Reject
Without WTI futures price	−481.860	−464.478	34.764	6.63	Reject
Without oil import price	−478.862	−464.478	28.768	6.63	Reject

Note: $LR = 2[\ln(H1) - \ln(H0)]$.

Table 3
Estimation results of stochastic frontier gravity model.

Explanatory variable	Explained variable ln*y*						
	Time-varying model			Time-invariant model		Inefficiency model	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ln*future*		1.368*** (2.59)<	9.273*** (6.18)<		1.671*** (3.08)<	10.222*** (6.60)<	0.924*** (13.63)<
ln*price*			−7.793*** (−5.56)<			−8.544*** (−5.83)<	−0.160*** (−8.90)<
ln*GDP*1	−0.522 (−0.34)<	−0.854 (−1.11)<	0.554 (0.82)<	1.697*** (3.86)<	0.508 (0.88)<	1.801*** (3.07)<	1.334*** (92.50)<
ln*GDP*2	1.414 (1.43)<	1.352 (1.45)<	1.130 (1.31)<	1.394 (1.43)<	1.382 (1.43)<	1.205 (1.20)<	0.039 (0.55)<
ln*output*	2.624*** (4.02)<	2.510*** (5.07)<	2.227*** (5.04)<	2.160** (4.57)<	2.185*** (4.68)<	2.022*** (4.28)<	1.042*** (25.48)<
ln*consume*	−2.812** (−2.27)<	−2.655** (−2.51)<	−2.238** (−2.43)<	−2.272** (−2.30)<	−2.280** (−2.34)<	−2.050** (−2.09)<	−0.585*** (−9.04)<
Cons	23.338 (0.53)<	28.776 (1.30)<	6.245 (0.33)<	−35.550 (−2.17)<	−7.203 (−0.39)<	−24.886 (−1.35)<	−17.156*** (−36.95)<
Politic							−4.708*** (−6.22)<
Govern							−2.277*** (−3.06)<
Regulate							17.743*** (27.27)<
ln*economic*							−8.389*** (−11.42)<
OPEC							16.346*** (3.85)<
η	0.146*** (4.12)<	0.134*** (4.26)<	0.114*** (4.01)<	_	_	_	_
δ^2	6.159	6.830	6.932	68.63	46.604	13.330	25.60
γ	0.037	0.152	0.274	0.898	0.857	0.576	0.99
Logarithmic likelihood value	−482.103	−478.862	−464.478	−492.604	−487.983	−472.367	−284.376

regression results in Table 2. It shows that the international crude oil futures price affects China's oil import from the “Belt and Road” region by influencing the oil import price. Among the three types of regression results of time-varying model, the coefficients of η are significantly positive at the level of 1%, which is consistent with the test results of the maximum likelihood ratio above, indicating that trade inefficiency exists and decreases with time. With the development of bilateral trade between China and the “Belt and Road” countries, the scale of oil trade with the “Belt and Road” countries tends to be growing gradually, and the trade efficiency of both sides is increasing. In the regression results of the two models, WTI futures prices are all significantly positive at the level of 1%, and ln*price* in Eqs. (3) and (6) are also significantly negative, further verifying the preliminary regression results. Currently, the crude oil futures of Shanghai Petroleum Exchange can be used to attract investors from the “Belt and Road” countries, so as to avoid the continuous and substantial increase of international oil prices through the price discovery function of the futures market. Except for the oil output and consumption of exporting countries, the coefficients of land are significantly negative at the level of 10% in all six regression results, indicating that the land-locked exporting country will restrain the oil trade with China. According to ITNs 3 and 4, most of China's oil exporters along the “Belt and Road” area are coastal countries, and oil are mainly transported by sea. Therefore, it is necessary to take precautions against the corresponding transportation risks.

In the estimation results of the inefficiency model, OPEC, the inefficiency variable, is significantly positive at the level of 1%, which indicates that the exporting country will establish more oil trade barriers with China if it belongs to OPEC. As the main source of China's oil imports, OPEC countries maintain great influence on international oil prices by coordinative production, and China is in a relatively passive position in the oil trade between the two sides. Therefore, it is necessary to improve the diversification of China's oil exporters and gradually reduce the share of OPEC countries in China's oil imports. The coefficients of Politic and Govern in the inefficiency variable are both negative at 1% level, which indicates that the oil import of China still comes from the countries with relatively turbulent domestic political situation. While the coefficient of Regulate is significantly positive at 1% level and relatively large, indicating that the improvement of control quality in oil-exporting countries will significantly increase the trade friction between the two sides. Therefore, in order to avoid the risk of China's oil import, countries with stable political situation and good diplomatic relations with China should be considered in priority when increasing the number of the oil exporters along the “Belt and Road”. In addition, the Index of Economic Freedom of exporting countries are all significantly negative at the 1% level, indicating that the more convenient the market investment and the smaller the tariff barriers, the greater the possibility of oil trade with China. Shanghai Futures Exchange can give priority to investors with relatively free market economy environment in the “Belt and Road” region when attracting oil futures investors.

5.3. Estimation of trade inefficiency model in different types of countries

Through the estimation of the inefficiency model above, it is found that whether the exporting country is an OPEC country has a significant impact on China's oil imports, and there is a big gap between the two types of countries in terms of trade efficiency. It is necessary to study the factors affecting China'oil imports with OPEC and non-OPEC countries respectively. Therefore, this paper divides the sample into two parts according to whether it is an OPEC

Table 4
Regression results of different types of countries.

		Explained variable lny	
		OPEC	Non-OPEC
Trade explanatory variables	ln*future*	3.933***(9.14)	1.110***(13.25)
	ln*price*	−3.872***(−8.47)	−0.494***(−11.90)
	Other variables	Control	Control
	Cons	4954.80***(4960.39)	8.367***(12.97)
Inefficiency variable	WTO	−14.123***(10.45)	−12.22***(−11.03)
	Politic	3.06***(2.92)	−14.127***(12.62)
	Govern	−3.763***(−3.63)	7.852***(7.45)
	Regulate	11.827***(10.69)	14.328***(13.28)
	FDI	−1.554*(−1.55)	3.992***(3.96)
	δ^2	33.565***(23.31)	36.66***(11.98)
	γ	0.99***(3448786)	0.99***(5322466)
	Logarithmic likelihood value	−106.857	−137.447
	Sample size	85	119

Note: *, **, and *** indicate significant levels at 10%, 5%, and 1%, respectively.

country, and estimates the inefficiency model separately. The results are shown in Table 4.

According to Table 4, after classifying and regressing the samples, the WTO coefficient of the inefficiency variables is significantly negative, which indicates that whether for OPEC or non-OPEC countries, the entry of exporting countries into the WTO will reduce the oil import trade friction with China few can further promote the signing of the FTA between China and the “Belt and Road” oil-exporting countries and reduce trade barriers such as tariff barriers between both sides. For OPEC countries, the improvement of political stability will not significantly boost their oil trade with China, because the OPEC countries that export large amounts of oil to China are Saudi Arabia, Iran and Iraq, where the political stability is relatively lower according to the World Bank's Global Governance indicators. However, compared with non-OPEC countries, the improvement of government efficiency in OPEC countries will promote the oil trade with China. Therefore, when the domestic political situation of exporting countries in the Middle East is turbulent, we should try our best to reduce the oil imports. Moreover, the coefficient of FDI in OPEC countries is significantly negative at 1% level, which indicates that the increase of the proportion of external investment will reduce the barriers to China's oil trade. We can increase overseas investment in OPEC countries in the “Belt and Road” region and improve the mutual trade relations.

6. Conclusions and suggestions

6.1. Conclusions

This paper studies the evolution of China's oil import network from the “Belt and Road” countries and the factors that influence the oil import by combining social network analysis and stochastic frontier gravity model. Through analyzing the oil trade network, we found that China's dependence on oil imports in recent years is much greater than that of other countries. The “Belt and Road” region is the main source of China's oil imports, and the oil imports from this region continues to increase from 2000 to 2021. At the present stage, we should focus on reducing risks and increasing the diversification of import sources from the “Belt and Road” areas. The Middle East countries, as the central region of China's “Belt and Road” oil import, are not only the focus of competition for oil resources between China and major importing countries, but also an important guarantee for the security of China's oil supply. At this stage, while exploring more oil import sources in Central Asia and Southeast Asia, we must also pay attention to maintaining the oil trade relationship between China and Middle East countries. In addition to the Middle East, Kazakhstan, Azerbaijan and other countries in the Central Asia region have strong oil export capacity. We should further strengthen the cooperation with the Central Asia region. For the south-east Asian countries, we should further improve the trade relationship with Indo-China Peninsula, so as to promote the establishment of new oil transportation pipelines. Ensure the safety of China's oil imports from the sources of oil imports and transportation modes.

By constructing a stochastic frontier gravity model including the intermediary effect of oil import price, we found that WTI futures price inhibits China's oil import from the “Belt and Road” countries by influencing the oil import price. At present, China's oil trade is dominated by the price of international crude oil futures market, being affected directly or indirectly by the international crude oil futures price. Therefore, we are trying to establish a crude oil futures trading market, with the participation of the “Belt and Road” countries, in case of international oil price being completely controlled by other countries. And through the trade inefficiency model, we found that the development of bilateral trade between China and the “Belt and Road” countries would effectively reduce the resistance of oil import. It is necessary to further deepen the “Belt and Road” strategy and improve the trade cooperation between China and oil exporting countries along the route, so as to establish a relatively stable “Belt and Road” oil supply chain.

6.2. Suggestions

Based on the above empirical analysis, this paper puts forward the following suggestions on how the Chinese government can further promote China's oil trade with the “Belt and Road” countries and how to obtain the right to speak on international oil prices:

In the post-epidemic era, uncertainties in the global energy market have increased, and many countries are also using new energy investments as an important means to promote economic recovery. The energy landscape is being reshaped accelerately. We should accelerate the research on key technologies and equipment in the field of new energy and improve the structure of energy consumption.

Build an oil pricing center in the Asia-pacific region including countries along the “Belt and Road”. Currently, there is no unified pricing standard for crude oil futures in the Asia-pacific region. Shanghai Futures Exchange can attract crude oil futures investors from the “Belt and Road” countries by providing a more convenient trading platform and reducing the entry restrictions of foreign-funded enterprises, thus gradually expanding the trading scale, enhancing the influence on international oil prices, and establishing a pricing system of crude oil futures in the Asia-Pacific region.

As the situation in Russia and Ukraine continues to deteriorate, the game around energy is escalating, and the international oil trade pattern is undergoing profound changes. China should guarantee the security of Sino-Russian oil trade, strengthen cooperation with OPEC, and promote the cooperation between China and Kazakhstan, Azerbaijan and other countries in Central Asia as well as Southeast Asian countries in the field of oil and gas. According to the results of the stochastic frontier gravity model, the entry of the exporting country into the WTO and the relatively free economic environment will promote the oil trade with China. Therefore, we should deepen the economic and trade cooperation with them by signing FTA with oil-exporting countries and increasing external investment, so as to promote further cooperation in oil trade and pipeline construction.

Expand the coverage of “Belt and Road”, attract more oil-rich countries to join, so as to enhance China's “Belt and Road” oil import diversification with the development of the “Belt and Road” strategy, more and more countries are gradually attracted. Currently, Italy has joined the “Belt and Road” strategy. Angola, Algeria and other countries located in Africa have rich oil resources. We should provide more economic assistance there and strengthen cooperation with these countries, attracting them to join the “Belt and Road” strategy, and promoting cooperation in the field of oil and gas, so as to further increase the source of our “Belt and Road” oil imports.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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