Research on Combined Optimization of Intercontinental Intermodal Transport Scheme by Railway Network and Double Difference Model

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Abstract. The China-EU freight train is a physical link connecting the Eurasian continent in the new era and a new bridge for expanding China-EU economic and trade cooperation. Since its opening in 2011, China-EU freight trains have developed rapidly. Since 2015, it has been normalized and fixed, and now it has entered a stage of steady growth. Based on the trade gravity model, this paper calculates the trade gravity coefficients between China and the rest of the world in 2015 and 2019, and then establishes the analysis and construction of China-EU freight trains and cross-border transport models. The combined optimization of intercontinental transport scheme and regional transport scheme is constructed, which is composed of tractor, semi-trailer and intercontinental railway intermodal transport. The transport network of this model consists of two types of nodes: multimodal transport station and highway transport station. Based on the double difference regression analysis of gravity coefficient, it is concluded that the central attractiveness of trade between China and the rest of the world is relatively low in the past, but under the overall downward trend of trade attractiveness between China and the rest of the world, the China-EU train has significantly promoted the growth of trade in recent years, which is attractive.

Keywords: China-EU freight train, transnational land transport, China-EU trade, attracting investment, regional transport optimization.

1. Introduction
Trade between China and Europe has a long history. Hundreds of billions of dollars’ worth of goods are transported between China and Europe every year [1], mainly by sea and air. International logistics and transport are playing an increasingly important role in international trade. With the introduction of the One Belt and One Road initiative, china-china freight trains have come into being. Since the opening of Chongqing-Xinjiang-Europe railway, all routes of China-Europe freight trains have been running under the strategic concept of Silk Road Economic Belt.

The opening of the china-Europe train service is a landmark achievement in deepening the "One Belt and One Road" initiative and an important step in China's all-round opening-up. On March 19, 2011, the first China-Europe freight train was successfully launched [2], marking a milestone in the supply chain transformation in the era of globalization. In the international trade transport mode, sea transport
and air transport occupy the absolute dominant position. The China-Europe freight train will change this pattern and become the third major mode of transport. The China-Europe freight train has optimized the transport structure and industrial layout and provided strong support for economic and trade exchanges between China and the countries along the One Belt and One Road route [3]. It has become the route with the closest links between China and the countries along the route. As an important lever and carrier to promote the smooth trade flow of One Belt and One Road, the China-China freight train is unleashing greater trade channel potential. At present, the China-Europe freight train service has achieved normalized scale operation and is moving forward from quantity growth to high-quality development. The Sino-European class has added a new option to the sino-European trade logistics transportation mode, which greatly improves the trade attraction between China and Europe.

2. Review

The goal of China's Silk Road Economic Belt strategy is to establish China's trans-continent cooperation Dr. Chen Lingling 1 Zhai Huiying 2 Corresponding author Zhang Yuanyuan 1 Wang Jianping 1 (1, North China Institute of Science and Technology; Abstract: The China-Europe freight train is a physical link connecting The Eurasian continent in the new era, and a new bridge to expand trade and economic cooperation between China and Europe [4]. Since its launch in 2011, the China-Europe freight train has developed rapidly. Since 2015, it has been normalized and immobilized, and now it has entered a stable growth stage. Based on the trade gravity model, this paper calculated the 2015 and 2019, China and the gravity coefficient of all countries in the world, and the gravity coefficient of double difference regression analysis, the conclusion is: the central attraction between trade is relatively low in the past, but in China with the rest of the world trade appeal under the overall downward trend, China-EU trains significantly promoted the trade in recent years, attractive, and successfully eliminated the trade gravity initial disadvantage[5]. The development of trade needs passageways, and the construction of passageways will also drive the growth of trade. The China-Europe freight train is a physical link connecting The Eurasian continent in the new era and a new opportunity to expand trade and economic cooperation between China and Europe. It has only been 5 years since the large-scale and regular operation of China-Europe freight trains began. Therefore, the relevant research literatures on China-Europe freight trains are mainly concentrated in recent years.

Zhao Yongbo and Guo Miao (2017) used the trade gravity model to discuss the role of the planned western corridor of China-Europe freight train in enhancing the trade potential between countries along the route and China. The research shows that when the western corridor of the China-Europe freight train is completed, the trade potential of countries along the route to China will be effectively enhanced. Yu Min and Liu Yiming (2019) used the trade gravity model to analyze the trade data between China and European countries, and found that the number of China-Europe freight trains is increasing rapidly, the trade volume between China and Europe is accelerating, and the trade attraction between China and Europe is increasing. Wang Xiongyuan and Bu Loufan (2019) found that since the opening of the China-Europe freight train, the level of international trade liberalization and facilitation among countries along the route has been significantly improved. Chen Wenhe and Chang Zhipeng (2019) studied the characteristics and influencing factors of trade networks in countries along the China-Europe freight train line, and found that: the density of trade networks in countries along the freight train line is on the rise, and the opening of the freight train line between China and Europe has an obvious promoting effect on trade between countries. Fang Xingming and Lu Yuxiu et al. (2020) evaluated the impact of the opening of China-Europe freight trains on urban trade openness, and found that the opening of China-Europe freight trains significantly improved urban trade openness, and the degree of impact was directly positively correlated with the opening of urban freight trains.
3. Analysis and Construction of China-EU Freight Train and Cross-Border Transportation Model

3.1. Model analysis

In view of the intercontinental railway structure of China and Europe trains, the intercontinental trains are assembled and sent through road tractors to multimodal transport stations, and the combination optimization of intercontinental transport scheme and regional transport scheme is constructed, which is the combination network of tractor, semi-trailer and intercontinental railway transportation. The transport network of this model consists of two types of nodes, namely multimodal transport station and highway transport station.

Figure 1. A proposed network for the illustrative example

The main function of intermodal transport stations is train assembly and transmission, connecting road transport and intercontinental railway transport. Multimodal transport stations include both domestic and foreign stations. Intercontinental train transport between domestic and foreign multimodal transport stations is the trunk transport link of the system, and road transport is the branch line freight collection link.

Objective function:

\[
\min z = \sum_{q \in Q} \sum_{i \in V_s} \sum_{j \in V_s} \left( l_{ij}^h \cdot e_i \cdot x_{ij}^t + l_{ij}^b \cdot e_j \cdot x_{ij}^t \right) + \sum_{n \in N} f_n \cdot e_n \cdot \beta_n
\]  

In this model, the total path cost (total fuel consumption) of the road-rail multimodal transport system is used as the objective function. It includes domestic road freight collection path cost and international railway transport path cost, in which domestic road cargo collection path cost includes the cost of tractor driving alone and trailer semi-trailer driving.

Each tractor is only allowed to drive alone and towed semi-trailer on each path, which ensures that the combination of tractor and semi-trailer can be realized.

\[
\sum_{i \in V_s} \left( x_{ij}^t + x_{ij}^d \right) = \sum_{k \in V_s} \left( x_{ij}^t + x_{kj}^t \right), \quad j \in V_s, q \in Q
\]
Only when the hub node is selected as the hub station can the OD flow be regarded as served by that node and brought into the calculation.

\[ Y_k \geq X_{ij}^{km} \geq 0, i, j, k, m \]  \hspace{1cm} (4)

\[ Y_m \geq X_{ij}^{km} \geq 0, i, j, k, m \]  \hspace{1cm} (5)

The number of hub stations should conform to the total quantity limit

\[ \sum_k Y_k = P, \forall k \]  \hspace{1cm} (6)

3.2. Example and analysis

In the intercontinental intermodal transport network of this problem, B ranges from 5000 to 14000km. In the domestic railway transport network, according to the competitiveness of railway and road transport in different distances, the range of H is 600 to 2000 km, and its range is set according to the following two situations:

\[ \begin{cases} [100, 200] km \in V_{dh}, j \in V_{dh} \\ [150, 300] km \in V_{dh}, j \in V_{dm} \end{cases} \]  \hspace{1cm} (7)

The transportation demand of this problem includes three categories, 1 range from 0 to 5 containers, 2 ranges from 0 to 10 containers, and 3 ranges from 10 to 30 containers.

From the specific point of view of China's cross-border transport mode, in 2015, there were 2.503 million inbound and outbound vehicles, 1.3632 million inbound and outbound trains, 474200 inbound and outbound ships and 744200 inbound and outbound aircraft. In 2019, there are 34.8668 million incoming and outgoing vehicles, 3.1692 million incoming and outgoing trains, 454500 incoming and outgoing ships and 1.0846 million incoming and outgoing aircraft. The rapid increase in the mode of entry and exit of trains and the decrease of the mode of entry and exit of ships indicates that the land trade transport mode represented by the Central European class is replacing the previous shipping and accelerating the trade circulation of the countries along the Eurasian Continental Bridge.

**Figure 2.** Data of China Europe Freight Train From 2011 to 2019
4. Trade attraction between China and Europe

4.1. The research methods

Trade gravity model is the most commonly used model to study trade attraction. The idea of trade gravity model comes from physicist Newton's law of gravitation. James Stewart applied gravitation to social science research for the first time. Isard & Peck (1954) intuitively discovered the law of larger trade flows between countries with closer geographical positions. Tinbergen (1962) and Poyhone (1963) were the first to use gravity model to study bilateral trade flows, and they came to the conclusion that the bilateral trade size of two countries is in direct proportion to their economic size, and inversely proportional to the distance between the two countries. Tinbergen's trade gravity model can be summarized as follows:

\[ T_{ij} = k \frac{Y_i Y_j}{d_{ij}} \]  

(8)

It should be noted, however, that the above model is a static model, because the trade gravity constant reflecting the size of the trade attraction does not change. In fact, in the dynamic process, the trade barriers between countries will change, and the transport efficiency in geographical distance will also change. Therefore, as time changes, the gravity constant \( k \) of trade will change, so it is no longer appropriate to call it a constant, and we will refer to it as the gravity coefficient of trade here. Through Equation (1), the formula of trade gravity coefficient can be deduced as follows:

\[ k_t = T_{ij} \frac{d_{ij}}{Y_i Y_j} \]  

(9)

In equation (2), the subscript \( t \) is added to represent the \( T \)-th phase. As for the research in this paper, because of the opening of China-Europe freight train and the increasing number of running Banks, the trade convenience between China and Europe is improved, so the trade attraction should increase \( k_t > k_{t-1} \) over time. However, China-EU trade is also affected by the whole global economy and trade environment, so it is inevitable to draw wrong conclusions when analyzing the change of the gravity coefficient of China-EU trade separately. In order to exclude the influence of global economy and trade environment on Sino-European trade, so as to obtain the real influence of Sino-European freight train on sino-European trade attraction, the double difference model is selected in this paper to decompose the change of \( k_T \). Let 2015 be the base period, expressed by \( t=0 \), and 2019 be the cumulative development period of the China-Europe freight train effect (2019 is selected as the effect development period in this paper, because it is assumed that the change of the gravity of the China-Europe freight train on the trade between China and Europe is a gradual accumulation process, so 2016-2018 is the window period), and expressed by \( T=1 \). The countries in The European region are denoted by \( D=1 \), and the countries outside Europe are denoted by \( d=0 \). The double difference model is as follows:

\[ k(t, d) = \alpha + \beta \cdot t + \gamma \cdot d + \delta \cdot (t \cdot d) \]  

(10)

4.2. The empirical analysis

First of all, according to the total amount of China with other countries import and export data (monthly statistics from Chinese General Administration of Customs), China's GDP data and the national GDP data (from the IMF's world economic outlook report), linear distance to the world's capital, the capital of China (measured from Google map) to calculate the coefficient of China and the countries of the world's trade gravity, received data in 177 countries. Then, the time variable \( T \) and the locale variable \( D \) were set, and OLS regression was carried out according to the double difference model (3). The regression results were shown in Column (0). The regression results show that, and are not significant, only the coefficient is. The regression results were not significant, possibly because some of the world's small countries with large random errors in their trade gravity coefficients might need to be excluded. The first step is to exclude countries with GDP less than us $10 billion in 2015, and then reduce the
sample number to 128. The regression results showed that and were not significant, and the coefficients and were significant. In the second step, countries with GDP less than US $20 billion in 2015 are excluded, and the number of sample countries is reduced to 102. The regression results showed that and were not significant, and the coefficients and were significant. Continue adding the exclusion criteria until step five excludes countries with 2015 GDP of less than US $50 billion.

After exclusion, the number of sample countries is reduced to 77. At this time, the regression results show that all the coefficients of the model are significant. It shows that the trade gravity coefficient of small countries does have a large random error, which affects the robustness of the model. After excluding countries with a GDP of less than US $50 billion in 2015, the significant regression results are as follows:

\[ k(t,d) = 61.49 - 18.92 \cdot t - 36.11 \cdot d + 40.11 \cdot (t \cdot d) \]  

(11)

The constant term coefficient = 61.49 indicates that the average trade gravity coefficient outside the base period is 61.49. The coefficient of time variable = -18.92, indicating that the overall gravity coefficient of trade between China and the rest of the world dropped by 18.92, which is consistent with the trend of anti-globalization in recent years, the trade war between China and the United States, and the transformation of China’s economy to consumption dominated by domestic demand. Regional difference coefficient = 36.11, indicating that the European region has a lower trade gravity coefficient than other regions, which is consistent with the geographical distance between China and Europe and the inconvenient trade transportation. The effect coefficient = 40.11, the sign of the coefficient is positive, which is consistent with the theory, indicating that the China-Europe freight train has effectively improved the trade attraction between China and Europe. Shows that the effect of the China-Europe freight train is greater than the regional difference of trade attraction between China and Europe, so the freight train eliminates the disadvantage of trade between China and China, and makes the current trade attraction between China and China slightly higher than that of other regions.

5. Evaluation of the train operation plan for China and Europe
The operation of CEIBS trains is unique and cannot be judged only in terms of costs and benefits. The greater benefit of the CEIBS train is to promote the domestic industry to the world and drive the development of the countries along the CEIBS train, so this paper uses the DEA algorithm to evaluate.

5.1. Model building
DEA is a typical multi-input and multi-output evaluation method. This paper deals with the weight with the help of the cone ratio model, and then uses the C2R model to solve it.

Suppose that in Decision Making units (DMU) are evaluated, and each DMU \( j = 1,2, L, n \) L has f inputs and g outputs. That is, the input vector \( j \quad X_j = (x_{1j}, x_{2j}, L, x_{fj})^T \), and the output vector \( j \quad Y_j = (y_{1j}, y_{2j}, L, y_{gj})^T \). Ijx represents the input quantity of the ith index of the JTH DMU; Rjy represents the output of the RTH index of the JTH DMU, 1, 2, L, f, g cross L.

Let the optimal solution of the above model be \( \lambda^*, s^*, s^{**}, S^* \), then

(1) When \( \delta_j^* = 1, s^{**} \neq 0, s^{*+} \neq 0 \) DMU \( j \) is weak DEA valid.
(2) When \( \delta_j^* = 1, s^{*+} = 0, s^{**} = 0 \) DMU \( j \) is DEA valid
(3) When \( \delta_j^* M1, \) DMU \( j \) is DEA invalid
5.2. Entropy weight method is used to determine the weight of indexes

Entropy weight method is applicable to a wide range and can be applied to the sum of indexes of all evaluation problems. In this paper, entropy weight method is used to determine the weight of input index and output index in DEA method.

There are an evaluation items and m evaluation indicators, which constitute the matrix \( R = (r_{ji})_{nm} \), where \( r_{ji} \) refers to the evaluation value of the ith index to the JTH project. The specific layout is as follows:

Calculate the proportion of the ith index to the index value

\[
P_{ji} = \frac{r_{ji}}{\sum_{j=1}^{n} r_{ji}}
\]  

The entropy value of the ith index, \( e_i \), was calculated

\[
e_i = -k \sum_{j=1}^{n} p_{ji} \cdot \ln p_{ji}
\]  

Calculate the entropy weight of the ith index \( I \)

\[
\omega_i = \frac{1-e_i}{\sum_{i=1}^{m} (1-e_i)}
\]  

6. Conclusion

The empirical results show that the trade attraction between China and the rest of the world has declined in recent years, but the China-Europe freight train has significantly improved the trade attraction between China and Europe. Based on this result, from a macro point of view: if China's overall import and export volume rises, then the total import and export volume between China and The European region will surely rise rapidly led by the China-Europe freight train. If The total import and export volume of China as a whole decline, then the total import and export volume of China and The European region must decline slowly led by the China-Europe freight train.

The macro data validates the empirical analysis results of this paper. Conclusion the development of trade needs channels, and the construction of channels will also promote the growth of trade. The China-EU freight train is a physical link connecting the Eurasian continent in the new era and a new opportunity to expand China-EU economic and trade cooperation. In recent years, thanks to the "Belt and Road Initiative" initiative, the China-EU freight train has been gradually accepted by the vast number of customers in China and Europe because of its advantages such as safety, speed, green and less affected by the natural environment. it has become the third way of logistics in China-EU trade besides shipping and air transportation. According to the data of China-EU freight trains, since the successful opening of the China-EU freight train in 2011, the number of China-EU freight trains and freight volume have increased rapidly. Since 2015, China-EU freight trains have been normalized and fixed. At present, the freight train between China and Europe has gone from the early stage of rapid growth to the stage of steady growth. Land trade transport, represented by the China-Europe class, is replacing the past sea transport and speeding up trade exchanges between countries along the Eurasian Continental Bridge. Based on the international trade gravity model, this paper calculates the trade gravity coefficient between China and the rest of the world in 2015 and 2019, and makes a double difference regression of the trade gravity coefficient. The regression results show that during the period from 2015 to 2019, the trade
gravity coefficient between China and the rest of the world has generally declined, accompanied by the reality of anti-globalization in recent years, trade war with China, and the fact that China's economy is dominated by domestic consumption.

The improved DEA method is used to evaluate it, this model does not rely on subjective evaluation, and entropy weight method is used to improve its shortcomings, so as to make the evaluation results more effective and reliable. According to the evaluation results, it can be concluded that the operation of China-Europe trains has made a qualitative leap in quantity, and there is still a lot of room for development in quality; if the operation plan is not effective, the China-Europe trains can reduce the safety accident rate and transportation time, and increase travel speed, transport value and other aspects to achieve the goal of improving capacity utilization and plan realization rate.

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