Research on the Matching of the Demand and Capacity of China-Mongolia Erenhot Port Trade and Railway Corridor Transportation Under the Belt and Road Initiative Based on the Grey Correlation Method and Countermeasures

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Abstract: As the strategic carrier of China's Belt and Road Initiative, Russia's Trans-Eurasian Corridor, the China-Mongolia-Russia Economic Corridor is a significant platform for strengthening international trade cooperation and enhancing international competitiveness. Erenhot, a city located in north China, serves as both the only railway port on the China-Mongolia border and the largest land port in connection with those countries, and also connects the most accessible transportation hubs in Eurasia. The grey correlation method provides a quantitative measurement of the development and change of a system, which is very suitable for dynamic process analysis. In this paper, the indicators and the data from the foreign trade and transportation development level of the Erenhot Port are taken as examples to build a multi-index chain correlation analysis and verification model. The grey correlation method was first used to make the index selection, the grey system theory was applied to make the correlation degree calculation, the VAR model was employed to conduct the correlation analysis among relevant indicators, and the ADF method was used to make the stationary test. The test result shows that the foreign trade volume is co-integrated with the import and export volume of railway cargo and has no positive correlation with the development level of regional railway transportation. In view of the test results and the increasing foreign trade of the Erenhot Port, railway corridors should be further developed, and the railway transportation level should be improved, thus providing strong support for the rapid development of the regional economy under the Belt and Road Initiative.

Keywords: The Belt and Road; Port transportation; Grey correlation method; VAR model; Railway transportation

1. INTRODUCTION

As an important node of the Belt and Road Initiative, the Erenhot Port is the only railway logistics port connected with the Silk Road Economic Belt, and its cargo transportation capacity is of great practical significance to foreign trade and regional economic cooperation and development. Based on the current situation of port economic development, relevant domestic scholars have conducted in-depth research on the analysis and evaluation of

MSEA 2023, May 26-28, Nanjing, People's Republic of China

DOI 10.4108/eai.26-5-2023.2334476

transportation efficiency, development strategies and utilization countermeasures of railway ports. Gao[1] analyzed the current situation of railway ports and the problems of transportation organization, and proposed to improve the efficiency of port transportation by strengthening organizational leadership and building a joint labor collaboration mechanism; Han[2] established a logistics network evaluation system based on purchaser-supplier relationship analysis to study the unstable factors affecting the organizational structure in the development of railway logistics; Wang[3] constructed the evaluation system of the development demand for China-Mongolia ports in Inner Mongolia Autonomous Region based on the principle of border trade and geo-economic related theories, and concluded that the ports have low transport capacity and poor logistics traffic; Zhang[4] analyzed the influence of the plan layout on the transport capacity according to the demand characteristics of the railway logistic parks with port service. Moreover, Li[5] focused on the key role of functional zoning, development path, freight volume prediction, investment and construction and transportation mode, and other aspects of the western inland railway port construction, and took the planning of Chongqing Railway Port in the Chongqing Western Modern Logistics Industry Park as an example for analysis, as shown in Figure 1.

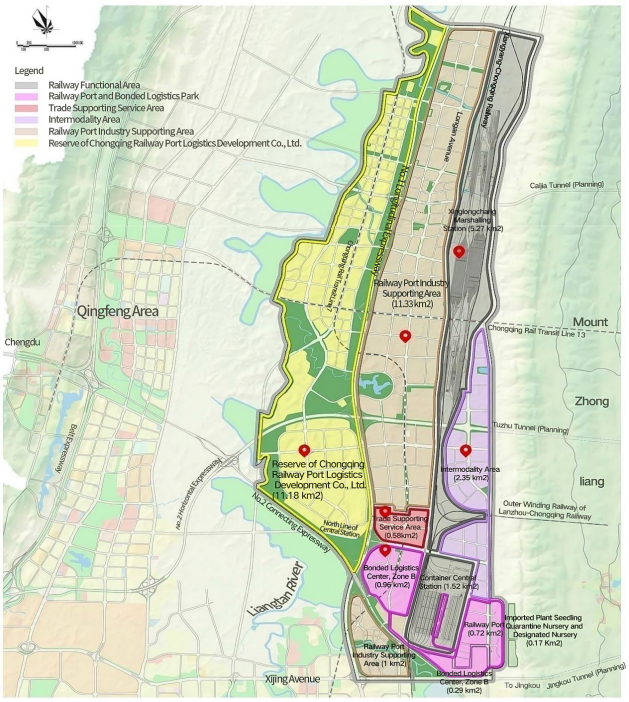

Figure 1 Planning of Chongqing Railway Port in the Chongqing Western Modern Logistics Industry Park

To sum up, the existing port logistics development is mainly based on policy analysis and development strategy for macroscopic research, with less relevant analytical research grounded on theory. Considering the actual situation of Erenhot port trade, this paper adopts the grey correlation method to determine the correlation between the indicators of foreign

trade and the logistics development level of this port, and initially clarifies the relationship between the growth of foreign trade and port logistics development. On this basis, it selects the factors that are more correlated with the foreign trade turnover of Erenhot Port, employs the co-integration theory, and establishes the VAR model to study the correlation among them.

2. ANALYSIS OF THE CORRELATION BETWEEN FOREIGN TRADE DEVELOPMENT LEVEL AND PORT LOGISTICS INDICATORS OF THE ERENHOT PORT

2.1 Selection of grey correlation indicators

Port logistics has been gradually formed and developed into an emerging concept with the deepening of people's understanding, and there is a lack of unified quantitative indicators to describe its development level and difficulty in collecting data about its added value, total logistics, logistics cost and employees. To ensure the reliability of the research, the ideal data should be preferably obtained by field research. However, since it requires a lot of human and financial resources to conduct field research, and it is unrealistic to obtain individual data over a longer period of time, the raw data in this paper are taken from the statistical data and yearbooks of Chinese and Mongolian statistical departments.

According to the research on the development level of foreign trade and logistics indicators of Erenhot Port, this paper uses the port foreign trade turnover (X_0) to indicate the development level of foreign trade, the port import turnover (X_1) and the port export turnover (X_2) to reflect the development status of port foreign trade, and the overall import volume of port cargo (X_3) and the overall export volume of port cargo (X_4) to mirror the port logistics scale. Among them, the import and export volume (X_5) of railway ports and the import and export volume (X_6) of highway ports are used to measure the development level and effectiveness of logistics of railway ports and highway ports respectively, and the correlation analysis[4] related indicators are established by considering the development level of port foreign trade, the scale of port logistics, and the effectiveness of port logistics, as shown in Table 1.

Table 1 Indicator System for Correlation Analysis of Foreign Trade and Port Logistics of the Erenhot Port

Target	Criterion	Specific Indicator
Port Foreign Trade Throughput (Unit: RMB hundred million)	Effectiveness of Port Foreign Trade	Port Foreign Trade Turnover X_0
		Port Import Turnover X_1
		Port Export Turnover X_2
Port Logistics Throughput (Unit: 10 kt)	Scale and Effectiveness of Port Logistics	Overall Cargo Import Volume X_3
		Overall Cargo Export Volume X_4
		Railway Import and Export Volume X_5
		Highway Import and Export Volume X_6

Considering the data availability and accuracy, the time series of 2010-2019 was selected, and the data were obtained from the annual government reports of China and Mongolia and the statistics bureaus in China and Mongolia, as shown in Table 2.

Table 2 Raw Data of Foreign Trade and Port Logistics of the Erenhot Port

Indicator	Port Foreign Trade Turnover (RMB hundred million) X_0	Port Import Turnover (RMB hundred million) X_1	Port Export Turnover (RMB hundred million) X_2	Cargo Import Volume (10 kt) X_3	Cargo Export Volume (10 kt) X_4	Railway Import and Export Volume (10 kt) X_5	Highway Import and Export Volume (10 kt) X_6
2010	182.22	120.32	61.89	651.87	210.27	743.9	118.24
2011	234.49	148.28	86.21	757.42	272.91	882.26	148.07
2012	254.05	139.38	114.47	826.57	333.79	993.96	166.40
2013	231.80	125.40	106.40	879.83	425.87	1015.60	290.10
2014	222.76	136.03	86.73	914.13	441.80	1052.20	303.70
2015	177.54	104.68	72.87	945.13	457.61	1078.80	323.90
2016	156.13	110.18	45.95	1104.8	330.90	1236.10	204.00
2017	205.03	150.84	54.19	1179.2	323.93	1327.30	175.80
2018	237.98	170.29	67.69	1306.79	349.33	1464.70	191.48
2019	268.60	164.30	104.30	1479.58	352.47	1471.00	361.05

2.2 Determination and analysis of the grey correlation between foreign trade turnover and related indicators of the Erenhot Port

Grey system theory is a new approach to studying the problems of sufficient data, poor information and uncertainties, which was first proposed by Chinese scholar Professor Deng. As a key element of grey system theory, grey correlation analysis is mainly used to judge the degree of correlation between factors in the system according to the similarity of the geometry of the factor change curves, so as to determine the major and minor factors affecting the development of the system, and its basic idea is to evaluate whether the connection is close based on the similarity of the geometry of the series curves. The closer the curves are, the greater the correlation between the corresponding series will be, and vice versa.

(1) Dimensionless processing of raw indicators

Due to the different physical meanings of the factors in the system, the data dimensions may vary, which makes it difficult to compare or obtain the correct conclusion when comparing. Therefore, when conducting grey correlation analysis, dimensionless data processing should be performed. The calculation was conducted as shown in Equation (1).

$$\begin{cases} x_i(k) = \dfrac{x_i^{'}(k)}{\dfrac{1}{m}\sum\limits_{k=1}^{m} x_i^{'}(k)}, i = 0,1,\cdots,n; k = 1,2,\cdots,m \\ x_i(k) = \dfrac{x_i^{'}(k)}{x_i^{'}(1)}, \quad i = 0,1,\cdots,n; k = 1,2,\cdots,m \end{cases} \tag{1}$$

(2) Calculation of correlation coefficients

The correlation coefficient of the corresponding factors of the comparison series and reference series was calculated as shown in Equation (2).

$$\zeta_i(k)=\frac{\min\limits_i\min\limits_k\left|x_0(k)-x_i(k)\right|+\rho\cdot\max\limits_i\max\limits_k\left|x_0(k)-x_i(k)\right|}{\left|x_0(k)-x_i(k)\right|+\rho\cdot\max\limits_i\max\limits_k\left|x_0(k)-x_i(k)\right|},k=1,\cdots,m \quad (2)$$

Where ρ is the discrimination coefficient, and $0<\rho<1$. The smaller the value of ρ is, the greater the difference between the correlation coefficients and the stronger the differentiation ability will be. Generally, ρ is set as 0.5. When the best (or worst) value of each indicator constitutes the reference data column and is used to calculate the correlation coefficient, an improved and simpler calculation method can also be used, written as Equation (3).

$$\zeta_i(k)=\frac{\min\limits_i\left|x_0'(k)-x_i'(k)\right|+\rho\cdot\max\limits_i\max\limits_k\left|x_0'(k)-x_i'(k)\right|}{\left|x_0'(k)-x_i'(k)\right|+\rho\cdot\max\limits_i\max\limits_k\left|x_0'(k)-x_i'(k)\right|},k=1,\cdots,m \quad (3)$$

The correlation between the current situation of foreign trade and the logistics development of various transportation modes of the Erenhot Port was analyzed by the grey correlation method. γ_{0i} indicates the correlation values of the comparison series and the reference series, and a correlation value close to 1 represents a high degree of correlation between the two. γ_{01} stands for the grey correlation of port import turnover to port trade turnover, γ_{02} for the grey correlation of port export turnover to port trade turnover, γ_{03} for the grey correlation of port import volume to port trade turnover, γ_{04} for the grey correlation of port export volume to port trade turnover, γ_{05} for the grey correlation of railway import and export volume to port trade turnover, and γ_{06} for the grey correlation of highway import and export volume to port trade turnover. Table 3 shows the correlation coefficients of relevant indicators of the Erenhot Port.

Table 3 Grey Correlation Coefficients of Foreign Trade Indicators and Related Logistics Indicators of the Erenhot Port

γ_{01}	γ_{02}	γ_{03}	γ_{04}	γ_{05}	γ_{06}
0.8708	0.7936	0.5676	0.5113	0.5829	0.4364
1.0000	0.9945	0.4327	0.4534	0.4560	0.3654
0.6215	0.4903	0.4172	0.5358	0.4637	0.3601
0.6222	0.4887	0.5657	0.6271	0.6009	0.5520
0.8890	0.8189	0.6844	0.5135	0.7331	0.4502
0.8278	0.7334	0.6720	0.3364	0.6428	0.2922
0.7490	0.6333	0.3952	0.5244	0.3969	0.5896
0.6155	0.4821	0.5213	0.9374	0.5166	0.5894
0.6309	0.4985	0.5500	0.7209	0.5509	0.4919
0.8740	0.7972	0.5146	0.5204	0.7892	0.4196

(3) Correlation calculation

The mean values of the correlation coefficients of each indicator of each evaluation object (comparison series) and the corresponding factors of the reference series were calculated

separately to reflect the correlation between each evaluation object and the reference series, which was referred to as the correlation series and noted as Equation (4):

$$r_{0i} = \frac{1}{m}\sum_{k=1}^{m}\zeta_i(k) \tag{4}$$

The grey correlation between the foreign trade indicators and the related logistics indicators of the Erenhot Port was calculated by averaging the grey correlation coefficients of each column in Table 3, as shown in Table 4.

Table 4 Grey Correlation of Foreign Trade Indicators and Related Logistics Indicators of the Erenhot Port

	Port Import Turnover	Port Export Turnover	Port Import Volume	Port Export Volume	Railway Import and Export Volume	Highway Import and Export Volume
Port Trade Turnover	0.7701	0.6730	0.5321	0.5681	0.5733	0.4547

2.3 Results of grey correlation analysis

The calculation results through the grey correlation in Table 4 show that there are different relationships between the foreign trade indicators and the indicators of port logistics development of the Erenhot Port, with port import turnover > port export turnover > railway import and export volume > port export volume > port import volume > highway import and export volume. Among them, the correlation value of import trade turnover is 0.7701, which is close to 0.8, and it reflects the growth level of import freight volume of the port; the correlation value between the foreign trade volume of the port foreign trade turnover and the import and export logistics indicator of the railway port is 0.5733, which is greater than 0.5, indicating the higher correlation between the foreign trade of the Erenhot Port and the import and export volume of the railway port; the correlation value between the foreign trade of the Erenhot Port and the import and export volume logistics indicator of the highway port is 0.4547, which is less than 0.5, indicating the weak correlation between the foreign trade of the Erenhot Port and the cargo import and export volume of the highway port. These results indicate that in the evaluation indicator system established in this paper[6], the growth of the port trade turnover has a greater impact on the import and export freight volume of the railway port, and also shows that under the influence of the general environment of the construction of China-Mongolia-Russia Economic Corridor, the China-Mongolia and China-Russia trade cooperation as well as the China Railway Express logistics impose a very urgent demand on the railway transportation logistics of the Erenhot Port[7]. Railway transportation occupies a major position and plays a crucial role in terms of economic and social development, foreign economic trade and international logistics development with its characteristics of large carrying capacity, high speed and all-weather operation[9]. It also shows that the railway transportation mode has an extremely significant position in the foreign trade development and construction of the Erenhot Port, and the relationship between the port's foreign trade turnover and the import and export volume of the railway port should be further studied[6].

3. ANALYSIS OF THE RELATIONSHIP BETWEEN FOREIGN TRADE TURNOVER AND RAILWAY IMPORT AND EXPORT FREIGHT VOLUME OF THE ERENHOT PORT

To thoroughly study the specific impact of railway import and export freight volume of the Erenhot Port on the growth of import and export trade turnover, this paper establishes a VAR model to further analyze the development relationship between the two in the long and short term.

3.1 VAR model variable selection and data sources

The indicators of railway import and export freight volume, which are more correlated with the foreign trade turnover of the Erenhot Port and relevant to this paper, were selected from the results of grey correlation analysis to construct a VAR model with the trade turnover of the Erenhot Port[7]. The relevant data from 1998-2020 were chosen for calculation. To eliminate heteroskedasticity, two time sequences of the import-export trade turnover and railway import and export freight volume of the Erenhot Port were taken as logarithms, noted as Lnmoney and Lnvolume, respectively. The raw data were all obtained from China Statistical Yearbook, as shown in Table 5.

Table 5 Correlation Data for the 1998-2020 Time Series

Year	*Money* (RMB hundred million)	*Volume* (10 kt)	*Lnmoney*	*Lnvolume*
1998	27.11	33.51	3.2999	3.5118
1999	28.45	48.21	3.3481	3.8756
2000	33.11	44.76	3.4998	3.8014
2001	43.89	84.25	3.7817	4.4338
2002	56.65	150.67	4.0369	5.0151
2003	74.49	324.87	4.3107	5.7834
2004	128.29	544.93	4.8543	6.3007
2005	181.47	732.82	5.2011	6.5969
2006	192.75	774.06	5.2614	6.6517
2007	208.18	789.83	5.3384	6.6718
2008	187.64	739.70	5.2345	6.6062
2009	166.17	741.31	5.1130	6.6084
2010	182.22	743.90	5.2052	6.6119
2011	234.49	882.26	5.4574	6.7825
2012	254.05	1013.96	5.5375	6.9216
2013	231.80	1015.60	5.4459	6.9232
2014	222.76	1052.20	5.4061	6.9586
2015	177.54	958.80	5.1792	6.8657
2016	156.13	966.10	5.0507	6.8733
2017	205.03	1327.30	5.3232	7.1909
2018	237.98	1464.70	5.4722	7.2894
2019	268.60	1471.00	5.5932	7.2937
2020	285.95	1501.15	5.6558	7.3140

3.2 Unit root test

In this paper, the ADF test method was used to conduct the stationarity test for various data within the 1998-2020 time series, and the Eviews 8.0 software was used to perform the unit root test on the related series[7]. The results are shown in Table 6.

Table 6 Results of Unit Root Test

	ADF Value	Test Category (C, T, K)	1%***	5%**	0%*	prob	Stationary or Not
Lnmoney	2.559893	(C, T, 4)	4.467895	3.644963	3.261452	0.2996	No
D(*Lnmoney*)	4.143256	(C, T, 4)	4.571559	3.690814	3.286909	0.0221	Yes
Lnvolume	2.375744	(C, 0, 4)	3.788030	3.012363	2.646118	0.1599	No
D(*Lnvolume*)	2.078569	(0, 0, 4)	2.679735	1.958088	1.607830	0.0388	Yes

In Table 6, the results of the unit root test illustrate that the prob values of Lnmoney and Lnvolume are greater than 0.05, and the original series is considered non-stationary. Through the first difference, the prob values of D (Lnmoney) and D (Lnvolume) are less than 0.05, and then the original hypothesis is rejected and the series after the first difference is considered to be stationary, indicating that the original series is a first single integrated series.

3.3 Determination of the optimal lag time

In this paper, the model is denoted as VAR (Erenhot Port) model, and the lag order in VAR (Erenhot Port) model should be selected as 2 according to the test of five indicators commonly used in the VAR model, namely LR (likelihood ratio) statistics, SC (Schwarz Criterion), AIC (Akaike information criterion), FRE (final prediction error) and HQ (Hannan-Quinn) information criterion. The VAR model is required to satisfy a series of stationary conditions and be determined as meaningful before the correlation analysis. The values of the reciprocal of the characteristic roots of the VAR (Erenhot Port) model in Figure 2 are all less than l, indicating that all the point positions are within the unit circle. It means that the VAR (Erenhot Port) model is stationary[8] and meaningful, and the optimal lag time of the model is determined as 2.

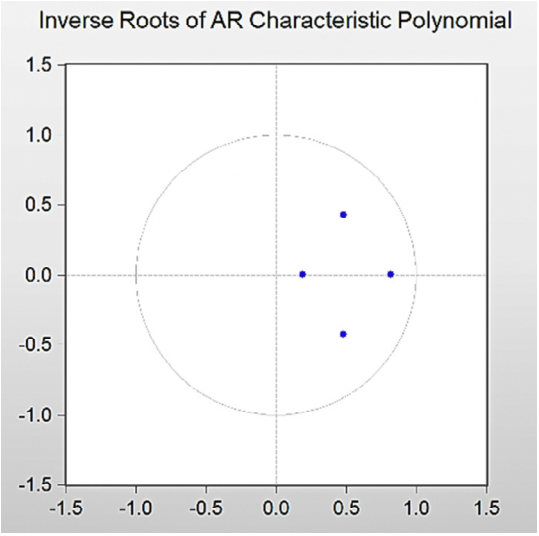

Figure 2 Distribution of Reciprocal Values of Characteristic Roots of the VAR (Erenhot Port) Model

3.4 Johanson cointegration test

Through the cointegration test, the selected time series are considered to be cointegrated if there is some stationary linear combination of a set of non-stationary time series under the condition that the selected time series are integrated of the same order[6]. The linear combination is mathematically represented as a cointegrating equation, indicating the existence of some long-run equilibrium relationship. Table 7 shows the results of the Johanson cointegration test of the VAR (Erenhot Port) model, with the cointegration equation as shown in Equation (5).

$$Lnmoney(-1) = 0.345490\ Lnvolume(-1) - 7.229371 \tag{5}$$

Table 7 Results of the Johanson Cointegration Test of the VAR (Erenhot Port) Model

Original Hypothesis	Characteristic Value	Trace Statistics Test		Maximum Eigenvalue Test	
		Trace Value	5% Threshold Value	Max-Eige Value	5% Threshold Value
None*	0.791056	37.75788	15.49471	31.31381	14.26460
At most 1*	0.275449	6.444049	3.841466	6.444069	3.841466

Note: * indicates the rejection of the original hypothesis at a 95% confidence level

The cointegration equation yields that the relationship between the two shows a positive cointegration, indicating that there is a dynamic equilibrium correlation between the import and export freight volume of the railway port and the import and export trade turnover of the Erenhot Port that affect each other in the long run. An increase of 1 unit of railway import and export freight volume of the Erenhot Port can affect the increase of 0.345 units of the import turnover. In this regard, it shows that accelerating the construction of the railway port channel, continuously improving the railway transportation level in the China-Mongolia-Russia Economic Corridor[10], enhancing the traffic hub distribution capacity, and ensuring smooth

and convenient railway import and export freight volume will together promote the foreign trade of the Erenhot Port.

3.5 Vector error correction model analysis

The cointegration equation indicates that the two sets of variables of the time series have a long-run equilibrium relationship, and this paper constructs a vector error correction (VEC) model to investigate the link between long-run equilibrium and short-run adjustment in the two sets of time variables. The error correction item $vecm_{t-1}$ in the model represents the disequilibrium error that deviates from the long-run equilibrium relationship in the variables of the time series, and the coefficient vector indicates the speed of transfer back to equilibrium when the equilibrium relationship in the variables of the time series deviates from the long-run equilibrium[7]. The vector error correction model constructed in this paper is recorded as the VEC (Erenhot Port) model, and the calculation results are shown in Equation (6):

$$\begin{aligned} D(Lnmoney) = &-0.057956 vecm_{t-1} + 0.248128 D(Lnmoney(-1)) \\ &-0.475648 D(Lnmoney(-2)) + 0.248000 D(Lnvolume(-1)) \\ &+0.294346 D(Lnvolume(-2)) + 0.033628 \end{aligned} \tag{6}$$

The value of the coefficient vector of the error correction item $vecm_{t-1}$ is -0.057956, which follows the requirement of the reverse correction mechanism.

Table 8 shows the correlation test results of the VEC (Erenhot Port) model, where the LR value is 39.60879, a relatively large value, while the AIC and SC values are -2.560879 and -1.863866, respectively, which are relatively small, indicating that the overall simulation effect of the VEC (Erenhot Port) model is relatively satisfactory.

Table 8 Overall Test Results of the VEC (Erenhot Port) Model

Information Criterion	Value
Determinant resid covariance	6.53E-05
Log likelihood	39.60879
Akaike information criterion	-2.560879
Schwarz criterion	-1.863866

3.6 Granger causality test

From the above analysis, it can be concluded that there are long-term stationary and short-term differential equilibrium relationships between the import and export trade turnover of the Erenhot Port and railway freight volume. The Granger causality test is required to determine whether there is a causal relationship between these two. The Granger causality test aims to test whether variable A has a predictive effect on variable B. If a change in variable A causes a change in variable B, it indicates that the change in variable A should occur at a time earlier than the change in variable B, but does not mean that there is an economic causality between variable A and variable B[7]. Granger causality test was performed on the VAR (Erenhot Port) model, as shown in Figure 3.

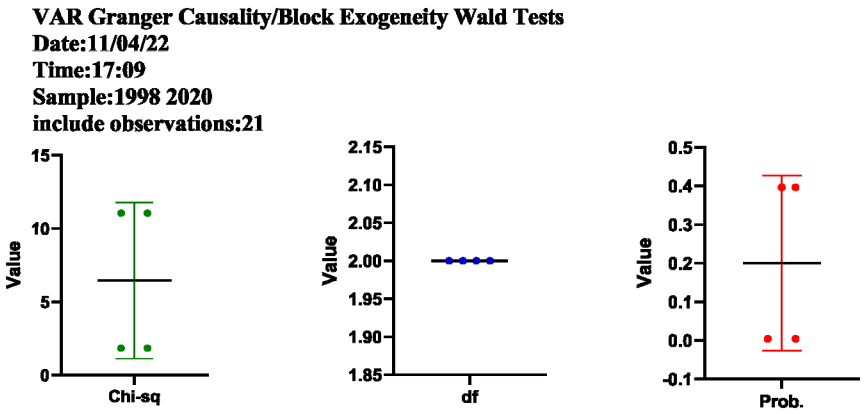

Figure 3 Results of Granger Causality Test of the VAR (Erenhot Port) Model

According to the results of the Granger causality test, the relationship between Lnmoney and Lnvolume shows a unidirectional causality, which means that at a 5% significance level, the import and export trade turnover of the Erenhot Port is the Granger cause of the port railway freight volume, while the latter is not the Granger cause of the former and has no Granger causality on the former. The results show that the port foreign trade turnover is currently co-integrated with the railway cargo import and export volume and has no positive correlation with the regional railway transport organization capacity. The increase in port foreign trade turnover will put forward the demand for railway channel transport capacity, and the increase of railway channel transport capacity provides support for the increase of port foreign trade turnover. However, the railway transport capacity cannot meet the increase of port foreign trade turnover, causing a distinct phenomenon of forced diversion of highway transport due to the inability to meet the needs of the growth of import and export cargo volume as well as a phenomenon of transport trade. In order to promote the unification of railway and port strategic layout and development planning, the railway authority should transform and upgrade the collection and distribution business, introduce advanced loading and unloading machinery and equipment, improve the efficiency of loading and unloading operations, optimize the operational link, and reduce the stay time of the short-way industrial trucks in the station. It should also realize close cooperation among all parties, optimize the operation process, and organize the articulation of vehicles and cargo. Moreover, the sector should arrange for the use of locomotives according to the operation plan, give full play to the advantages of intensive railway resources and ecological and environmental protection, continue to develop the construction of heavy-duty railway projects in the port area and the electrification of railway lines, and achieve the matching support of trade volume and railway transport channel demand and capacity through the transport capacity reserve for the "highway-railway transfer" of ports.

4. CONCLUSION

In combination with the study and analysis, the increase in trade turnover in the Erenhot Port has driven the increase in railway import and export freight volume. Faced with the logistics demand of high growth of railway import and export freight volume, the Erenhot Port must accelerate the construction of railway passages[11] and improve the level of transportation development. With the gradual implementation of the national policy of accelerating the railway construction of the Erenhot Port and the policy of highway-railway transfer, railway transportation occupies an important position in the construction and development of the China-Mongolia-Russia Economic Corridor, plays an increasingly irreplaceable and significant role, and also has a positive and active effect on the economic construction of the Erenhot Port.

ACKNOWLEDGMENT

This research was supported in part by the Impact of Mongolia's accession to the Asia-Pacific Trade Agreement on the transportation industry in Inner Mongolia Autonomous Region under Grant BTZY202135.

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