CONVERTER MAGAZINE
Volume 2021, No. 8

Improved Model of Throughput Prediction and Freight Rate Game Decision of Container Port Group

Geng Can *, Zhong Ming
School of Dalian Maritime University, Dalian, China
**Corresponding author*

Abstract

Given the fact that vicious internal competition and the epidemic have led to a decline in operating income, how to improve the total operating income of container port group has become an important issue for decision makers of container port group. In order to increase the total operating revenue of port group and suppress the vicious price competition within the port group, a second-order forecasting game model is proposed, which is based on Improved GM (1,1) model, logit model and Bertrand Nash equilibrium model. Firstly, the GM (1,1) model is improved by using the three-point smoothing method to predict the future container throughput; secondly, the logit model is used to simulate the choice behavior of container freighter to container port according to the container port utility; finally, the non-cooperative game and cooperative game revenue of container port group are calculated by using the Bertrand Nash equilibrium model. The results show that the prediction accuracy of container throughput is 0.68% higher than before, and the total operating revenue of cooperative game and non-cooperative game is 52.3% and 35.5% higher than the original revenue, respectively. The research shows that the second-order prediction game model can make a more accurate prediction of the container throughput, and can effectively improve the operating income of the container port group, which lays a theoretical foundation for the managers of the port group to formulate a reasonable freight rate.

Keywords: *Container port group; game model; GM (1,1) model; Bertrand-Nash equilibrium.*

I. Introduction

Container transport plays a key role in promoting global economic development and trade flows. In order to adapt to market fluctuations, container ports are required to plan their container transport prices rationally and provide efficient and economical transport services for containers to ensure that the port is competitive. Usually, when container ports set container transport prices, the container ports competing for the same cargo source cannot communicate effectively with each other before making decisions, which usually leads to vicious competition at the transport price level between container ports. With the advancement of regional port integration, a port head office has emerged in the region to unify and lead the development of the regional container port cluster. As the decision maker of the port group, maximising the economic benefits of the container port group in the region has become one of the key issues it needs to address.

Currently, game theory is widely used in price competition between ports. HAN et al[1] developed a game model to analyse the competition between the ports of Busan and Shanghai for transshipment containers. ZHANG et al[2] constructed a Bertrand price competition model based on both cooperative and non-cooperative scenarios to study the price competition between Hong Kong and Shenzhen container ports. A non-cooperative and cooperative game model constructed by SAEED et al[3] to examine the equilibrium tariffs of container ports. PARK et al [4] applied the two-port Bertrand model constructed by SAEED et al [3] to examine the equilibrium tariff of the container port of Busan in both the non-cooperative and cooperative games. minh et al [5] developed a Bertrand-Nash game model to discuss the price competition strategy between container port clusters in northern Vietnam. Meanwhile there are more methods for port throughput forecasting, such as linear regression method, combinatorial model method, neural network model method, genetic programming method and grey model method. The GM (1,1) grey model proposed by Deng Julong [6] is suitable for small sample, information-poor time series simulation and forecasting. Huang Yuehua [7] improved the GM (1,1) model to enhance the accuracy of the GM (1,1) model. Meanwhile, the impact of unexpected events on port operations and global shipping trade is evident. Zhu Jian [8] found that the development of the world economy has a large impact on the cargo throughput of China's coastal ports. The study by Liu Wenjun et al [9] showed that the unexpected epidemic has a short-term negative impact on the operational capacity of China's ports, but will not change the stable and positive situation of China's port development; Zhang Yongfeng et al [10] elaborated on the transmission mechanism and intuitive impact of shipping and industry under the epidemic conditions, and argued that all parties in the shipping industry should build a multi-party mutual help and exchange and sharing platform to cope with the impact.

In the above game model studies, the throughput settings are directly calculated using the throughput data of a particular year. This paper adds a GM (1,1) grey model to the previous study for future annual throughput forecasting, which provides suggestions for more accurate equilibrium tariff calculation; at the same time, this paper adds a logit discrete choice model to the original Bertrand-Nash game model. The logit discrete choice model is used to establish a container port service utility model and a service demand model, and the utility of the container port is used to simulate the behaviour of container shippers in choosing a container port. At the same time, this paper uses the three-point smoothing method to optimise the original data chain of the GM (1,1) model and improve the GM (1,1) model to improve the accuracy of the throughput prediction, while considering the impact on port throughput and land transport costs under the influence of unexpected events according to existing research, which improves the prediction accuracy and enhances the practicality of the game model.

In the above game model studies, the throughput settings are directly calculated using the throughput data of a particular year. This paper adds a GM (1,1) grey model to the previous study for future annual throughput forecasting, which provides suggestions for more accurate equilibrium tariff calculation; at the same time, this paper adds a logit discrete choice model to the original Bertrand-Nash game model. The logit discrete choice model is used to establish a container port service utility model and a service demand model, and the utility of the container port is used to simulate the behaviour of container shippers in choosing a container port. At the same time, this paper uses the three-point smoothing method to optimise the original data chain of the GM (1,1) model and improve the GM (1,1) model to improve the accuracy of the throughput prediction, while considering the impact on port throughput and land transport costs under the influence of unexpected events according to existing research, which improves the prediction accuracy and enhances the practicality of the game model.

In this paper, three aspects are investigated: (1) The GM (1,1) grey forecasting model is improved and predicts the container throughput of the Liaoning regional container port cluster in the next few years without epidemic disruption, and predicts the future container throughput of the Liaoning region under the influence of the epidemic based on the study of Liu Wenjun et al [9]. (2) The decline in regional container port throughput and the increase in operating costs under the impact of the outbreak are considered. This paper will use the Bertrand-Nash game model to find out the equilibrium solution of the tariff of each container port in the region, and use the logit discrete choice model to establish a container port service utility model and a service demand model to analyse the container shippers' choice of container ports, and provide reasonable suggestions for the regional container port cluster to cope with the impact brought by the unexpected event and the formulation of tariff. (3) The impact of other costs of container transport, such as land transport charges, waiting costs, etc. on container ports is refined. The general expression for other costs constructed by KASELIM [11] was used to calculate and estimate the waiting costs under the impact of contingencies. Thus, this paper investigates the issue of price cooperation between local container ports from the perspective of container transport costs and container throughput.

II. Model Construction

2.1 Description of the Problem and Assumptions

The service utility of a container port refers to the degree of satisfaction of shippers with container ports of different service levels and service capabilities. This paper models the choice behaviour of container shippers for container ports based on the utility of container ports. The geographical distribution of container ports in the current region is used to classify container ports into Port 1, Port 2, Port 3....n (denoted as: Port P_1,Port P_2 and PortP_3...P_n Port). Based on the current container throughput and transport costs, the price game between container ports in the region under the change of container throughput is discussed using the game model and the GM(1,1) model.

The model assumptions in this paper are: (1) The model does not take into account berthing fees, port charges, etc. that are not related to the location of the container port and are equally priced, as the model predicts customer choice based on differences in service costs. (2) All container ports will provide similar container transport services, but due to the location of the container port and natural conditions, etc., the services provided by each container port cannot be a complete substitute for the services provided by other container ports. (3) The total container throughput forecast within a region will not vary with changes in container handling charges at a particular port. (4) The user's choice of port will depend only on the cost of shipping containers, regardless of other reasons. The logic diagram of the model structure is shown in Figure 1.

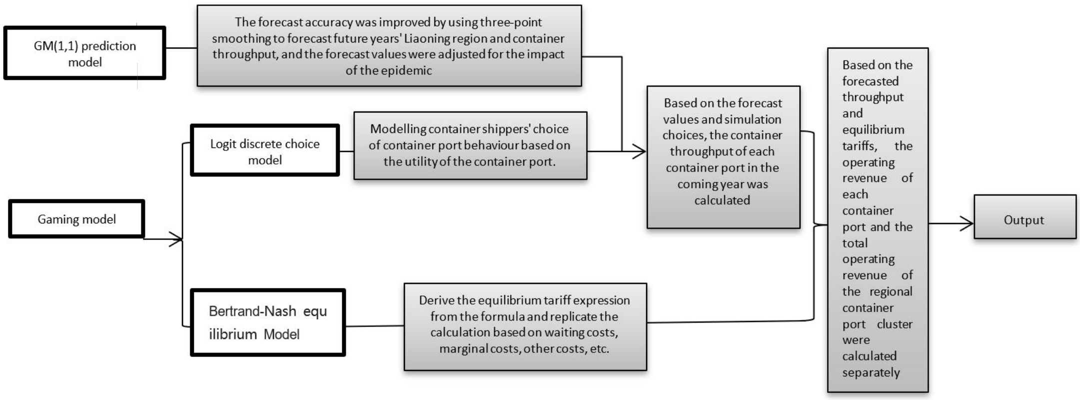

Figure 1: Model logic diagram

2.2 Build and Solve a GM (1, 1) Grey Prediction Model

2.2.1 Building a GM (1, 1) Grey Prediction Model

(1) Let the historical port throughput data be:

$$x^{(0)}=\left\{x^{(0)}(1),x^{(0)}(2),x^{(0)}(3),\ldots x^{(0)}(n)\right\} \tag{1}$$

Where: $x^{(0)}$ denotes the original unoptimised data chain, $x^{(0)}(1),x^{(0)}(2),x^{(0)}(3),\ldots x^{(0)}(n)$ denotes the raw container throughput data for year 1, year 2...year n respectively.

(2) Constructing a new data series using three-point smoothing:

$$\begin{cases} x^{(0)\prime}(1)=\dfrac{3x^{(0)}(1)+x^{(0)}(2)}{4} \\ x^{(0)\prime}(k)=\dfrac{x^{(0)}(k-1)+2x^{(0)}(k)+x^{(0)}(k+1)}{4} \\ x^{(0)\prime}(n)=\dfrac{x^{(0)}(n-1)+3x^{(0)}(n)}{4} \end{cases} \tag{2}$$

Where: $x^{(0)\prime}$ denotes the original data chain after optimization, $x^{(0)\prime}(1), x^{(0)\prime}(2), x^{(0)\prime}(3), \ldots x^{(0)\prime}(n)$ The raw container throughput data for year 1, year 2...year n after optimisation are indicated respectively.

(3)First order accumulation of throughput data gives:

$$x^{(1)}=\left\{x^{(1)}(1), x^{(1)}(2), x^{(1)}(3), \ldots x^{(1)}(n)\right\} \tag{3}$$

Where: $x^{(1)}$ denotes the data chain obtained by accumulating the original data chain after optimization, The formula for calculating $x^{(1)}(1), x^{(1)}(2), x^{(1)}(3) \cdots x^{(1)}(n)$ is shown in equation (4)

$$x^{(1)}(t)=\sum_{k=1}^{t} x^{(0)}(k), t=1.2.3 L n \tag{4}$$

(4) The sequence of immediate neighbours is generated from $x^{(1)}$ the sequence:

$$z^{(1)}=\left\{z^{(1)}(1), z^{(1)}(2), z^{(1)}(3), \ldots z^{(1)}(n)\right\} \tag{5}$$

Where: $z^{(1)}$ denotes the sequence of immediately adjacent mean values generated by data chain $x^{(1)}$, The formula for calculating $z^{(1)}(1), z^{(1)}(2), z^{(1)}(3), \ldots z^{(1)}(n)$ is shown in equation (6)

$$z^{(1)}(k)=\frac{1}{2}(x^{(1)}(k-1)+x^{(1)}(k))(k=1,2,3,\cdots n) \tag{6}$$

(5) Let the definition and expression of $x^{(0)}(k)$, $x^{(1)}(k)$, $z^{(1)}(k)$ be as shown above, then the expression for the grey differential equation is:

$$x^{(0)}(k)+az^{(1)}(k)=b \tag{7}$$

Called as the GM (1,1) model, where: a,b are coefficient to be determined and will be estimated using the least squares method.
(6) Equation

$$\frac{dx^{(1)}}{dt}+ax^{(1)}=b \tag{8}$$

Eq. (8) is the different whitening equation for the GM(1,1) model, where: t in time and a,b are coefficient to be determined.

2.2.2 GM (1, 1) Grey Prediction Model Solved

Least squares estimation of the $(ab)^T$ -parameter column according to equation (7)

$$\left(a\ b\right)^T = \left(B^T B\right)^{-1} B^T Y \tag{9}$$

$$B = \begin{pmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \cdots & \\ -z^{(1)}(n) & 1 \end{pmatrix} \quad Y_n = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \cdots \\ x^{(0)}(n) \end{pmatrix} \tag{10}$$

Solve (8) to obtain the time equivalent

$$\hat{x}^{(1)}\left(k+1\right) = \left(x^{(0)}\left(1\right) - \frac{b}{a}\right)e^{-ak} + \frac{b}{a}\left(k = 1,2,\cdots,n\right) \tag{11}$$

$\hat{x}^{(1)}$ is the cumulative value of the original throughput series prediction, and a further first order cumulative reduction of equation (11) is calculated as

$$\hat{x}^{(0)}\left(k+1\right) = \hat{x}^{(1)}\left(k+1\right) - \hat{x}^{(1)}\left(k\right) \tag{12}$$

Obtain grey prediction values $\hat{x}^{(0)}$

2.3 Service Utility and Service Demand Models for Container Ports

In this game model, the utility function for port i(i=1,2,3…n) can be represented by the following equation (SAEED[3]):

$$U_i = a_i + b(P_i + O_i) \tag{13}$$

Where: U_i refers to the utility of port i; a_i refers to a derived constant that can be determined by a variety of methods (e.g. linear regression); b refers to the price coefficient; P_i refers to the charges (e.g. handling and handling fees, etc.) to be paid for the container to be transported through container port i; O_i refers to all costs other than port charges (e.g. land port transport charges, pre-arrival storage charges, vessel waiting costs, etc.).

Other specific expressions for the cost O_i have been studied in the papers by KASELIMI [11] and SAEED[3] with the following equations:

$$O_i = C_i + f\left(x_i / A_i\right) \tag{14}$$

Where: C_i refers to inland transportation costs, which are fixed costs for inland transportation of containers and are not related to the container port.；

$f\left(x_i / A_i\right)$ refers to the waiting cost function for shippers at container port i with container throughput and total port capacity x_i and A_i respectively. Next the waiting costs are calculated using the findings of SAEED[3].

According to MALCHOW[12], the market share of individual container ports is represented by the following formula:

$$Q_i = e^{U_i} \bigg/ \left(\sum_{i=1}^{n} e^{U_i} \right) \tag{15}$$

In the SAEED[3] study, X is used to represent the total throughput of all container ports in the Liaoning region with the following formula:

$$X = Be^{\theta \times L} \tag{16}$$

Where: B and θ are constants, and $0 < \theta < 1$; L is Logarithmic sum, Determined by equation (17).

$$L = \ln\left(\sum_{i=1}^{n} e^{U_i}\right) \tag{17}$$

Therefore, the container throughput of each container port can be expressed as

$$x_i = X \times Q_i \tag{18}$$

In this paper, the operating revenue of container port i in Liaoning region is calculated by using the container throughput, and the operating revenue of container port group is

$$\pi_i = x_i \left(P_i - g_i \left(x_i / A_i \right) \right) \tag{19}$$

Where: $g_i\left(x_i/A_i\right)$ refers to the marginal cost function of container port i. When the marginal cost function is assumed to be constant, it will be expressed as E_i .

2.4 Constructing a Second-Order Game Model and Solving It

2.4.1 Non Cooperative Game Model

The non-cooperative game is the game in which each container port will compete independently, neither cooperating with the other, to maximise its own operating revenue. Therefore, the equilibrium point of port i is found using the Bertrand-Nash equilibrium model, i.e. the derivative, which can be described by the following equation:

$$\frac{\partial \pi_i}{\partial P_i} = 0 \tag{20}$$

Eq. (20) can be converted to

$$\pi_i = Be^{\theta L} Q_i (P_i - E_i) \tag{21}$$

The derivative of equation (21) with respect to P_i gives

$$Be^{\theta L} Q_i + \frac{\partial Be^{\theta L} Q_i}{\partial P_i} (P_i - E_i) = 0 \tag{22}$$

First treat equation (22) in logarithmic terms.:

$$\ln(Be^{\theta L} Q_i) = \ln B + \theta L + \ln(Q_i) \tag{23}$$

Derivative of equation (23):

$$\frac{\partial \ln(Be^{\theta L} Q_i)}{\partial P_i} {=} \partial \ln B + \partial(\theta L) + \partial \ln(Q_i) \tag{24}$$

From equation (19):

$$\frac{\partial(Be^{\theta L} Q_i)}{\partial P_i} = Be^{\theta L} Q_i [b(\theta Q_i + 1 - Q_i)] \tag{25}$$

Substituting equation (25) into equation (22) gives

$$P_i = E_i - \frac{1}{b(\theta Q_i + 1 - Q_i)} \tag{26}$$

Equation (26) is the corresponding function of the price of container port i.

2.4.2 Cooperative Game

In the ensuing cooperative game, the following joint scenario is assumed in this paper: the container port clusters in the region play a cooperative game under the unified leadership of a higher authority to maximise the revenue of the regional container port operations.

The formula for the total profit of the container port clusters in the region in the hypothetical scenario is as follows:

$$\pi=\sum_{i=1}^{n}\pi_i=\sum_{i=1}^{n}(P_i-E_i)x_i \tag{27}$$

The derivative of equation (27) with respect to P_i gives

$$\frac{\partial\pi}{\partial P_1}=\frac{\partial Be^{\theta L}Q_1}{\partial P_1}\left(P_1-E_1\right)+Be^{\theta L}Q_i+\frac{\partial(Be^{\theta L}Q_2)}{\partial P_1}\left(P_2-E_2\right)+\cdots+\frac{\partial(Be^{\theta L}Q_n)}{\partial P_1}\left(P_n-E_n\right) \tag{28}$$

According to equation (25), substitute into equation (28) and simplify to obtain:

$$\frac{\partial\ln(Be^{\theta L}Q_2)}{\partial P_1}=\frac{\partial\theta L}{\partial P_1}-\frac{\partial L}{\partial P_1}=\theta bQ_1-bQ_1 \tag{29}$$

In the same way as the derivation of the non-cooperative game part, equation (28) can be transformed into:

$$\begin{aligned}\frac{\partial\pi}{\partial P_1}=&Be^{\theta L}Q_1[b(\theta Q_1+1-Q_1)](P_1-E_1)+Be^{\theta L}Q_2[b(\theta Q_1+1-Q_1)](P_2-E_2)\\&+\cdots+Be^{\theta L}Q_n[b(\theta Q_1+1-Q_1)](P_n-E_n)\end{aligned} \tag{30}$$

Simplifying gives

$$P_1=E_1-\frac{1+Q_2[b(\theta-1)](P_2-E_2)+Q_3[b(\theta-1)](P_3-E_3)+\cdots+Q_n[b(\theta-1)](P_n-E_n)}{b(\theta Q_1+1-Q_1)} \tag{31}$$

Similar price responses have been made by other container ports, which have the following price response functions:

$$P_2=E_2-\frac{1+Q_1[b(\theta-1)](P_1-E_1)+Q_3[b(\theta-1)](P_3-E_3)+\cdots+Q_n[b(\theta-1)](P_n-E_n)}{b(\theta Q_2+1-Q_2)} \tag{32}$$

...

$$P_n=E_n-\frac{1+Q_1[b(\theta-1)](P_1-E_1)+Q_2[b(\theta-1)](P_2-E_2)+\cdots+Q_{n-1}[b(\theta-1)](P_{n-1}-E_{n-1})}{b(\theta Q_n+1-Q_n)} \tag{33}$$

III. Analysis of the Calculation Examples

3.1 Calculation and Testing of the GM (1,1) Model

(1) In this paper, the container throughput data of Liaoning region from 2015-2019 were used to forecast the container throughput of Liaoning region in 2020 and 2021, the original data are shown in Table 1 and the forecast data are shown in Table 2

Table 1: Container throughput in Liaoning region from 2015-2020 in million TEU

Year	2015	2016	2017	2018	2019	2020
Raw throughput data	1828	1879	1950	1878	1689	1311
Optimised throughput data	1840.75	1884	1914.25	1848.75	1736.25	-

Table 2: GM(1,1) Forecast Container Throughput in Liaoning Region in 10,000 TEU

Year	2015	2016	2017	2018	2019	2020	2021
Predicted values before optimisation	1808.3	1962.9	1877.9	1867.1	1754.5	1695.8	1646.7
Predicted value after optimization	1840.75	1920.05	1867.1	1815.5	1735.3	1717.8	1692.6

From the table we can see that due to the impact of the new crown pneumonia, the container throughput in Liaoning region in 2020 has seen a significant decline. In the study of Liu Wenjun et al[9], their prediction is that the container capacity in Liaoning region in 2020 will be about 0.624-0.783 of the normal situation, and in 2021 the container capacity in Liaoning region will be about 0.794-0.811 of the normal situation. Therefore, this paper predicts that the container throughput in Liaoning region in 2021 will be about 13.135 million TEU. figure 2 shows the comparison between the predicted and actual container throughput in Liaoning region from 2015 to 2021

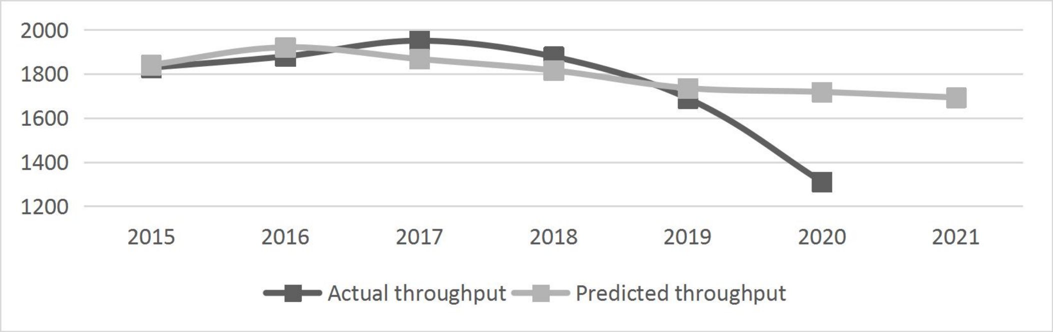

Figure 2: Actual values for the forecast domain of container throughput in Liaoning

(2) This paper uses the relative error test to carry out the test, and the steps are as follows:

Calculation of residual value.:

$$e(k) = x^{(0)\prime}(k) - \hat{x}^{(0)}(k), \quad (k = 1, 2, \cdots n) \tag{34}$$

Calculation of relative error:

$$rel(k) = \frac{e(k)}{x^{(0)}(k)} * 100\%, \quad (k = 1, 2, \cdots n) \tag{35}$$

Calculating the mean relative error:

$$\overline{e}(k) = \frac{1}{n} \sum_{k=1}^{n} |rel(k)| \tag{36}$$

Derive accuracy:

$$p^0 = (1 - \overline{e}(t)) \tag{37}$$

The test proves that the prediction accuracy of the optimized model is 97.35% higher than the standard value of 95% and higher than the 96.77% before optimization, so the model accuracy meets the requirements and is better than the original model.

3.2 Game Model Parameter Setting

In order to facilitate the understanding and use of the pricing rules and to facilitate the implementation of the Nash equilibrium of the Bertrand game, the model is next assigned a demonstration. Prior to this, the necessary parameters are defined.

3.2.1 Setting of the Container Throughput of Each Port

In this paper, the container throughput of each port is used to represent the demand for container services at each port. Table 1 shows the throughput of each container port in the Liaoning region, as shown in Figure 3. From the table we can see that the container throughput of Dandong Port, Panjin Port and Huludao Port accounts for a very small proportion of the container throughput, therefore these three ports are not included in the calculation of this model.

Table 3: 2019 Container Port Container Throughput in Liaoning Region 10,000 TEU

Dalian Port	Yingkou Port	Jinzhou Port	Dandong Port	Panjin Port	Huludao Port	Total
876	548	188	40	32	6	168

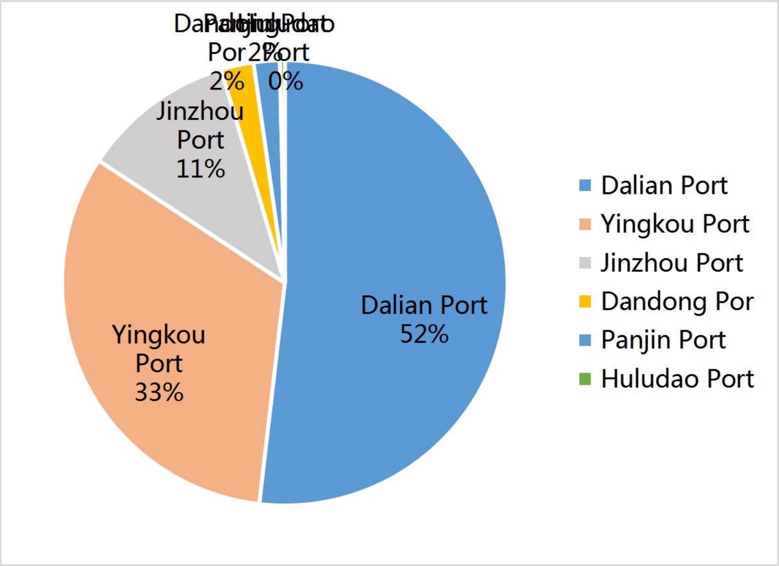

Figure 3: Proportion of container port throughput in Liaoning by region

3.2.2 Estimate the Values of a_i and b

As shown in equation (1), specific constants a_i and price parameters b are required to value the utility function. In order to determine the values of a_i can be assumed $a_1 = a_2 = \ldots = a_n = a$. In this paper, linear regression is used to determine the values of a and b.

Container handling uplines, market shares, lump sum fees and projected throughputs for all container ports are listed in Table 2 as parameter inputs to the linear regression. This allows us to use the data in Table 2 to calculate handling charges and other user costs. and apply the linear regressions shown in Table 3 to calculate the values of a and b.

Table 4: Basic parameters of container ports

Ports	Container handling on line / million TEU	Market share	Package fee/US$	Forecast year projected throughput / million TEU
Dalian Port	1500	0.5187	60	684
Yingkou Port	1000	0.3245	62	428

Jinzhou Port	350	0.1113	58	147
Source: Based on reports issued by the Ministry of Transport and data obtained from the author's enquiries and enquiries with container ports and carriers.				

To quantify the utility of each container port, this paper will be transformed using the logarithmic solution expression (15), which results in the following:

$$\ln Q_i = \ln\left(\lambda e^{U_i} \Big/ \left(\sum_{i=1}^{n} \lambda e^{U_i} \right) \right) \tag{38}$$

Simplifying equation (39), the following expression is obtained:

$$U_i = \ln Q_i + \ln\left(\sum_{i=1}^{n} \lambda e^{U_i}\right) \tag{39}$$

Where $\ln\left(\sum_{i=1}^{n} e^{u_i}\right)$ is also L, In this paper, the estimated throughput of container ports in the Liaoning region for the forecast year is used as a proxy parameter: that is 1313.5(mil TEU), therefor L=16.39.

The parameters needed to find the linear regression are shown in Table (3). The calculation of other costs is described in the next section.

Table 5 Parameters required to solve for a and b

Ports	Effectiveness	Handling charges/(USD/TEU)	Other costs/(USD/TEU)
Dalian Port	15.73	60	274.72
Yingkou Port	15.25	62	281.58
Jinzhou Port	14.25	58	306.64

After linear regression analysis using the software SPSS, a was 33.47 and b was -0.053.

3.2.3 Calculate Other Costs (O_i)

The other costs consist of two components: 1. The first component is the inland transportation cost, which has been assumed to be fixed in the previous assumptions and for which the inland transportation data in this paper were derived through telephone enquiries with transport companies by the authors, as well as web queries. 2. The second component is the waiting cost, which quotes the expression used by SAEED [3] to represent the other user waiting in numerical experiments cost. The expression is as follows:

$$f\left(x_i/d_i\right)_i = 0.5 \times \left(\frac{x_i}{0.8 d_i} \right)^4 \tag{40}$$

The specific data are shown in Table 4

Table 6: Other costs per container port USD / TEU

Ports	Inland transportation costs	Waiting costs	Total
Dalian Port	239.67	35.05	274.72
Yingkou Port	245.20	36.38	281.58
Jinzhou Port	265.41	39.23	304.64
Data source: Based on annual reports of individual ports, survey by the author			

.

3.2.4 Marginal Cost

This paper derives the marginal costs for Dalian, Yingkou and Jinzhou ports for 2019 based on their annual reports and estimates the marginal costs for the forecast year based on the study by Zhang Yongfeng [10] et al. This paper finds that the marginal costs have increased by approximately 124%. The marginal costs specified in this paper are shown in Table 7.

Table 7: Marginal costs by container port US$/TEU

Ports	Marginal Costs 2019	Forecasted annual marginal cost
Dalian Port	25.48	31.60
Yingkou Port	29.10	36.08
Jinzhou Port	33.04	40.97
Data source: Based on annual reports of individual ports, survey by the author		

3.2.5 Determine the Value of θ

The rationale for finding the value of θ is that the total demand for a port is determined by the total utility of that port. However, this paper assumes that the total demand of a container port will not change in a period because the total port traffic depends on exogenous factors such as economic development and liner tariff strategies, which have a certain degree of inertia, and liner tariff strategies show relative stability over a period of time, so the total demand of a container port will not change significantly in the short term. Therefore, changes in container port service charges will not have a profound impact on total demand, but the demand for container ports may be affected by such changes, and thus change to some extent. The value of θ is therefore quite low and is specified as 0.01 in the study by MINH[5], so the value of θ in this study is also assumed to be a small value, i.e.

3.3 Substitute Parameters for the Non-Cooperative Game Model and the Cooperative Game Model

3.3.1 Calculation Results of the Non-Cooperative Game Model

Substituting the data in Table 5 into equation (14), the calculated results are shown in Table 8.

Table 8: Calculation results of the non-cooperative game

Ports	Market share	Handling fees	Market share after non-cooperative gaming	Handling fees after non-cooperative gaming/(USD/TEU)	Current revenue/US$ million	Revenue after non-cooperative gaming / USD million
Dalian Port	0.5187	60	0.4359	70.38	40878.7	40240.9
Yingkou Port	0.3245	62	0.4268	63.88	26426.3	35811.2
Jinzhou Port	0.1113	52	0.1378	62.17	9835.2	11261.0

3.3.2 Calculation Results of the Cooperative Game Model

Substituting the data in Table 5 into equations (19) to (21), the results were calculated as shown in Table 7.

Table 9: Calculated results of the cooperative game

Ports	Market	Handling	Market	Handling fees after	Current	Revenue

	share	fees	share after cooperative gaming	cooperative gaming/(USD/TEU)	revenue/US$ million	after cooperative gaming / USD million
Dalian Port	0.5187	60	0.4698	91.32	40878.7	51673.9
Yingkou Port	0.3245	62	0.4008	88.09	26426.3	50841.3
Jinzhou Port	0.1113	52	0.1297	87.92	9835.2	14978.1

3.3.3 Analysis of the Results of the Game

The calculation results of the non-cooperative game and the cooperative game reveal the following situations that exist in the container ports in Liaoning.:

(1) Container handling charges are lower than the equilibrium tariff

From the calculation results of the non-cooperative game and the cooperative game, we can see that the container handling charges of the container ports in Liaoning region are lower than the equilibrium tariff. This proves that the container ports in Liaoning region are rich in resources and have sufficient capacity. Because the container ports in Liaoning region are mainly for domestic shippers, the lower container handling charges reduce the transportation cost of shippers, which benefits domestic shippers and drives the economic development of scale of import and export trade in the region radiated by the container port cluster in Liaoning: e.g. Liaoning, Jilin and Heilongjiang. We are also aware of the impact of lower container handling charges on container ports. Lower operating revenues may lead to reinvestment in container ports and lagging construction and development of ports, and container ports can only maintain good competitive strength if they are constantly developing. Therefore, it is necessary to consider the operating income of both the shipper and the port when deciding on container handling charges in order to make a reasonable decision.

(2) Low reflection of price changes in the utility of container ports in Liaoning

The value of the utility function b determined by linear regression in equation (1) reflects the elasticity of response of the utility of the local container port to changes in container port handling charges. Compared to the b-values in other regions, the b-values are -0.078 for northern Vietnam according to MINH[5], -0.046 for Busan according to PARK[13], -0.056 for Greek ports according to POLYDOROPULOU [14], and according to SAEED[3], the b-value for Karachi port in Pakistan was -0.05. This implies that container shippers in the Liaoning region are not sensitive to changes in container port handling charges. This result shows that the container port cluster in Liaoning region is not effective in trying to attract shippers by reducing container handling charges, as the cost of shippers is more spent on other aspects such as land transportation charges, storage charges, etc. Therefore, if Liaoning container ports want to improve the quality of service and attract freighters, they need to improve the road-port connection and improve the loading and unloading efficiency. Because the freight people prefer, the total transportation cost is lower, the waiting cost is lower container port.

(3) Better game outcomes for cooperative than non-cooperative games

From the calculations above, we find that the operating revenue of the cooperative game is better than that of the non-cooperative game in terms of port clusters.
In the non-cooperative game, Yingkou Port, which has the highest revenue improvement, has seen its revenue

improve from US$264,263,000 to US$358,112,000 before and after equilibrium, an improvement of 35.5%: Jinzhou Port's revenue has improved from US$98,352,000 before equilibrium to US$112,610,000, an improvement of 14.33%: while Dalian Port's revenue has decreased instead of increased, from 408.787 million USD to US$402.409 million USD, a decrease of 1.56%. Total profits for the Liaoning container port group rose by just 13.18%. This shows that although Liaoning container ports have room to increase their profits, too much competition can lead to vicious price competition between ports, which will not only limit the profitability and development of Liaoning container ports, but also affect the cargo trade and development of the region radiated by Liaoning container ports. Figure 4 shows the revenue situation of each container port in Liaoning region under the non-cooperative game.

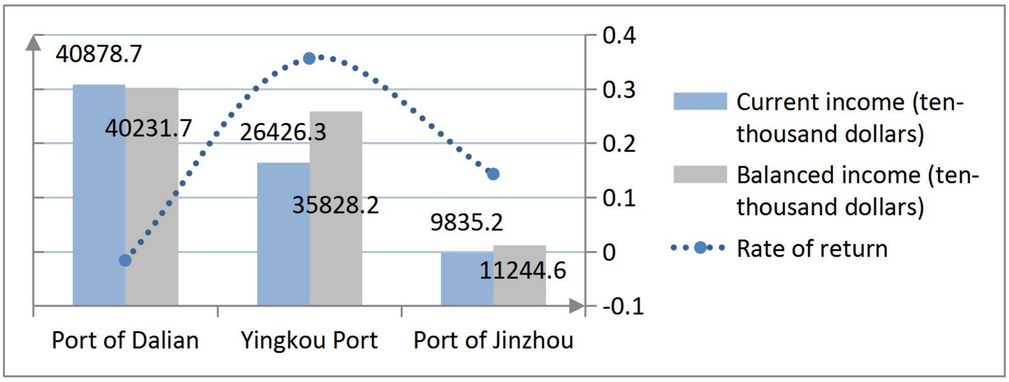

Figure 4: Revenue by container port in a non-cooperative gaming scenario

The revenue of container ports in the Liaoning region all improved significantly during the cooperation game, with the revenue of the Port of Dalian improving by 26.4% to US$516,739,000 from US$408,787,000 before equilibrium. Yingkou Port's revenue improved by 92.4% to US$508,413,000 from US$264,263,000 before balance. Jinzhou Port's revenue improved by 52.3% to US$149,781,000 from US$98,352,000 before balance. Meanwhile the total revenue of container ports in the Liaoning region also saw a large increase, up 52.3% from pre-balance. An increase of this magnitude suggests that if a price cooperation mechanism can be formed between ports, then they will be able to respond better to avoid losses and earn profits in a reasonable manner when faced with an unexpected public event such as an epidemic. Figure 5 illustrates the gains for each container port under the cooperative game.

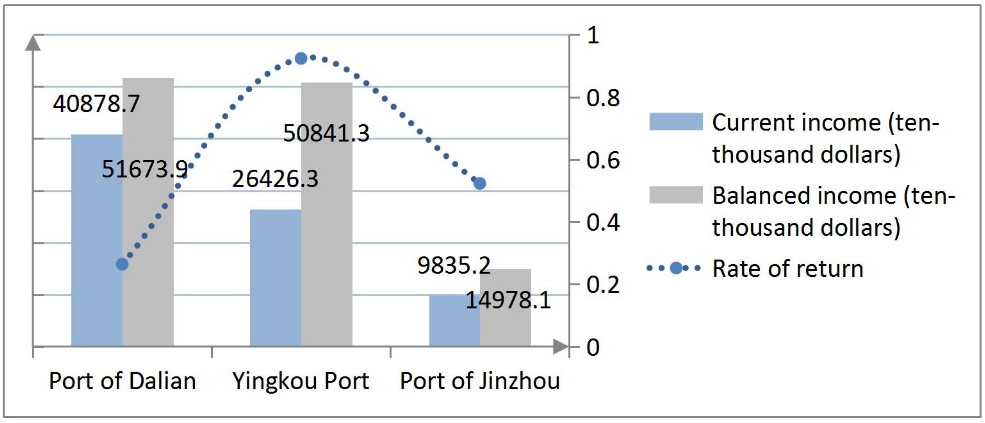

Figure 5: Revenue of individual container ports in the cooperative game scenario

It is proven that both the non-cooperative game and the cooperative game increase the total revenue of the container ports in the region, and the cooperative game outperforms the non-cooperative game, proving that the model is valid. If the number of ports in the region continues to increase, it is sufficient to increase the number of container ports i in the model

IV. Conclusion

In this paper, the GM (1,1) model is improved and the forecast of container throughput in Liaoning region is made for the problem of price competition and cooperation within the container port cluster in the region, and the forecast is adjusted according to the existing research. The game model was also used to calculate the equilibrium tariff of the container port group in Liaoning region and verify the validity of the model, which laid a theoretical foundation for the port managers to formulate reasonable policies. The results of the study show that: (1) the operating revenue of the container port cluster in Liaoning is higher in the cooperative game than in the non-cooperative game. (2) Container shippers in the Liaoning region are not price responsive to container freight prices and prefer container ports with bottom land transport prices. (3) In the context of today's epidemic, container port clusters can effectively mitigate the losses caused by the epidemic through unified and led price cooperation.

References

[1] HAN X U, PARK G K, AHN T Y. On the application of game theory to thecompetition among major ports in North East Asia for transsshipmentcargoes[J].Journal of Korean Institute of Intelligent Systems, 2012,22(2): 261-266 .DOI:10.5391/JKIIS.2012.22.2.261.

[2] ZHANG P, YANG L, WANG H. Game analysis of price competition betweenHong Kong and Shenzhen container port based on Bertrand Model[C]//The 2nd Conference on Environmental Science and Information Application Technology, 2010, 8:168-173.DOI: 10.1109/ESIAT.2010.5568933

[3] SAEED N, LARSEN O I. An application of cooperative game among containerterminals of one port[J]. European Journal of Operation Research, 2010,203(2): 393-403.DOI: 10.1016/j.ejor.2009.07.019

[4] PARK N K, SUH S C. Port competition study: cooperative game model[J]. Journal of Contemporary Management, 2015, 3: 15-38 .

[5] MINHDN,S JUNE Kimb. Application of game theory to analyze the competition and cooperation scenarios among container terminals in Northern Vietnam[J]. The Asian Journal of Shipping and Logistics, 2019, AJSL-215: 7-10.DOI: 10.1016/j.ajsl.2019.08.001

[6] Deng Julong. Gray Forecasting and Decision Making [M]. Wuhan: Huazhong University of Technology Press, 2002:176-177.

[7] Huang Yuehua, Chen Haishan. Application of the optimized GM(1, 1) power model in port throughput forecasting [J]. China Navigation, 2016, 39 (2) :131-134.

[8] Zhu Jian. A study on the factors influencing the cargo throughput of China's coastal ports since the financial crisis: A concurrent discussion on the transformation of China's economy from external demand-driven to domestic demand-driven [J].

[9] A Study on the Factors Influencing the Cargo Throughput of China's Coastal Ports since the Financial Crisis: A Concurrent Study on the Evidence of China's Economic Transformation from External to Domestic Demand Driven [J]. International Business (Journal of the University of International Business and Economics), 2011(3): 16-25.

[10] Liu WJ, He XH, Hu WF. Research on the impact of major outbreaks on port operational capacity [J]. Transportation Information and Safety, 2020, 38(2):102-111+119.

[11] Zhang YF, Gong JW, Yin M. The impact of the new crown pneumonia epidemic on China's port and shipping industry and its countermeasures [J]. Journal of Transportation Engineering, 2020,20(3):159-167.

[12] KASEMILI E N, NOTTEBOOM T, SAEED N. A game theoretical approach tothe inter-relation between terminal scale and port competition[C]. In Proceedingsof International Association of

Maritime Economists (IAME) Conference, 2011, 23(2): 1-26.

[13] MALCHOW N M, KANAFANI A. A disaggregate analysis of port selection[J].Transportation Research, 2004, 40(7): 313-337. DOI:10.1016/j.tre.2003.05.001

[14] PARK G K, Han X, Lu D. Analysis of port competition using game theory. Okayama [C] Japan: SCIS&ISIS Okayama Convention Center, 2010: 2-29

[15] Polydoropoulou A, Litinas N. Demand models for Greek passenger shipping[J]. Maritime Transport: The Greek Paradigm, 2007, 21: 297-322. DOI: 10.1016/S0739-8859(07)21009-1